Lung recruitability: How to assess and define?

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Why recruitability is important?

ARDS: loss of lung volume
Positive pressure: two-side effect

Perlman CE, Am J Respir Cell Mol Biol 2011
Approach I: Morphology
CT analysis: Gattinonni method

Lower Percentage of Potentially Recruitable Lung

5 cmH₂O of PEEP

45 cmH₂O of Pplat

Gattinoni L. et al, NEJM 2006
CT analysis: Gattinoni method

Higher Percentage of Potentially Recruitable Lung

5 cmH₂O of PEEP

45 cmH₂O of Pplat

Gattinoni L et al, NEJM 2006
CT analysis: Gattinoni method

Gattinoni L et al, NEJM 2006
Quantitative CT analysis: Gattinoni method

- Voxel-by-voxel
- Tissue weight
- Recruitment: the change in the weight of non-aerated tissue between two elastic pressures
CT analysis: Rouby method

Quantitative CT analysis: Rouby method

- Anatomically delineated regions
- Gas volume
- Recruitment: the increase in the volume of gas penetrating in non-aerated and poorly aerated lung regions between ZEEP and PEEP conditions
Quantitative CT analysis

- How to define recruitment by CT remains controversy
- Time consuming
- Infeasible and potentially risky in clinical practice
Approach II: Mechanics
Hysteresis-like behavior

Mead J. et al, JAP 1957
Elastic Hysteresis?

- “The work done by the material when it returns to its original shape is less than the work required to deform it;
- There are nonconservative forces associated with internal friction.”

11.19 Typical stress-strain diagram for vulcanized rubber. The curves are different for increasing and decreasing stress, a phenomenon called elastic hysteresis.

Stress-strain curve for increasing stress (stretching the object)
Stress-strain curve for decreasing stress (letting the object spring back)
"Most of the lungs’ hysteresis does not relate to nonreversible stress-strain characteristics of tissue elements"

Fig. 5. Saline (solid line) and air (dotted line) volume-pressure plots obtained in excised dog lungs.
Hysteresis-like behavior

Multiple P-V Curves: Recruitment

Ranieri VM. et al, AJRCCM 1994
Derecruitment on CT and P-V curves

Lu Q. et al, Crit Care 2006
Derecruitment on CT and P-V curves

Lu Q. et al, Crit Care 2006

\[ Y = 92.3 + 0.7X, \]
\[ R = 0.82, p < 0.0001 \]
Direct measurement of lung volume

Dellamonica J. et al, ICM 2011
Highly recruitable

Non-recruitable

Chen L. Unpublished Data
“Recruitment” should be caused by lungs not by chest wall
Assumptions

• Upshift on quasi-static P-V curves during inflation denotes alveolar recruitment rather than elastic hysteresis

• $\Delta EELV$ measured by nitrogen washout/in is accurate

• $\Delta\text{Paw}$ is equal to $\Delta\text{Palv}$

• $\Delta\text{Ppl}$ is equal to $\Delta\text{Pes}$

Chen L. Unpublished Data
Assumptions hold true in this patient

✓ Upshift on quasi-static P-V curves during inflation denotes alveolar recruitment rather than elastic hysteresis
✓ $\Delta$EELV measured by nitrogen washout/in is accurate
✓ $\Delta$Paw is equal to $\Delta$Palv
✓ $\Delta$Ppl is equal to $\Delta$Pes

Chen L. Unpublished Data
Still too complicated?
Yes!
Crs-estimated Vrec vs. measured Vrec

Dellamonica J. et al, ICM 2011
Crs-estimated Vrec vs. measured Vrec

P<0.0001, $R^2=0.93$

Chiumello D. et al, AJRCCM 2015
Rationale

Chen L., Richard JC., Brochard L., et al
Unpublished data @ CCCF poster section
Rationale

\[ V_{\text{der,est}} = \text{real } \Delta \text{EELV} - \text{predicted } \Delta \text{EELV} \]

\[ = \Delta \text{EELV measured by spirometer} - \text{Crs at PEEPlow} \times \Delta \text{PEEP} \]
Recruitability was determined by V_{der} measured using reference method and a threshold of 200 ml.

Chen L., Richard JC., Brochard L., et al
Unpublished data @ CCCF poster section
Thank you.