Recruitment maneuvers: when, how and in who?

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Non-anaesthetised healthy rabbit

Anaesthesiated rabbit after induction

Atelectasis mechanism

FRC / EELV

Closing volume

Lung stability

atelectasis
Rules for “openning up the lung”:

• “The mayor inspiratory pressure given during more time you open up more alveoli”

• There is always a minimum critical open pressure under that you don’t open almost nothings” (healthy lungs 30 cmH2O and ARDS 40-60 cmH2O)
In who and when?
Which patients?:

- Radiological criteria: x-ray not valid, only CT
Which patients?:

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Which patients?:

- Radiological criteria: x-ray not valid, only CT

- \( \text{PO}_2/\text{FiO}_2 \) ratio: < 300 in healthy patients

- Oxygen saturation < 95% with \( \text{FiO}_2 \) 45% in healthy people.

- Oxygen saturation < 92% with \( \text{FiO}_2 \) 45% in healthy children under 1 year.
Study done in pediatric patients from 4 kg-60 kg.

\[ C_{dyn} = 1 \text{ ml/cmH}_2\text{O} / \text{kilo of weight} \text{ until 50 kg} \]
Apneic oxygenation time:
Proportional direct to FRC

![Graph showing the relationship between SaO2 and time for different age groups.]
Non-invasive estimation of shunt and ventilation-perfusion mismatch


Noninvasive assessment of shunt and ventilation-perfusion mismatch at the Bedside. Dr Ben Stenson
Non-invasive estimation of shunt and ventilation-perfusion mismatch

$\text{SpO}_2 \%$

$\text{FiO}_2 \%$ or $\text{PiO}_2 \text{Kpa}$
When do you do a RM?

- As soon as the patient need it BUT before it is indispensable:
  - Hemodynamic stability with good preload
  - NEVER in a hypovolemic patient
  - No recommendable just after the induction

- Anesthesia, preferably before surgery starts (laparoscopy) and after any disconnection.

- Critical care, every morning and after any disconnection (the less the better).
How to do it?
Positive End-Expiratory Pressure after a Recruitment Maneuver Prevents Both Alveolar Collapse and Recruitment/Derecruitment
Jeffrey M. Halter, Jay M. Steinberg, Henry J. Schiller, Monica DaSilva, Louis A. Gatto, Steve Landas, and Gary F. Nieman
Am J Respir Crit Care Med 2003;167: 1620–1626,
Conventional mechanical ventilation: Recruit maneuvers (RM)

1. CPAP or sustained insufflation:
   - 40 cmH₂O / 40 seconds
   - NEVER in children (bradycardia).

2. Few cycles at high pressure:
   - 4-6 cycles 50 cmH₂O.
   - NEVER in children (barotrauma risk).

3. PCV with constant driving pressure y PEEP:
   - Fixed driving pressure of 15 cmH₂O
   - Positive end-expiratory pressure (PEEP) was incrementally increased by steps of 5 cmH₂O from ZEEP to a PEEP of 20-30 cmH₂O.
   - Decrement PEEP titration in steps of 2 cmH₂O until you reach the maximum C dyn (collapse point).
   - Second open up maneuver and set a final PEEP 2 cmH₂O above the collapse point.
Prolonged recruitment manoeuvre improves lung function with less ultrastructural damage in experimental mild acute lung injury

Andréia F. Rzezinski, Gisele P. Oliveira, Viviane R. Santiago, Raquel S. Santos, Debora S. Ornellas,
Marcelo M. Morales, Vera L. Capelozzi, Marcelo B.P. Amato, Marcus B. Conde, Paolo Pelosi,
Patricia R.M. Rocco
Recruit maneuvers (RM)
Prolonged recruitment manoeuvre improves lung function with less ultrastructural damage in experimental mild acute lung injury

Andréia F. Rzezinski\textsuperscript{a}, Gisele P. Oliveira\textsuperscript{a}, Viviane R. Santiago\textsuperscript{a}, Raquel S. Santos\textsuperscript{a}, Debora S. Ornellas\textsuperscript{a}, Marcelo M. Morales\textsuperscript{b}, Vera L. Capelozzi\textsuperscript{c}, Marcelo B.P. Amato\textsuperscript{d}, Marcus B. Conde\textsuperscript{e}, Paolo Pelosi\textsuperscript{f}, Patricia R.M. Rocco\textsuperscript{a,}\textsuperscript{x}
Recruit maneuvers (RM): PCV with driving pressure of 15 cmH2O

VCV for a driving pressure < 15 cmH2O

Collapse point: Reduce of Cdyn

+ Lung protective ventilation
Individual PEEP

- Overdistension
- Collapse

Open alveoli

25

Individual PEEP

5
Dyn Compliance

- Overdistension
- Collapse

Individual PEEP

25 5
Driving pressure (cmH2O)

- Overdistension
- Collapse

Individual PEEP

25

5
Critical open pressure: COP

COP: *intra-individual* variability

Different units with different COP can coexist within the lung (i.e., a bimodal distribution)

The critical opening pressure may be different within a same lung (dependent or non-dependent part of the lung)
Pressure safety range of barotrauma with lung recruitment manoeuvres

A randomised experimental study in a healthy animal model

Javier Garcia-Fernández, Susana Canfrán, Ignacio A. Gómez de Segura, Fernando Suarez-Sipmann, Delia Aguado and Göran Hedenstierna
RECRUITMENT, OVERDISTENSION AND BAROTRAUMA PRESSURES IN HEALTHY RABBIT LUNGS: Materials and Methods

- 14 female New Zealand rabbits (weight 2.8 ± 0.1 kg)

Two groups:

- PEEP-50

García-Fernández J¹, Canfrán S², Gómez de Segura IA², Suárez-Sipmann F³, Aguado D², Hedenstierna G. European Journal of Anaesthesiology 2011; 28:78-79.
Materials and Methods
## Results

<table>
<thead>
<tr>
<th></th>
<th>PEEP-20 group</th>
<th>PEEP-50 group</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Anatomic open lung</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MIP (cmH$_2$O)</td>
<td>$22.0 \pm 2.7$</td>
<td>$21.0 \pm 2.2$</td>
</tr>
<tr>
<td><strong>Overdistended threshold MIP</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(cmH$_2$O)</td>
<td>$33.0 \pm 2.7$</td>
<td>$34.0 \pm 2.2$</td>
</tr>
<tr>
<td><strong>Barotrauma MIP</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(cmH$_2$O)</td>
<td>$55.0 \pm 3.5$</td>
<td>$67.0 \pm 2.7$ *</td>
</tr>
<tr>
<td><strong>Safety range</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(cmH$_2$O)</td>
<td>$22.0 \pm 5.7$</td>
<td>$33.0 \pm 2.7$ *</td>
</tr>
</tbody>
</table>

* $P < 0.01$

García-Fernández J ¹, Canfrán S ², Gómez de Segura IA ², Suárez-Sipmann F ³, Aguado D ², Hedenstierna G. European Journal of Anaesthesiology 2011; 28:78-79.
Respiratory pressures in anatomically open lung and barotrauma conditions. Maximal inspiratory pressure (MIP, highest bar value), driving pressure and positive end-expiratory pressure (PEEP) during recruitment manoeuvres in two groups of rabbits wherein a maximum PEEP of 50 cmH_{2}O (left) or 20 cmH_{2}O (right) was applied. There were no significant differences in the anatomically open lung MIP between groups. There were significant differences in the barotrauma MIP (P = 0.003) and barotrauma driving pressure (*PEEP-50 vs. PEEP-20, P < 0.001) between groups.

García-Fernández J¹, Canfrán S², Gómez de Segura IA², Suárez-Sipmann F³, Aguado D², Hedenstierna G. European Journal of Anaesthesiology 2011; 28:78-79.
CONCLUSIONS

• There is a wide safety range of pressures with both pressure controlled RMs in healthy small lungs.
• However, an increased safety margin may be obtained when a higher PEEP is employed during RM, by maintaining a low and constant driving pressure during the all RM:
  • Barotrauma MIP $> 55$ cmH$_2$O vs $> 65$ cmH$_2$O
  • Safety range $> 20$ cmH$_2$O vs $> 30$ cmH$_2$O
Lung recruitment manoeuvres do not cause haemodynamic instability or oxidative stress but improve oxygenation and lung mechanics in a newborn animal model

An observational study

Agustin Mendiola de la Osa, Javier Garcia-Fernandez, Francisco J. Llorente-Cantarero, Mercedes Gil-Campos, María C. Muñoz-Villanueva, María J. De la Torre Aguilar, Ignacio Ibarra de la Rosa and Juan L. Pérez-Navero
Fig. 2

- **PaO₂ (kPa)**
  - 32.40
  - 31.40
  - 40.26

- **Vt (ml)**
  - 47.75
  - 95.12
  - 4.7

- **Cdyn (ml cm H₂O⁻¹)**
  - 2.5
  - 1.4

Open-lung PEEP

- cm H₂O
  - Steps 1 to 15
What this paper contributes to our knowledge
In a neonatal piglet model with normal lung mechanics, pressures resulting in pneumothorax following a recruitment maneuver were greater than those typically used clinically. Hemodynamic impairment was commonly seen, with animals at zero PEEP having greater impairment that those at higher PEEP. Limiting driving pressure during recruitment can reduce hemodynamic compromise.
Neonatal Pneumothorax Pressures Surpass Higher Threshold in Lung Recruitment Maneuvers: An In Vivo Intervventional Study

Patricio González-Pizarro, MD®, Javier García-Fernández, MD PhD, Susana Canfrán, DVM PhD and Fernando Gilsanz, MD PhD

Table 1. Maximal Inspiratory Pressure Resulting in Pneumothorax According to Group After Randomization

<table>
<thead>
<tr>
<th>Animal</th>
<th>Group</th>
<th>Pneumothorax Maximal Inspiratory Pressure, cm H2O</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PEEP</td>
<td>70</td>
</tr>
<tr>
<td>2</td>
<td>Zero PEEP</td>
<td>65</td>
</tr>
<tr>
<td>3</td>
<td>PEEP</td>
<td>105</td>
</tr>
<tr>
<td>4</td>
<td>PEEP</td>
<td>95</td>
</tr>
<tr>
<td>5</td>
<td>Zero PEEP</td>
<td>85</td>
</tr>
<tr>
<td>6</td>
<td>Zero PEEP</td>
<td>85</td>
</tr>
<tr>
<td>7</td>
<td>Zero PEEP</td>
<td>115</td>
</tr>
<tr>
<td>8</td>
<td>Zero PEEP</td>
<td>95</td>
</tr>
<tr>
<td>9</td>
<td>PEEP</td>
<td>105</td>
</tr>
<tr>
<td>10</td>
<td>PEEP</td>
<td>85</td>
</tr>
</tbody>
</table>

![Graph showing PIP (cm H2O) with different groups and conditions]
The authors present compelling evidence to suggest that a recruitment maneuver, particularly with an approach of incremental increases in PEEP and fixed driving pressure, should be well tolerated in mechanically ventilated newborns with normal lungs.
Transient hemodynamic effects of recruitment maneuvers in three experimental models of acute lung injury

Sung-Chul Lim, MD; Alexander B. Adams, MPH; Dana A. Simonson, BA; David J. Dries, MSE, MD; Alain F. Broccard, MD; John R. Hotchkiss, MD; John J. Marini, MD

Cardiac output

Mean arterial pressure

The best benefits with RM

- Early states of ARDS
- Diffuse ARDS
- Collapse lung models:
  - Anesthesia atelectasis
  - Neonates and small children
Bad results with RM

- Chronic obstructive pulmonary disease (COPD)
- Unilateral pneumonia
- Heterogeneous ARDS
- Late states of ARDS
Contraindications of RM

- Intracranial Hypertension
- TBI
- Emphysema
- Terminal respiratory diseases before lung transplantation

In this cases, is better to prevent than to treat atelectasis
Thanks

¿Questions?

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