Continuous Negative Abdominal Pressure (CNAP) - Augments PEEP, Reduces Lung Injury

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Abdominal pressure

Increased abdominal pressure

Dependent Collapse
hyperinflation or collapse

PEEP 6cmH\textsubscript{2}O

![Diagram showing hyperinflation and collapse](image)
hyperinflation or collapse

PEEP 6cmH$_2$O

- 0%
- 30%

PEEP 12cmH$_2$O

- 10%
- 15%

Hiperdistensão
Colapso cumulativo
hyperinflation or collapse

PEEP 6cmH$_2$O
- 0% Hyperdistensão
- 30% Colapso cumulativo

PEEP 12cmH$_2$O
- 10% Hyperdistensão
- 15% Colapso cumulativo

PEEP 18cmH$_2$O
- 30% Hyperdistensão
- 0% Colapso cumulativo
Decreased abdominal pressure

3.5 cmH$_{2}$O

1.8 cmH$_{2}$O!!

Normal

Eviscerated

Ventral

Dorsal

Vertical gradient

Respiration Physiology 1970; 8: 332–
Vertical position

Supine to Vertical  1 hour-Vertical

in oxygenation. Relief of abdominal compression on lung bases associated with verticalization may allow caudal displacement of the diaphragm and subsequently recruitment of dependent lung area [4, 8]. The higher volumes

CNAP Device

Patent for CNAP device is applied (BK, TY, DE).
Hypothesis

- CNAP reduce abdominal pressure, recruit dorsal atelectasis
Hypothesis

- CNAP reduce abdominal pressure, recruit dorsal atelectasis
- CNAP reduce lung injury.
Methods

Instrumentation

Pig

Intubation
A line
CV line
S-G line
Esophageal balloon
EIT
Methods

Instrumentation

- Intubation
- A line
- CV line
- S-G line
- Esophageal balloon
- EIT

Lung Injury

- Surfactant depletion
  + VILI

Pig
Methods

Instrumentation
- Pig
- Intubation
- A line
- CV line
- S-G line
- Esophageal balloon
- EIT

Lung Injury
- Surfactant depletion
- + VILI

Progressive de-recruitment
- ± CNAP -5cmH₂O
- Decremental PEEP steps
  - 20
  - 18
  - 16
  - 14
  - 12
  - 10
  - 8
  - 6
  - 4

- CT
- Pleural pressure measurements
P/F ratio

PEEP, cmH$_2$O

mmHg
P/F ratio

PEEP, cmH₂O

(* P<0.05, vs. PEEP)
Expiratory transpulmonary pressure

PEEP, cmH\(_2\)O

<table>
<thead>
<tr>
<th>PEEP, cmH(_2)O</th>
<th>exp PL_PEEP</th>
<th>exp PL_CNAP</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>-2.5</td>
<td>-3</td>
</tr>
<tr>
<td>18</td>
<td>-2</td>
<td>-3</td>
</tr>
<tr>
<td>16</td>
<td>-1.5</td>
<td>-3</td>
</tr>
<tr>
<td>14</td>
<td>-1</td>
<td>-3</td>
</tr>
<tr>
<td>12</td>
<td>0</td>
<td>-2</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>-2</td>
</tr>
<tr>
<td>8</td>
<td>2</td>
<td>-1.5</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>-1</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>0</td>
</tr>
</tbody>
</table>

2.5 cmH\(_2\)O
PEEP (NO CNAP)

Transpulmonary pressure: cmW

Pearson r = 0.85
P = 0.000
P/F ratio

PEEP (NO CNAP)  PEEP + CNAP

Transpulmonary pressure: \text{cmW}

Pearson r = 0.85  Pearson r = 0.34

\text{P = 0.000}  \text{P = 0.004}
Ventilation

PEEP (No CNAP)
### Ventilation

<table>
<thead>
<tr>
<th>PEEP (No CNAP)</th>
<th>PEEP+CNAP</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Diagram" /></td>
<td><img src="image2.png" alt="Diagram" /></td>
</tr>
</tbody>
</table>

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*Note: Diagrams represent the ventilation settings for PEEP and PEEP+CNAP.*
Aeration

PEEP10

Non-aeration: 79%
Aeration

PEEP10

PL: -0.5

Non-aeration: 79%

PEEP 10 + CNAP -5

PL: 2.3

Non-aeration: 27%!!
Aeration

PEEP10

PL: -0.5

Non-aeration: 79%
Aeration

Non-aeration: 79%

PEEP 10
PL: -0.5

PEEP 6 + CNAP -5
PL: -1.0
Aeration

PEEP10
PL: -0.5
Non-aeration: 79%

PEEP 6 + CNAP -5
PL: -1.0
Non-aeration: 56%!!
Aeration

PEEP (NO CNAP)

Transpulmonary pressure: cmW
Aeration

PEEP (NO CNAP)  PEEP + CNAP

Transpulmonary pressure: cmW  Transpulmonary pressure: cmW
Pleural pressure distribution

ventral

PEEP (NO CNAP)

Ppl nondependent

Ppl dependent

10.5
Pleural pressure distribution

ventral

PEEP (NO CNAP)

PEEP + CNAP

Ppl nondependent Ppl dependent

Ppl nondependent Ppl dependent

10.5

7.1
Shape of chest wall

PEEP (NO CNAP)
Shape of chest wall

PEEP (NO CNAP)

PEEP + CNAP

5cm of caudal shift
Gross pathology

PEEP (NO CNAP)
Gross pathology

PEEP (NO CNAP)  

PEEP + CNAP
Wet to Dry

![Graph showing comparison between PEEP (No CNAP) and CNAP + PEEP.](image)

(* P<0.01, vs. PEEP)
Cytokine

IL-6 in BAL

PEEP (No CNAP)  \(\text{CNAP + PEEP}\)

IL-6 in tissue

PEEP  \(\text{CNAP}\)

nondependent  middle  dependent

(# \(P<0.05\), vs. PEEP)  (* \(P<0.01\), vs. PEEP)
Conclusion

CNAP + PEEP vs. PEEP

- Selectively Recruits
- Improves Lung Function
- Mechanism different to additional PEEP
- Lessens Injury
Pleural pressure distribution

ventral

Ppl nondependent
Ppl dependent

Ppl nondependent
Ppl depndent

dorsal
Pleural pressure distribution

ventral

PEEP (NO CNAP)

PEEP + CNAP

dorsal
Ventilation

PEEP (NO CNAP)

PEEP + CNAP

Pearson $r = 0.70$, $p = 0.000$

Pearson $r = -0.16$, $p = 0.178$
ARDS (No CNAP)

Vertical gradient

P_{pl}

4

10

14

dorsal

ventral
ARDS (No CNAP)

- Ventral
- Hyperinflation
- Collapse

PEEP 12

$P_{pl} = P_L$

4

14

8

10

-2
ARDS (CNAP)

Vertical gradient

PEEP 7

\[ P_{pl} = P_L \]

2

5

7

0