Lung Stress and Strain in ARDS

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Chest wall elastance

Stiff

“Soft”

E \textsubscript{tot}

25

5 cmH\textsubscript{2}O

E \textsubscript{L}

E \textsubscript{w}

E \textsubscript{tot}

25

15 cmH\textsubscript{2}O

E \textsubscript{L}

E \textsubscript{w}

E \textsubscript{tot}

15

15
Clinical equivalents

Stress $\approx$ PL transpulmonary pressure

Strain $\approx \frac{V_T}{FRC}$

The linkage is the specific elastance

\[ PL = E_{1\text{spec}} \ast \frac{V_T}{FRC} \]

Barotrauma

Volotrauma
<table>
<thead>
<tr>
<th></th>
<th>FRC</th>
<th>TLC</th>
<th>Sp E</th>
<th>PL (TLC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ml</td>
<td>ml</td>
<td>cm H₂O</td>
<td>cm H₂O</td>
<td></td>
</tr>
<tr>
<td>2.5</td>
<td>7.5</td>
<td>4</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>300</td>
<td>900</td>
<td>6</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td>6000</td>
<td>12</td>
<td>24</td>
<td></td>
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</tbody>
</table>
Strain vs VT/kg IBW

PEEP 5 cmH$_2$O

Slope \( P_L/P_{aw} = E_w/E_{tot} \) \([0.2 - 0.8]\)

A
- Surgical control group
- Medical control group

B
- ALI patients
- ARDS patients

Chiumello et al, Am J Respir Crit Care Med. 2008
Stress-strain curve of healthy pigs

Specific Lung Elastance: 5.8 cmH₂O

Tidal Strain

\[ P^* \Delta V = \text{Energy Input} \]

Dissipated
- Surface Tension
- Sliding EM
- Opening and Closing

Undissipated
- Elastic System

Continuous Strain

\[ \text{PEEP}^* \Delta V = \text{Energy Input} = 0 \]
EXAPLES OF ENERGY COMPUTATIONS AT DIFFERENT PRESSURES

ZEEP

LOW PEEP

HIGH PEEP
Global stress able to damage healthy (or “baby”?) lung in clinical practice is uncommon.

However, when the lung starts to deteriorate the rate of damage is impressively fast, why?

If global stress is so rare, how can we explain the following slide?
Stress distribution:

high stiffness zone

Average ratio in normal subjects: $1.37 \pm 0.15$
Hypothesis

Lesions should first occur where physiological stress risers are located.
Before appearance first new densities

END EXPIRATION

END INSPIRATION

TIME 1: 5.7±6.5 hours

Courtesy of dr. Cressoni M.
First CT scan with new densities

TIME 2: $8.4 \pm 6.3$ hours

*Courtesy of dr. Cressoni M.*
Last CT scan with distinguishable densities

TIME 3: 15±12 hours

Courtesy of dr. Cressoni M.
First CT scan with one-field edema

TIME 4: 18±11 hours

Courtesy of dr. Cressoni M.
First CT scan with all-field edema

END EXPIRATION

END INSPIRATION

TIME 5: 20±11 hours

Courtesy of dr. Cressoni M.
VILI cumulative time course

- **Severity trend**
  - T2
  - T3
  - T4-5

- **CT scan only**
  - Gas Exchange
  - Lung mechanics

- **Hours**
  - 0
  - 5
  - 10
  - 15
  - 20
  - 25

*Courtesy of dr. Cressoni M.*
LUNG IMAGING

CT SCAN
INFLATION

INHOMOGENEITY

PET
FDG UPTAKE
Ki/lung inhomogeneity interaction and gas/tissue composition
Lung protective strategy

Less energy

+  

More homogeneous lung
Deutsches MEETING
Frankfurt, January 13-14 2017

Dubito Ergo Sum — Rethinking Respiratory Intensive Care

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