Protective ventilation for ALL patients

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Conflicts of Interest

I declare NO conflicts of interest

Pelosi P for the PROVE Network (www.provenet.eu)
PROtective VEntilation NETWORK

To perform
Large multicenter clinical studies, randomized controlled trials, and meta-analyses

http://www.provenet.eu/

Pelosi P for the PROVE Network (www.provenet.eu)
To prevent or cure acute respiratory distress syndrome: that is the question!

Paolo Pelosi\textsuperscript{a} and Patricia R.M. Rocco\textsuperscript{b}

Curr Opin Crit Care 2014, 20:1 – 2

Pelosi P for the PROVE Network (www.provenet.eu)
The ARDS Lung

Lower lesion
alveolar-capillary membrane

P = 5 cmH₂O
PaO₂/FiO₂ > 150
EDEMA-ATELECTASIS
LOWER PEEP-LOWER MORTALITY

Higher lesion
alveolar-capillary membrane

P = 10 cmH₂O
PaO₂/FiO₂ < 150
HIGHER EDEMA-ATELECTASIS
HIGHER PEEP-HIGHER MORTALITY
Ventilator-Induced Lung Injury


Pelosi P for the PROVE Network (www.provenet.eu)

- BAROTRAUMA
- VOLUTRAUMA
- BIOTRAUMA
Use of Lower Tidal Volumes Benefits Patients with ARDS


- 1,297 patients with ARDS from 6 RCTs
- outcome: hospital death

<table>
<thead>
<tr>
<th></th>
<th>No</th>
<th>Low Vₜ at similar PEEP</th>
<th>High Vₜ at similar PEEP</th>
<th>Odds ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brochard</td>
<td>116</td>
<td>–</td>
<td>–</td>
<td>1.17 [0.39 – 3.47]</td>
</tr>
<tr>
<td>Brower</td>
<td>52</td>
<td>13/26</td>
<td>12/26</td>
<td>1.17 [0.39 – 3.47]</td>
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<tr>
<td>Brower</td>
<td>861</td>
<td>134/342</td>
<td>171/429</td>
<td>0.68 [0.51 – 0.90]</td>
</tr>
<tr>
<td>Stewart</td>
<td>120</td>
<td>30/60</td>
<td>28/60</td>
<td>1.14 [0.56 – 2.34]</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th></th>
<th>No</th>
<th>Low Vₜ + high PEEP</th>
<th>High Vₜ + low PEEP</th>
<th>Odds ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amato</td>
<td>53</td>
<td>13/29</td>
<td>17/24</td>
<td>0.33 [0.11 – 1.05]</td>
</tr>
<tr>
<td>Villar</td>
<td>95</td>
<td>17/50</td>
<td>24/45</td>
<td>0.41 [0.18 – 0.94]</td>
</tr>
</tbody>
</table>

Pelosi P for the PROVE Network (www.provenet.eu)
• international observational study
• 2,396 patients with mild, moderate or severe ARDS
• $V_T > 8 \text{ ml/Kg}$ in 40% of patients

Pelosi P for the PROVE Network (www.provenet.eu)
Ventilation in Intensive Care Unit–patients with Uninjured Lungs

Protective ventilation includes:

- Tidal volume size 6–8 ml/kg predicted body weight
  - Evidence comes from 2 RCTs [4] and 1 meta–analysis [5]

Pelosi P for the PROVE Network (www.provenet.eu)
Use of Lower Tidal Volumes Benefits Patients without ARDS


- 2,184 ICU patients without ARDS from 7 studies
- outcome: duration of ventilation

Pelosi P for the PROVE Network (www.provenet.eu)
Use of Lower Tidal Volumes Benefits Patients \textit{without} ARDS

Serpa Neto A. \textit{Crit Care Med.} 2015; \textbf{43}:4155

- 2,184 ICU patients without ARDS from 7 studies
- outcome: hospital stay and ARDS development

Pelosi P for the PROVE Network (www.provenet.eu)
Use of Lower Tidal Volumes
Benefits Patients without ARDS

Serpa Neto A. Crit Care Med. 2015; 43:4155

Peak pressure = 20-24 cmH₂O
Plateau pressure = 16-19 cmH₂O
PEEP = 5-6 cmH₂O
PaO₂/FiO₂ = 260 mmHg

Volume controlled = 51%
Pressure controlled = 49%
RANDOMIZED CONTROLLED TRIALS

✓ PRotective VENTilation in Patients Not Fulfilling the Consensus Definition for Moderate or Severe ARDS (PReVENT-NL)
Academisch Medisch Centrum - Universiteit van Amsterdam (AMC-UvA).
NCT02153294 NLM Identifier: NCT02153294
Pts without moderate or severe ARDS:
$V_T \leq 6$ vs. $8–10$ ml/kg PBW

✓ Preventive Strategies in Acute Respiratory Distress Syndrome (ARDS) (EPALI)
Corporacion Parc Tauli.
NCT02070666 NLM Identifier: NCT02070666
Pts without ARDS: $V_T \leq 6$ vs. $8$ ml/kg PBW

✓ A new ARDS Network trial

Pelosi P for the PROVE Network (www.provenet.eu)
• international observational study
• 1,022 patients without ARDS
• 7.9 [6.8–9.1] mL/kg PBW
• \( V_T > 8 \text{ ml/Kg} \) in 40% of patients

Pelosi P for the PROVE Network (www.provenet.eu)
Ventilation in Intensive Care Unit–patients with Uninjured Lungs

Protective ventilation includes:

Tidal volume size 6 ml/kg predicted body weight

* evidence comes from 2 RCTs [31,32], 1 meta–analysis and 2 IPD meta–analyses [17,18,33]*

Ventilation in Intensive Care Unit–patients with the Acute Respiratory Distress Syndrome (ARDS)

- mild ARDS
  - Protective ventilation includes:
    - Tidal volume size 6–8 ml/kg predicted body weight
    - * evidence comes from 2 RCTs [4] and 1 meta–analysis [5]*
  - * Pelosi P for the PROVE Network (www.provenet.eu)*

- moderate and severe ARDS
  - Protective ventilation includes:
    - Tidal volume size 6–8 ml/kg predicted body weight
    - * evidence comes from 2 RCTs [4] and 1 meta–analysis [5]*
Experimental edema due to intermittent positive pressure ventilation with high inflation pressures
Protection by PEEP


Ventilator Induced Lung Injury
Tidal Volume or PEEP?

- P = 14 cm H2O
  PEEP = 0 cm H2O
- P = 45 cm H2O
  PEEP = 10 cm H2O
- P = 45 cm H2O
  PEEP = 0 cm H2O

Lower Tidal Volume & Higher PEEP
Higher Tidal Volume & Lower PEEP

Pelosi P for the PROVE Network (www.provenet.eu)
Use of Higher PEEP Benefits Patient with Moderate or Severe ARDS

Briel M. et al. *JAMA* 2010; 303:865

- 2,299 ICU patients with ARDS from 3 investigations
- outcome: death

Pelosi P for the PROVE Network ([www.provenet.eu](http://www.provenet.eu))
**Recommendation.** We suggest that adult patients with moderate or severe ARDS receive higher rather than lower levels of PEEP (conditional recommendation, moderate confidence in effect estimates).

Importantly, changes in PEEP will influence inspiratory plateau pressure, and clinicians should consider the risks and benefits for the individual patient of increasing PEEP when plateau pressure is greater than or equal to 30 cm H$_2$O.
LOOK AT THINGS DIFFERENT
Permissive atelectasis to minimize VILI

Cressoni M et al. Anesthesiology. 2016 Feb 12. [Epub ahead of print]

Stress $\sigma = \Delta F/\Delta S$ ($P_L$)

Strain $\varepsilon = \Delta L/L_0$ ($V_T/EELV$)

$\Delta P = V_T/Cst,rs = V_T/EELV$

Energy $= \Delta P^2 \times (2 \times Est)$

Power $= \text{Energy} / \text{Time}$

Intensity $= \text{Power} / \text{Area}$

Higher Dishomogeneities

Less VILI with Less Stress, Strain, $\Delta P$, Power, Intensity

Pelosi P for the PROVE Network (www.provenet.eu)
Biological Impact of Transpulmonary Driving Pressure in Experimental Acute Respiratory Distress Syndrome


Pelosi P for the PROVE Network (www.provenet.eu)
Biological Impact of Transpulmonary Driving Pressure in Experimental Acute Respiratory Distress Syndrome


Pelosi P for the PROVE Network (www.provenet.eu)
Biological Impact of Transpulmonary Driving Pressure in Experimental Acute Respiratory Distress Syndrome


Pelosi P for the PROVE Network (www.provenet.eu)
Ventilator-related causes of lung injury: The mechanical power


Ventilator-related causes of lung injury:

The mechanical power

\[
\text{Power}_{rs} = 0.098 \cdot RR \cdot \left\{ \Delta V^2 \cdot \left[ \frac{1}{2} \cdot EL_{rs} + RR \cdot \frac{(1 + I : E)}{60 \cdot I : E} \cdot R_{aw} \right] + \Delta V \cdot PEEP \right\}
\]

Pelosi P for the PROVE Network (www.provenet.eu)
Power and Biological Markers in Experimental ARDS

Samary CS et al. Anesthesiology. 2016 Nov;125(5):1070-1071

Increased $V_T$ and PEEP = 3 cmH$_2$O
The Biological Effects of Higher and Lower PEEP in Pulmonary and Extrapulmonary ALI with IAH


Pelosi P for the PROVE Network (www.provenet.eu)
Volutrauma leads to higher lung inflammation than atelectrauma in experimental ARDS


**VOLUTRAUMA vs ATELECTRAUMA**

Comparable Tidal Volume and Driving Pressure

Pelosi P for the PROVE Network (www.provenet.eu)
Volutrauma leads to higher lung inflammation than atelectrauma in experimental ARDS

Static strain is more injurious than dynamic strain!

Pelosi P for the PROVE Network (www.provenet.eu)
PEEP and Lymphatic drainage
Pelosi P, Rocco PRM, de Abreu MG (Crit Care 2018 – in press)

No PEEP

PEEP

Pelosi P for the PROVE Network (www.provenet.eu)
Aeration and Recruitment in ALI/ARDS at end-expiration and end-inspiration


Plateau Pressure (cmH$_2$O)

<table>
<thead>
<tr>
<th>PEEP (cmH$_2$O)</th>
<th>End Expiration</th>
<th>End Inspiration</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>21 ± 1.8</td>
<td>26 ± 1.4</td>
</tr>
<tr>
<td>5</td>
<td>31 ± 1.8</td>
<td>38 ± 2.1</td>
</tr>
<tr>
<td>10</td>
<td>46 ± 3.2</td>
<td>46 ± 3.2</td>
</tr>
</tbody>
</table>

Pelosi P for the PROVE Network (www.provenet.eu)
PEEP of 15 cmH₂O does not reduce lung inhomogeneities in ARDS


The clinical question is:
Atelectrauma is less harmful than volutrauma due to a further increase of PEEP?

Pelosi P for the PROVE Network (www.provenet.eu)
1. Increased capillary pressure

2. Impeded drainage (compression thoracic duct)

PEEP

RV

LV

plasma

capillaries

edema

Lymph flow (thoracic duct)

PV

Courtesy Prof Hedenstierna
Impact of acute hypercapnia and augmented PEEP on right ventricle function in ARDS


Boufferace K et al. Current Opinion in Critical Care 2011, 17:30–35

Pelosi P for the PROVE Network (www.provenet.eu)
PEEP in ARDS – The Lung Safe Study

Bellani G et al. JAMA Feb 23 2016, 315 (8): 788-800

- PEEP was relatively low (12 cmH₂O or lower) independently from ARDS severity
- Hypoxemia was treated by increasing FiO₂

PEEP, cm H₂O

Inspired Fraction of Oxygen

Pelosi P for the PROVE Network (www.provenet.eu)
PEEP: High vs Low - RCTs

![Bar chart showing 60-day mortality (%) for ALVEOLI, LOVS, and EXPRESS trials with Low PEEP and High PEEP comparisons.](chart.png)

- ALVEOLI: N = 545, Low PEEP P = 0.29 vs High PEEP
- LOVS: N = 983, Low PEEP P = 0.17 vs High PEEP
- EXPRESS: N = 767, Low PEEP P = 0.22 vs High PEEP

Pelosi P for the PROVE Network ([www.provenet.eu](http://www.provenet.eu))
Effect of Lung Recruitment and Titrated Positive End-Expiratory Pressure (PEEP) vs Low PEEP on Mortality in Patients With ARDS


Lung Recruitment and Titrated PEEP in Moderate to Severe ARDS
Is the Door Closing on the Open Lung?

Sarina K. Sahetya, MD; Roy G. Brower, MD

Pelosi P for the PROVE Network (www.provenet.eu)
The Funeral for Positive End-Expiratory Pressure …*better known as PEEP*

“It was a dream for generations of anesthesiologists and intensivists”

Pelosi P for the PROVE Network (www.provenet.eu)
Lung Recruitability Is Better Estimated According to the Berlin Definition of ARDS at Standard 5 cm H$_2$O PEEP: A Retrospective Cohort Study


Pelosi P for the PROVE Network (www.provenet.eu)
Bedside Selection of PEEP in Mild, Moderate, and Severe Acute Respiratory Distress Syndrome


<table>
<thead>
<tr>
<th>A</th>
<th>LOV</th>
<th>ExPress</th>
<th>Stress Index</th>
<th>Esophageal pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Lower-PEEP group**

| FIO₂ | 0.3  | 0.4  | 0.4  | 0.5  | 0.5  | 0.6  | 0.7  | 0.7  | 0.8  | 0.9  | 0.9  | 0.9  | 1.0  |
| PEEP | 5    | 5    | 8    | 8    | 10   | 10   | 10   | 12   | 14   | 14   | 14   | 16   | 18   | 18–24 |

**Higher-PEEP group (after protocol changed to use higher levels of PEEP)**

| FIO₂ | 0.3  | 0.3  | 0.4  | 0.4  | 0.5  | 0.5–0.8 | 0.8  | 0.9  | 1.0  |
| PEEP | 12   | 14   | 14   | 16   | 16   | 18     | 20   | 22   | 22–24 |

SatO₂ 88-95
PaO₂ 55-80 mmHg

No routine RMGs!

Pelosi P for the PROVE Network (www.provenet.eu)
Prone position homogenizes aeration and ventilation at low PEEP.

Supine

Prone

Lung inflation

Lung Height (%)

0 0 40 60 80 100

0 1 2 3 4 5 6 7

Prone group

Supine group

PEEP = 10 cmH₂O

P/F<150 mmHg while on F¹O₂>0.60;


Ventilation in Intensive Care Unit—patients with Uninjured Lungs

**Protective ventilation includes:**

- Tidal volume size: 6 ml/kg predicted body weight
  - Evidence comes from 2 RCTs [31,32], 1 meta-analysis and 2 IPD meta-analyses [17,18,33]*

Ventilation in Intensive Care Unit—patients with the Acute Respiratory Distress Syndrome (ARDS)

**Protective ventilation includes:**

- Tidal volume size: 6–8 ml/kg predicted body weight
  - Evidence comes from 2 RCTs [4] and 1 meta-analysis [5]

**Level of PEEP**

- 5–10 cm H$_2$O
  - Evidence comes from 3 RCTs [7,8,9] and 1 IPD meta-analysis [10]

- ≥ 10 cm H$_2$O but < 15cmH$_2$O
  - Evidence comes from 4 RCTs [7,8,9] and 1 IPD meta-analysis [10]
In non ARDS patients lower VT + lower PEEP are associated with a shorter length of ICU stay


MD <0 favors strategy A (Low $V_T$/Low PEEP)

Pelosi P for the PROVE Network (www.provenet.eu)
Associations between PEEP and outcome of patients without ARDS at onset of ventilation: a systematic review and meta-analysis of randomized controlled trials


**Low PEEP** = 2.0 ± 2.8 cmH\(_2\)O  
**High PEEP** = 9.7 ± 4.0 cmH\(_2\)O

### Study or Subgroup

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>High PEEP</th>
<th>Low PEEP</th>
<th>Risk Ratio</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Events</td>
<td>Total</td>
<td>Weight</td>
<td>M-H, Random, 95% CI</td>
</tr>
<tr>
<td>1.3.2 Hospital Mortality</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weigelt JA</td>
<td>16</td>
<td>45</td>
<td>17 34 25.5%</td>
<td>0.71 [0.42, 1.19]</td>
</tr>
<tr>
<td>Pepe PE</td>
<td>13</td>
<td>44</td>
<td>18 48 21.8%</td>
<td>0.79 [0.44, 1.41]</td>
</tr>
<tr>
<td>Nelson LD</td>
<td>5</td>
<td>20</td>
<td>6 18 9.5%</td>
<td>0.75 [0.28, 2.04]</td>
</tr>
<tr>
<td>Carroll GC</td>
<td>6</td>
<td>22</td>
<td>1 28 2.6%</td>
<td>7.64 [0.99, 58.85]</td>
</tr>
<tr>
<td>Michalopoulos A</td>
<td>0</td>
<td>21</td>
<td>0 22</td>
<td>Not estimable</td>
</tr>
<tr>
<td>Manzano F</td>
<td>19</td>
<td>64</td>
<td>16 63 22.7%</td>
<td>1.17 [0.66, 2.06]</td>
</tr>
<tr>
<td>Lesur O</td>
<td>9</td>
<td>30</td>
<td>14 33 17.6%</td>
<td>0.71 [0.36, 1.39]</td>
</tr>
<tr>
<td>Subtotal (95% CI)</td>
<td>246</td>
<td>246</td>
<td>100.0%</td>
<td>0.87 [0.62, 1.21]</td>
</tr>
<tr>
<td>Total events</td>
<td>68</td>
<td>72</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**High PEEP:** No effect on duration of MV – Lower rate of ARDS (high I\(^2\))

Pelosi P for the PROVE Network ([www.provenet.eu](http://www.provenet.eu))
• international observational study
• 1,022 patients without ARDS
• PEEP > 5 cmH₂O in 60-40% of patients
Ventilation in Intensive Care Unit–patients with Uninjured Lungs

Protective ventilation includes:

- Tidal volume size: 6 ml/kg predicted body weight
  - Evidence comes from 2 RCTs [31,32], 1 meta-analysis and 2 IPD meta-analyses [17,18,33]*

Level of PEEP (<10 cmH₂O)
- ??
  - Convincing RCT evidence is lacking 1 meta-analysis

Ventilation in Intensive Care Unit–patients with the Acute Respiratory Distress Syndrome (ARDS)

Protective ventilation includes:

- Tidal volume size: 6–8 ml/kg predicted body weight
  - Evidence comes from 2 RCTs [4] and 1 meta-analysis [5]

- Tidal volume size: 6–8 ml/kg predicted body weight
  - Evidence comes from 2 RCTs [4] and 1 meta-analysis [5]

- Tidal volume size: 6–8 ml/kg predicted body weight
  - Evidence comes from 2 RCTs [4] and 1 meta-analysis [5]

Protective ventilation includes:

- Level of PEEP: 5–10 cm H₂O
  - Evidence comes from 3 RCTs [7,8,9] and 1 IPD meta-analysis [10]

- Level of PEEP: ≥ 10 cm H₂O but < 15 cmH₂O
  - Evidence comes from 3 RCTs [7,8,9] and 1 IPD meta-analysis [10]

Pelosi P for the PROVE Network (www.provenet.eu)
Driving Pressure ($\Delta P_{rs}$)


\[ \Delta P = P_{\text{plat,rs}} - P_{\text{PEEP}} = \frac{V_T}{Cst} = \frac{V_T}{EELV} \]
Driving pressure and survival in the ARDS


Pelosi P for the PROVE Network (www.provenet.eu)
• 2,396 pts with mild, moderate or severe ARDS

Pelosi P for the PROVE Network (www.provenet.eu)
653 patients from 12 studies

RR for hospital death

median settings in the first 3 days

<table>
<thead>
<tr>
<th></th>
<th>ALL</th>
<th>ECMO</th>
<th>ECCO₂R</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>653</td>
<td>545</td>
<td>108</td>
</tr>
<tr>
<td>RR [95%–CI] (p–value) for hospital death</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vₚ, ml/kg PBW</td>
<td>0.97 [0.87–1.08] (p = 0.602)</td>
<td>0.94 [0.83–1.06] (p = 0.294)</td>
<td>1.03 [0.80–1.32] (p = 0.817)</td>
</tr>
<tr>
<td>PEEP, cm H₂O</td>
<td>0.97 [0.92–1.02] (p = 0.249)</td>
<td>0.97 [0.91–1.03] (p = 0.323)</td>
<td>0.92 [0.83–1.02] (p = 0.125)</td>
</tr>
<tr>
<td>Pplat, cm H₂O</td>
<td>1.03 [0.97–1.09] (p = 0.298)</td>
<td>1.03 [0.97–1.10] (p = 0.308)</td>
<td>0.94 [0.81–1.10] (p = 0.454)</td>
</tr>
<tr>
<td>ΔP, cm H₂O</td>
<td>1.07 [1.02–1.12] (p = 0.004)</td>
<td>1.06 [1.01–1.12] (p = 0.029)</td>
<td>1.19 [1.04–1.35] (p = 0.009)</td>
</tr>
</tbody>
</table>

adjusted for risk of death, age and severity of ARDS

Pelosi P for the PROVE Network (www.provenet.eu)
Ventilation in Intensive Care Unit—patients with Uninjured Lungs

Protective ventilation includes:

- **Tidal volume size**
  - *6 ml/kg predicted body weight*
  - Evidence comes from 2 RCTs [31,32], 1 meta–analysis and 2 IPD meta–analyses [17,18,33]*

- **Level of PEEP (< 10 cmH₂O)**
  - ??
  - *Convincing RCT evidence is lacking 1 meta–analysis*

= Pelosi P for the PROVE Network (www.provenet.eu)
PRoVENT – Practice of Ventilation in ICUs Worldwide


- international observational study
- 1,022 patients without ARDS
- Driving pressure associated with mortality

Pelosi P for the PROVE Network (www.provenet.eu)
• international observational study
• 1,022 patients without ARDS
• $\Delta P$ 10.0 [6.0-13] cm H$_2$O
• $\Delta P > 12$ cmH$_2$O in 30-40% of patients

Pelosi P for the PROVE Network (www.provenet.eu)
### Ventilation in Intensive Care Unit—patients with Uninjured Lungs

**Protective ventilation includes:**

- **Tidal volume size**
  - 6 ml/kg predicted body weight
  
  - *evidence comes from*
    - 2 RCTs [31,32], 1 meta–analyses and 2 IPD meta–analyses [17,18,33]*

- **Level of PEEP (<10 cmH₂O)**
  - ??

  - *Convincing RCT evidence is lacking*
    - 1 meta-analysis

- **Driving pressure (<13cmH₂O)**
  - studies are lacking

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### Ventilation in Intensive Care Unit—patients with the Acute Respiratory Distress Syndrome (ARDS)

#### Protective ventilation includes:

- **mild ARDS**
  - **Tidal volume size**
    - 6–8 ml/kg predicted body weight

  - *evidence comes from*

- **Level of PEEP**
  - 5–10 cm H₂O

  - *evidence comes from*
    - 3 RCTs [7,8,9] and 1 IPD meta–analysis [10]

- **Low driving pressure**
  - (< 13cmH₂O)

  - *suggestion comes from several studies and*
    - 1 IPD meta–analysis [10]

---

#### moderate and severe ARDS

- **Tidal volume size**
  - 6–8 ml/kg predicted body weight

- **Level of PEEP**
  - ≥ 10 cm H₂O but < 15cmH₂O

- **Low driving pressure**
  - (< 13cmH₂O)

  - *suggestion comes from several studies and*
    - 1 IPD meta–analysis [10]

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*Pelosi P for the PROVE Network ([www.provenet.eu](http://www.provenet.eu))

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[31,32,17,18,33*,4,7,8,9,10]
LungSafe – Practice of Ventilation in ICUs Worldwide

Bellani G JAMA. 2016 Feb 23;315(8):788-800

Pplat and Mortality in ARDS

- international observational study
- 2,396 patients with mild, moderate or severe ARDS

Pelosi P for the PROVE Network (www.provenet.eu)
Plateau pressure or Driving Pressure and Survival in the ARDS


Pelosi P for the PROVE Network (www.provenet.eu)
LungSafe – Practice of Ventilation in ICUs Worldwide

Bellani G JAMA. 2016 Feb 23;315(8):788-800

- 2,396 pts with mild, moderate or severe ARDS
LungSafe – Potentially modifiable factors contributing to outcome from ARDS

Laffey GC et al. Intensive Care Med 2016 (Epub Ahead of Print)

- 2,396 pts with mild, moderate or severe ARDS
- Higher PEEP, lower plateau and driving P, & lower respiratory rate are associated with better survival

Pelosi P for the PROVE Network (www.provenet.eu)
Ventilation in Intensive Care Unit–patients with Uninjured Lungs

**Protective ventilation includes:**

- Tidal volume size
  - 6 ml/kg predicted body weight
    - evidence comes from 2 RCTs [31,32], 1 meta–analysis and 2 IPD meta–analyses [17,18,33]*

- Level of PEEP (< 6 cmH₂O)
  - ??
    - Convincing RCT evidence is lacking 1 meta–analysis

- Driving pressure
  - (< 13 cmH₂O)
    - studies are lacking

Ventilation in Intensive Care Unit–patients with the Acute Respiratory Distress Syndrome (ARDS)

**Protective ventilation includes:**

- Tidal volume size
  - 6–8 ml/kg predicted body weight
    - evidence comes from 2 RCTs [4] and 1 meta–analysis [5]

- Level of PEEP
  - 5–10 cm H₂O
    - evidence comes from 3 RCTs [7,8,9] and 1 IPD meta–analysis [10]

- Driving pressure
  - (< 13 cmH₂O)
    - Pplat (< 25–27 cmH₂O)
      - suggestion comes from several studies and 1 IPD meta–analysis [10]

Pelosi P for the PROVE Network (www.provenet.eu)
Factors associated with ARDS

1) Higher (> 17 cmH₂O) plateau pressure
   (odds ratio 1.12, 95% CI interval 1.04 to 1.21)

Factors associated with ICU acquired pneumonia

1) Higher tidal volume
   (odds ratio 1.003, 95% CI 1.0003 to 1.01)

2) Higher (>5 cmH₂O) applied PEEP levels
   odds ratio 0.89, 95% CI 0.80 to 0.99

Pelosi P for the PROVE Network (www.provenet.eu)
PRoVENT – Practice of Ventilation in ICUs Worldwide


• international observational study
• 1,022 patients without ARDS
• Pplat 15.0 [13.0-20.0] cm
• Pplat > 17 cmH₂O in 30-40% of patients

Pelosi P for the PROVE Network (www.provenet.eu)
Ventilation in Intensive Care Unit—patients with Uninjured Lungs

Protective ventilation includes:
- Tidal volume size: 6 ml/kg predicted body weight
  - evidence comes from 2 RCTs [31,32], 1 meta–analysis and 2 IPD meta–analyses [17,18,33]*
  - Level of PEEP (< 6 cmH\(_2\)O)
    - Convincing RCT evidence is lacking
    - 1 meta–analysis
  - Driving pressure (< 13 cmH\(_2\)O)
    - Plateau pressure (< 17 cmH\(_2\)O)
      - studies are lacking

Ventilation in Intensive Care Unit—patients with the Acute Respiratory Distress Syndrome (ARDS)

Protective ventilation includes:
- Tidal volume size: 6–8 ml/kg predicted body weight
  - evidence comes from 2 RCTs [4] and 1 meta–analysis [5]
  - Level of PEEP
    - mild ARDS: 5–10 cm H\(_2\)O
      - evidence comes from 3 RCTs [7,8,9] and 1 IPD meta–analysis [10]
  - Driving pressure (< 15 cmH\(_2\)O)
    - Pplat (< 25-27 cmH\(_2\)O)
      - suggestion comes from several studies and 1 IPD meta–analysis [10]

Pelosi P for the PROVE Network (www.provenet.eu)
Practice of Ventilation in ARDS

Bellani G JAMA. 2016 Feb 23;315(8):788-800

Pelosi P for the PROVE Network (www.provenet.eu)
Practice of Ventilation in ICUs


Pelosi P for the PROVE Network (www.provenet.eu)
“Permissive Atelectasis” in ALL MV patients

Pelosi P, Rocco PRM, de Abreu MG (Crit Care 2018 – in press)

Expiration

Inspiration

Pelosi P for the PROVE Network (www.provenet.eu)
Permissive Atelectasis!

“Less is More”

\[ \Delta P = P_{\text{plat,rs}} - \text{PEEP} = \frac{V_T}{C_{st}} = \frac{V_T}{E_{ELV}} \]

\[ V_T / \Delta P \]

Energy = \( (\Delta P)^2 / (2 \times \text{Est}) \)

\[ \text{Power} = \text{Energy} / \text{Time (RR)} \]

Regional Intensity = Power / Surface
Permissive Atelectasis!

“Less is More”

\[ \Delta P = P_{\text{plat}, rs} - PEEP = \frac{V_T}{Cst} = \frac{V_T}{EELV} \]

Energy = \( \frac{(\Delta P)^2}{2 \times \text{Est}} \)

\[ \text{Power} = \frac{\text{Energy}}{\text{Time} \ (RR)} \]

Regional Intensity = Power / Surface

In ARDS patients
PEEP based on lower PaO\textsubscript{2}/FiO\textsubscript{2} Table
PRONE POSITION!
Protective Mechanical Ventilation
In ALL patients

LOWER IS BETTER
...ALSO PEEP in severe ARDS!