Lung protection in thoracic surgery anaesthesia

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Introduction
Figure 1. Normal Rat Lungs and Rat Lungs after Receiving High-Pressure Mechanical Ventilation at a Peak Airway Pressure of 45 cm of Water.

After 5 minutes of ventilation, focal zones of atelectasis were evident, in particular at the left lung apex. After 20 minutes of ventilation, the lungs were markedly enlarged and congested; edema fluid filled the tracheal cannula. Adapted from Dreyfuss et al. with the permission of the publisher.
Ventilator-associated Lung Injury (VALI)

Definition: Lung damage caused by application of positive or negative pressure to the lung by mechanical ventilation.
Mechanisms of VALI

Volutrauma: Damage caused by alveolar over-distension. High volume causes injury

Barotrauma: High pressure induced lung damage

Similar histological appearance, high-permeability pulmonary oedema in uninjured lung & exacerbated damage in injured lung (OLV)
Mechanisms of VALI

Atelectotrauma: Lung injury associated with repeated recruitment and collapse.

Theoretically prevented by using a level of positive end-expiratory pressure (PEEP) greater than the lower inflection point of the pressure volume curve.
Volutrauma

Atelectrauma
End-Expiration

Extreme Stress/Strain

Tidal Forces
(Transpulmonary and Microvascular Pressures)

Moderate Stress/Strain

Rupture

Signaling

Epithelial & Endothelial Cells Accommodate Their Surfaces

Mechano signaling via integrins, cytoskeleton, ion channels

inflammatory cascade

Cellular Infiltration and Full-Blown Inflammation

- Global stress/strain reduced by lowering Trans-Pulmonary Pressure (TPP)
- Local stress/strain less if TPP is more homogeneously applied (prone position)
- Local stress/strain reduced if PEEP “keeps open”
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*

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>GROUP RECEIVING TRADITIONAL TIDAL VOLUMES</th>
<th>GROUP RECEIVING LOWER TIDAL VOLUMES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ventilator mode</td>
<td>Volume assist—control 12</td>
<td>Volume assist—control 6</td>
</tr>
<tr>
<td>Initial tidal volume (ml/kg of predicted body weight)†</td>
<td>≤50</td>
<td>≤30</td>
</tr>
<tr>
<td>Plateau pressure (cm of water)</td>
<td>6–35</td>
<td>6–35</td>
</tr>
<tr>
<td>Ventilator rate setting needed to achieve a pH goal of 7.3 to 7.45 (breaths/min)</td>
<td>1:1–1:3</td>
<td>1:1–1:3</td>
</tr>
<tr>
<td>Ratio of the duration of inspiration to the duration of expiration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oxygenation goal</td>
<td>Pao₂ 55–80 mm Hg, or SpO₂ 88–95%</td>
<td>Pao₂ 55–80 mm Hg, or SpO₂ 88–95%</td>
</tr>
<tr>
<td>Allowable combinations of FiO₂ and PEEP (cm of water)‡</td>
<td>0.3 and 5</td>
<td>0.3 and 5</td>
</tr>
<tr>
<td></td>
<td>0.4 and 5</td>
<td>0.4 and 5</td>
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<tr>
<td></td>
<td>0.4 and 8</td>
<td>0.4 and 8</td>
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<td>0.5 and 8</td>
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<td>0.5 and 10</td>
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<td></td>
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<td>0.6 and 10</td>
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<tr>
<td></td>
<td>0.7 and 10</td>
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<td></td>
<td>0.8 and 14</td>
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<tr>
<td></td>
<td>0.9 and 14</td>
<td>0.9 and 14</td>
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<tr>
<td></td>
<td>0.9 and 16</td>
<td>0.9 and 16</td>
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<tr>
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<td>1.0 and 18</td>
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<td></td>
<td>1.0 and 20</td>
<td>1.0 and 20</td>
</tr>
<tr>
<td></td>
<td>1.0 and 22</td>
<td>1.0 and 22</td>
</tr>
<tr>
<td></td>
<td>1.0 and 24</td>
<td>1.0 and 24</td>
</tr>
<tr>
<td>Weaning</td>
<td>By pressure support; required by protocol when FiO₂ &lt;0.4</td>
<td>By pressure support; required by protocol when FiO₂ &lt;0.4</td>
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</tbody>
</table>
Conventional vrs. Protective ventilation in patients with ARDS

Protective: Tidal volume about 4-6ml/kg
Accept hypercarbia

Conventional: Tidal volume of 10ml/kg
Maintain a normocarbia
Deflation

Inflation

Lower inflection point

Upper inflection point

Volume

Pressure

12~18 cmH2O

26~32 cmH2O
Transpulmonary pressure

Driving pressure

Pressure

time

PIP

Pplat

$\Delta P = 20$

PEEP
PEEP Table by ARDSNet

- ARDS Network, 2000: Multicenter, randomized 861 patients

<table>
<thead>
<tr>
<th>Principle for FiO2 and PEEP Adjustment</th>
<th>0.3</th>
<th>0.4</th>
<th>0.5</th>
<th>0.6</th>
<th>0.7</th>
<th>0.8</th>
<th>0.9</th>
<th>1.0</th>
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<tr>
<td>FiO2</td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>PEEP</td>
<td>5</td>
<td>5-8</td>
<td>8-10</td>
<td>10</td>
<td>10-14</td>
<td>14</td>
<td>14-18</td>
<td>18-24</td>
</tr>
</tbody>
</table>

NEJM 2000; 342: 1301-1308
What we know from ICU literature:

1. Non-physiological ventilation in healthy lungs induces ALI.
3. VALI has important implications remote to the lungs and may be associated with significant morbidity and mortality.
Intraoperative lung-protective ventilatory strategies in thoracic Anaesthesia
AIMS: to decrease the extent of injury:
Acute respiratory distress syndrome (ARDS)
Acute Lung injury (ALI)
Atelectasis
Pneumothorax

Spontaneous ventilation or positive pressure ventilation

- Sedation with face mask/LMA/ETT and SV
- Plan in place to convert to PPV
Bronchial blocker or DLT

BBs provided equivalent surgical exposure to left-sided DLTs during left-sided open or video-assisted thoracoscopic surgery thoracic procedures.

However BBs required longer to position.

Reducing VT (4-6ml/kg vrs 8-10ml/kg)

- Fernández-Pere ER. Intraoperative tidal volume as a risk factor for respiratory failure after pneumonectomy. Anesthesiology 2006; 105: 14–8


Low TV and PEEP

During OLV, lowering VT and increasing PEEP, with the same low plateau pressure, reduced oxygenation compared with larger VT (8ml/kg) and lower PEEP.

How much PEEP?

PEEP minimises lung collapse and prevents the repeated opening and collapse of lung units, but impairs intraoperative oxygenation during OLV, by increasing pulmonary vascular resistance and a shift of blood flow to the non-dependent lung.

Optimal PEEP to maintain oxygenation after reduction in VT during OLV remains unknown.

PROTHOR trail

Protective Ventilation with higher versus Lower PEEP during one lung ventilation for thoracic surgery
# Protective lung ventilation during general anesthesia: is there any evidence?

Silvia Coppola, Sara Froio, Davide Chiumello*

## Ventilatory strategy

<table>
<thead>
<tr>
<th>Abdominal</th>
<th>First author (ref)</th>
<th>Year</th>
<th>N pts</th>
<th>V&lt;sub&gt;f&lt;/sub&gt; (ml/kg)</th>
<th>PEEP (cmH&lt;sub&gt;2&lt;/sub&gt;O)</th>
<th>Recruitment maneuver (Yes/No)</th>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wiggie [21]</td>
<td>2000</td>
<td>39</td>
<td>66</td>
<td>6</td>
<td>15</td>
<td>0</td>
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<tr>
<td>Wiggie [22]</td>
<td>2004</td>
<td>30</td>
<td>6</td>
<td>12-15</td>
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<td>Determann [23]</td>
<td>2008</td>
<td>40</td>
<td>6</td>
<td>12</td>
<td>10</td>
<td>0</td>
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<tr>
<td>Weingarten [25]</td>
<td>2010</td>
<td>40</td>
<td>6</td>
<td>10</td>
<td>12</td>
<td>0</td>
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<tr>
<td>Treschon [24]</td>
<td>2012</td>
<td>101</td>
<td>6</td>
<td>12</td>
<td>5</td>
<td>5</td>
<td>No</td>
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<tr>
<td>Sevegrini [26]</td>
<td>2013</td>
<td>56</td>
<td>7</td>
<td>9</td>
<td>10</td>
<td>0</td>
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<tr>
<td>Furler [27]</td>
<td>2013</td>
<td>400</td>
<td>6-8</td>
<td>10-12</td>
<td>6-8</td>
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<tr>
<td>PROVHICO [28]</td>
<td>2014</td>
<td>900</td>
<td>&lt;8</td>
<td>&lt;8</td>
<td>12</td>
<td>0</td>
<td>Yes</td>
</tr>
</tbody>
</table>

## Thoracic

| Schilling [33] | 2005 | 32 | 5 | 10 | 0 | 0 | No | Pulmonary TNF-α, IL-8, IL-10: lower TNF-α |
| Michelet [36] | 2006 | 52 | 5 | 9 | 5 | 0 | No | Systemic II, IL-6, IL-8: lower Oxygenation: Better Postoperative MV length: shorter |
| Yang [35] | 2011 | 100 | 6 | 10 | 5 | 0 | No | Oxygenation: better Postoperative pulmonary complications: lower |

## Cardiac

| Chaney [49] | 2000 | 25 | 6 | 12 | 5 | 5 | No | Postoperative lung mechanics: better |
| Koner [42] | 2004 | 44 | 6 | 10 | 5 | 0 | No | Systemic II, TNF-α: similar Hospital LOS: similar Postoperative pulmonary function: similar |
| Zupancich [44] | 2005 | 40 | 8 | 10-12 | 10 | 2-3 | No | Pulmonary and systemic II-8, IL-6: lower |
| Reis [47] | 2005 | 62 | 4-6 | 6-8 | 10 | 5 | Yes | Systemic II, IL-10: lower Systemic II, TNF-α, IFN-γ: similar |
| Reis [48] | 2005 | 69 | 4-6 | 6-8 | 10 | 5 | Yes | Postoperative hypoxemia: lower Postoperative IFR: better |
| Wiggie [41] | 2005 | 44 | 6 | 12 | 9<sup>*</sup> | 7<sup>*</sup> | No | Systemic TNF-α, IL-6-8-2-4-10: similar Pulmonary TNF-α, IL-6-8-2-4-10: lower TNF-α |
| Sunder [43] | 2011 | 149 | 6 | 10 | 5<sup>*</sup> | 4.5<sup>*</sup> | No | Time to extubation: similar Extubation at 6-8 h after surgery: better Reinflation: lower |
Outcomes

Cardiac surgery
7 RCT (38.9%)

Explored outcomes
• Biochemical markers: 3 studies
• Clinical outcomes: 3 studies
• Both: 1 study

Abdominal surgery
8 RCT (44.4%)

Explored outcomes
• Biochemical markers: 3 studies
• Clinical outcomes: 4 studies
• Both: 1 study

Thoracic surgery
3 RCT (16.7%)

Explored outcomes
• Biochemical markers: 1 study
• Clinical outcomes: 2 studies

Figure 1. The number and percentage of randomized controlled trials (RCTs) included in Table 1, divided by type of surgery.
Results for using lung protective strategies

Abdominal surgery slight benefit
Cardiac surgery equivocal
Thoracic surgery shows clear benefit
Intraoperative lung-protective ventilatory strategies

- Tidal volumes 5-7ml/kg
- Limit plateau airway pressures to 25 cmH2O
- PEEP of 5 cm H2O to patients without auto-PEEP.
- COPD patients pressure-control ventilation instead of volume-controlled ventilation.

Unzueat MC, Casas JI, Moral MV. Anesth Analg 2007; 104:1029-33
Questions
Picken, Myburgh: The use of intraoperative transoesophageal echocardiography as a monitor for haemodynamic instability during pulmonary hydatid cyst; SAJAA Vol 19, No 3 (2013)
Thank you
Meta-analysis: Intraoperative ventilatory strategies to prevent postoperative pulmonary complications

Meta-analysis also showed a decrease in lung injury development (RR 0.29; 95% CI 0.14-0.60; I 0%; NNT 29), pulmonary infection (RR 0.62; 95% CI 0.40-0.96; I 15%; NNT 33) and atelectasis (RR 0.61; 95% CI 0.41-0.91; I 0%; NNT 29) in patients ventilated with higher levels of PEEP, with or without recruitment maneuvers.
Number Needed To Treat (NNT)

Lower TV: Decrease in lung injury development: NNT = 37

Higher PEEP: Decrease in lung injury development: NNT = 29

Higher PEEP: Prevention of pulmonary infection: NNT = 33

Higher PEEP: Prevention of atelectasis: NNT = 29
Conclusion

Use lung protective strategies in the sick
Numbers Needed to Harm (NNH)
Beware of hypo-ventilation and hypercapnoea