



2019 台灣胸腔暨重症加護醫學會

2019 Taiwan Society of Pulmonary and Critical Care Medicine

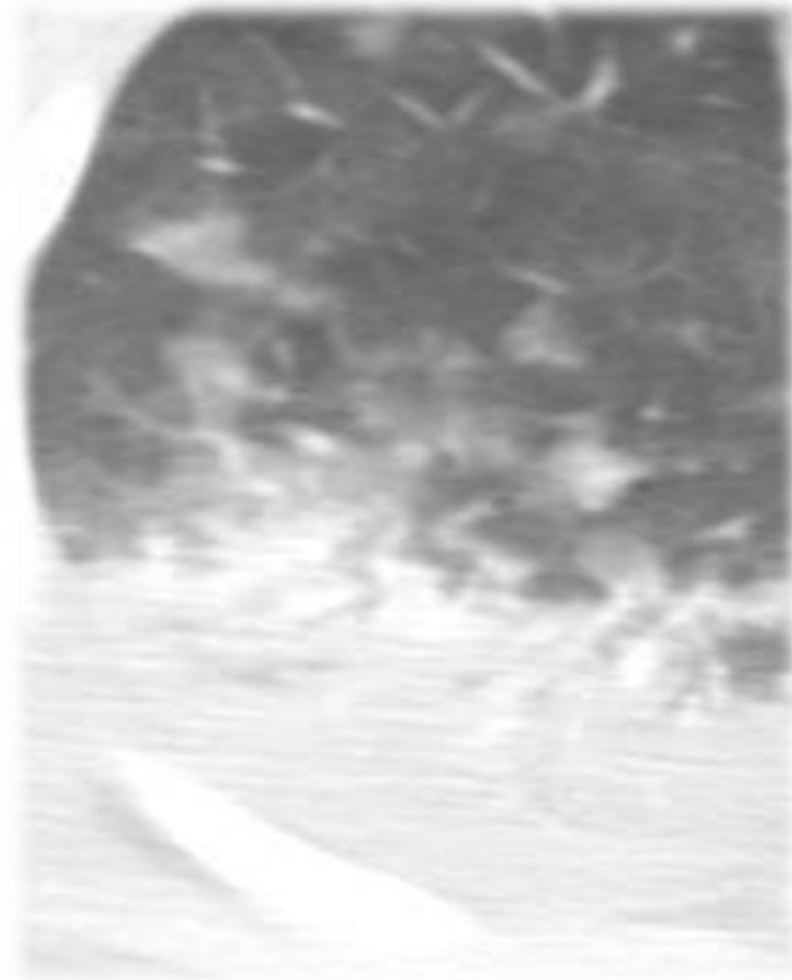
Two similar best respiratory system
compliance in **ARDS** patients

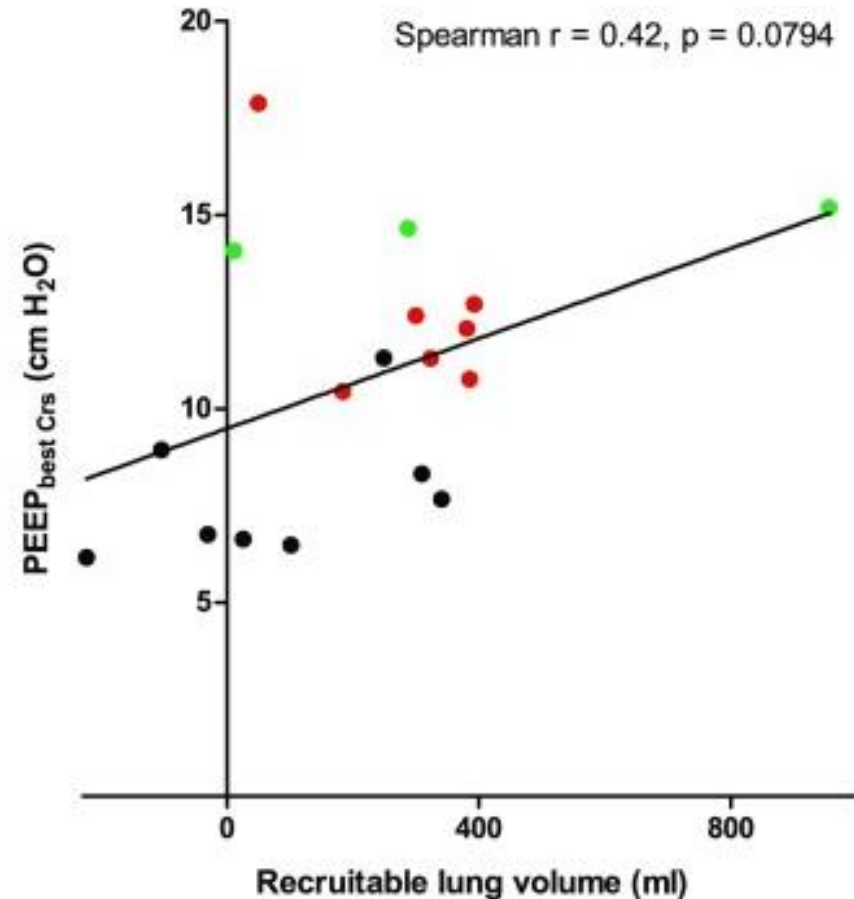
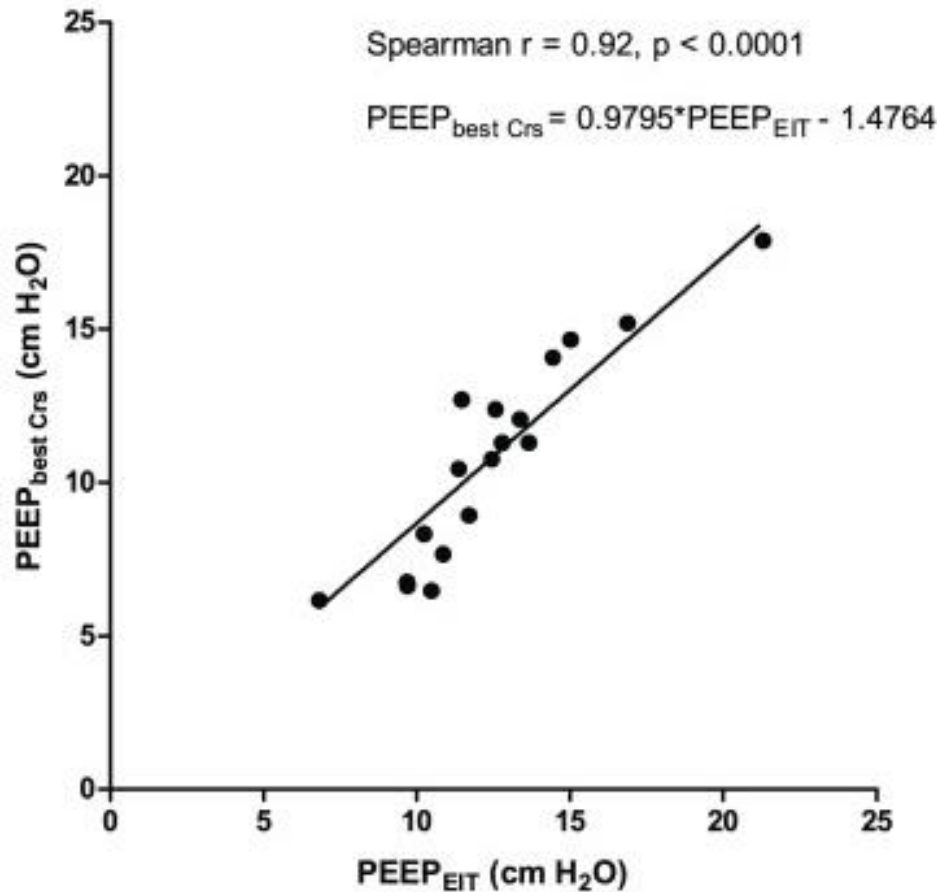
Analyzed by

**Electrical impedance
tomography (EIT)**

成大醫院胸腔內科

蘇柏嵐 林偉傑 陳昌文





- No relationship between PEEP level selected by best compliance and recruited volume
- Recruited volume could not be surrogate for PEEP selection
 - During study, same systemic compliances at two different PEEP were noted (<1 ml/cm H₂O)

*In some cases, compliance increases following PEEP decrements and reaches a plateau, that is, maximum value of compliance with difference $<1\text{mL/cmH}_2\text{O}$. In these cases, consider optimal PEEP as **$2\text{cmH}_2\text{O}$ above the highest PEEP** within the plateau range.*

ART trial. JAMA. 2017

*...If at 2 different PEEPs the static compliance was identical, we chose the one with the **lower plateau pressure**...*

Pintado et al. Respir Care 2013

Study Population

Physiologic study

33 acute respiratory distress syndrome patients in NCKUH

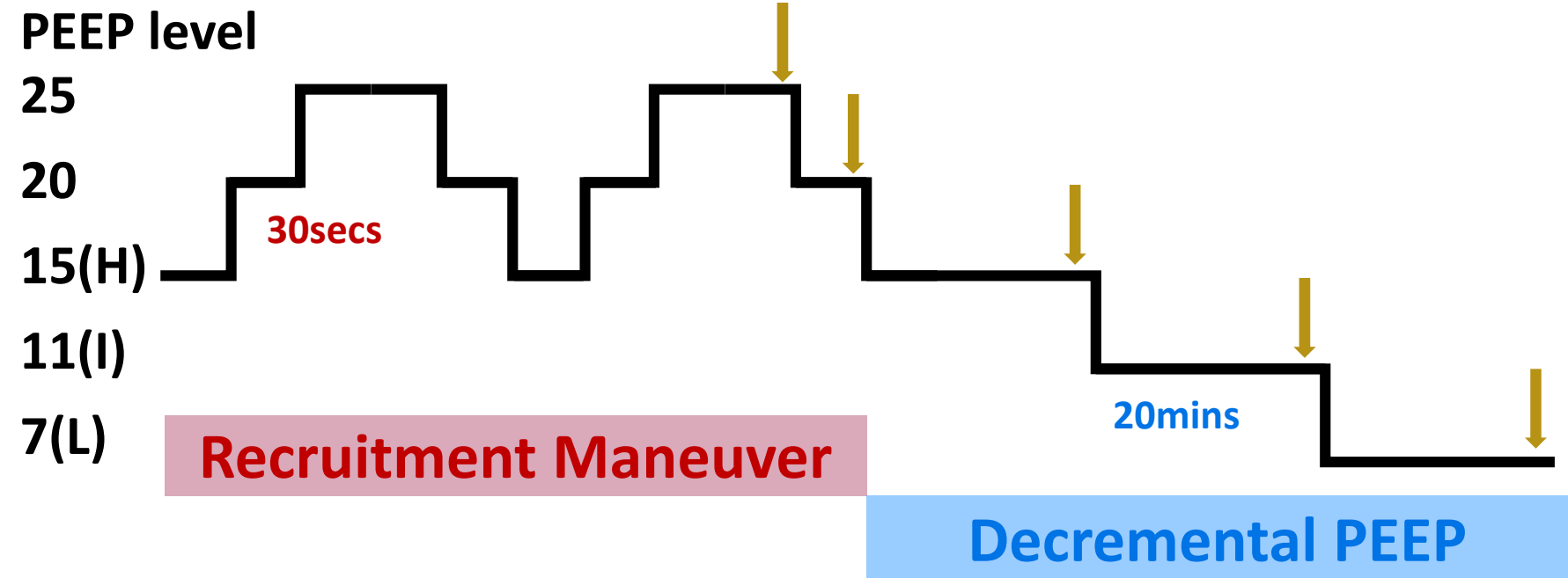
Study Protocol

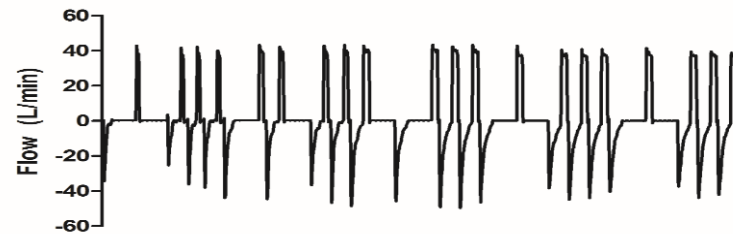
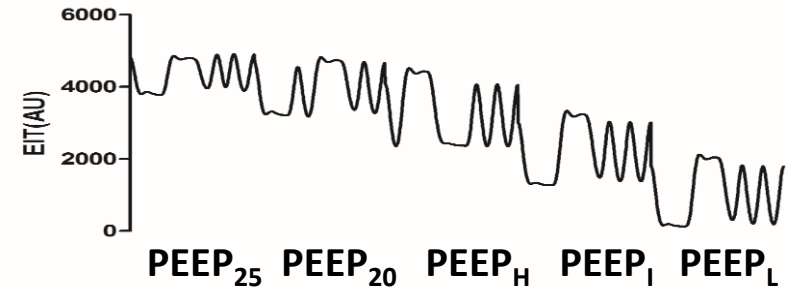
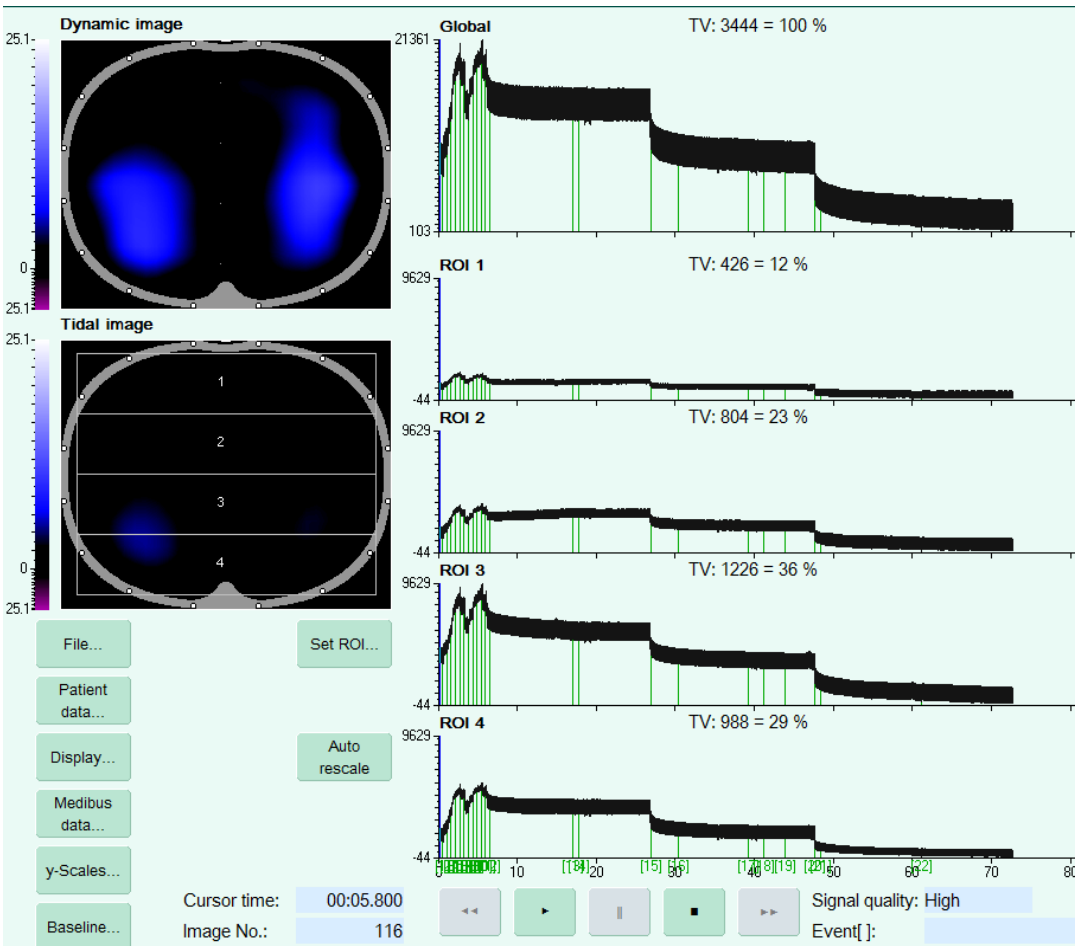
Protective ventilation (6-8ml/kg IBW), RR < 30/min, FiO₂ ≥ 50%

Perform **recruitment maneuver** and followed by **decremental PEEP**

Electrical impedance tomography were recorded in whole course

End-expiratory/end-inspiratory occlusion at final five level
for calculation of lung mechanics





Case	1	2	3	4	5	6	7	8	9	10	11
Gender/Age	M/65	F/40	M/30	M/73	F/64	F/67	M/36	M/41	M/70	M/74	M/60
MV days	11	2	6	3	3	3	3	13	3	8	3
ARDS Severity	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Severe	Moderate
Diagnosis	Pneumonia	Pneumonia, Turner syndrome	PJP, Behçet's disease	KP Pneumonia	Pneumonia	Pneumonia	Miliary tuberculosis	Pneumonia	Pneumonia, Lung cancer	Acute cholecystitis with KP bacteremia	PJP, T-cell lymphoma
Outcome	Survival	Survival	Survival	Death	Death	Survival	Survival	Survival	Death	Death	Death
PEEP_H (cm H₂O)	15.6	14.7	14.5	14.3	13.9	14.8	14.6	15.4	15.9	13.7	15.9
PEEP_I (cm H₂O)	11.4	10.4	10.3	10.7	9.4	10.6	10.8	11.6	13.2	9.5	13.0
PEEP_L (cm H₂O)	6.8	6.2	6.1	6.6	5.2	6.5	6.8	7.7	8.4	5.4	8.6
Crs, PEEP_H (ml/cm H₂O)	25.5	27.2	36.8	33.8	34.5	21.6	56.9	43.9	42.5	42.8	31.2
Crs, PEEP_I (ml/cm H₂O)	32.8	31.8	36.1	37.5	34.6	27.9	59.0	54.3	44.4	44.8	30.3
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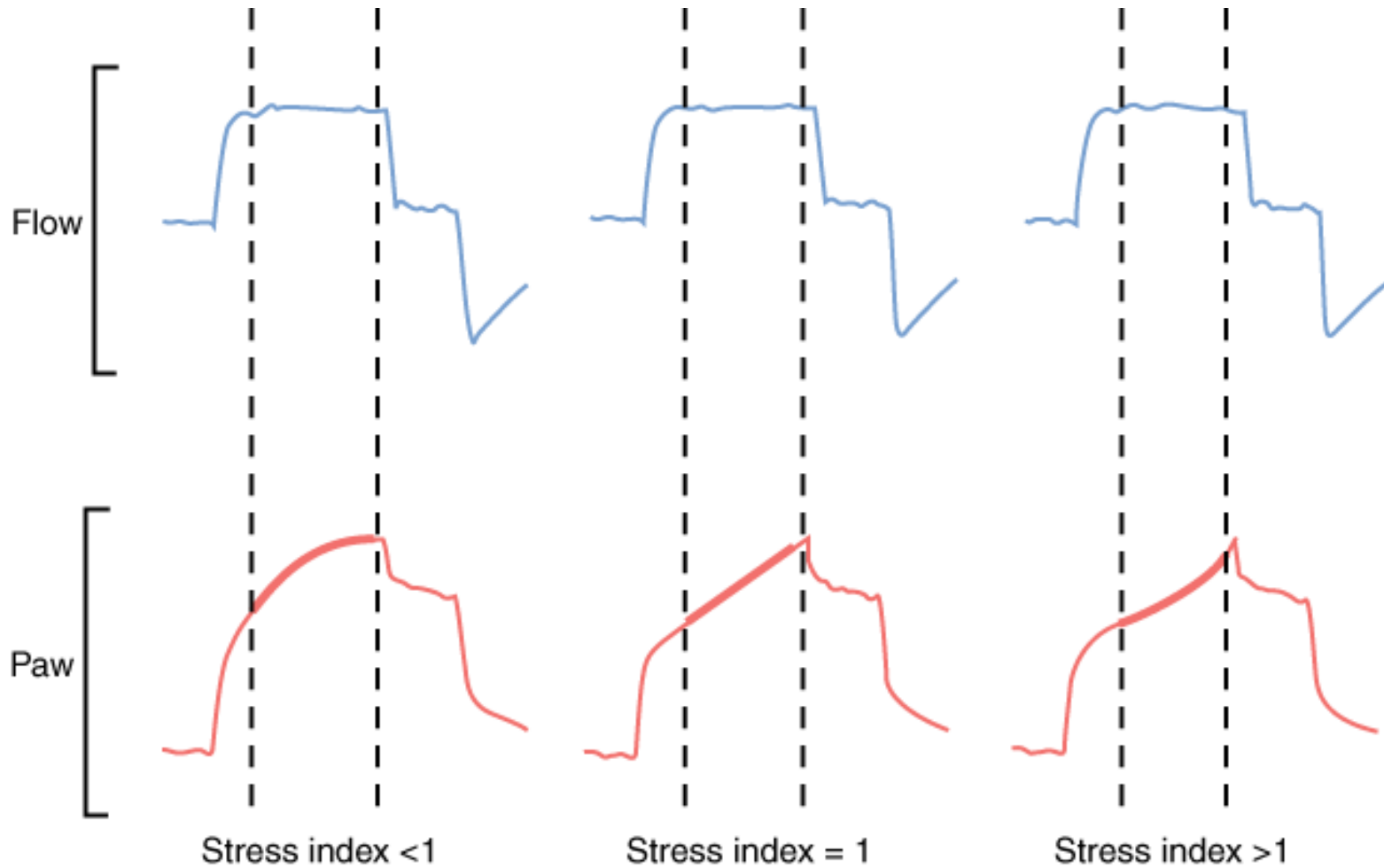
3 patients with similar compliance at PEEP_I and PEEP_H
8 patients with similar compliance at PEEP_L and PEEP_I

Stress index

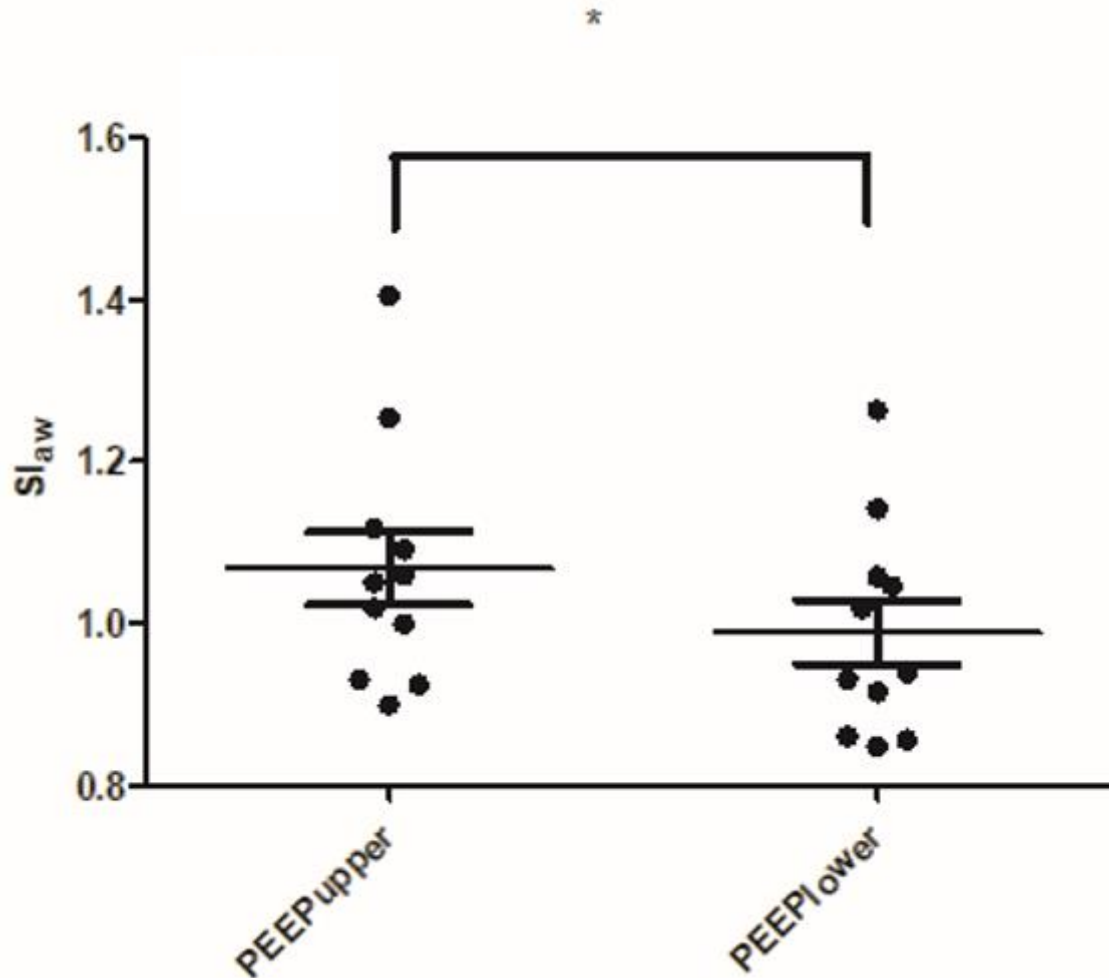
EIT-based measurement

Stress index

EIT-based measurement



$$\text{airway pressure} = a \times \text{inspiratory time}^b + c$$



$PEEP_{upper}$ has higher stress index

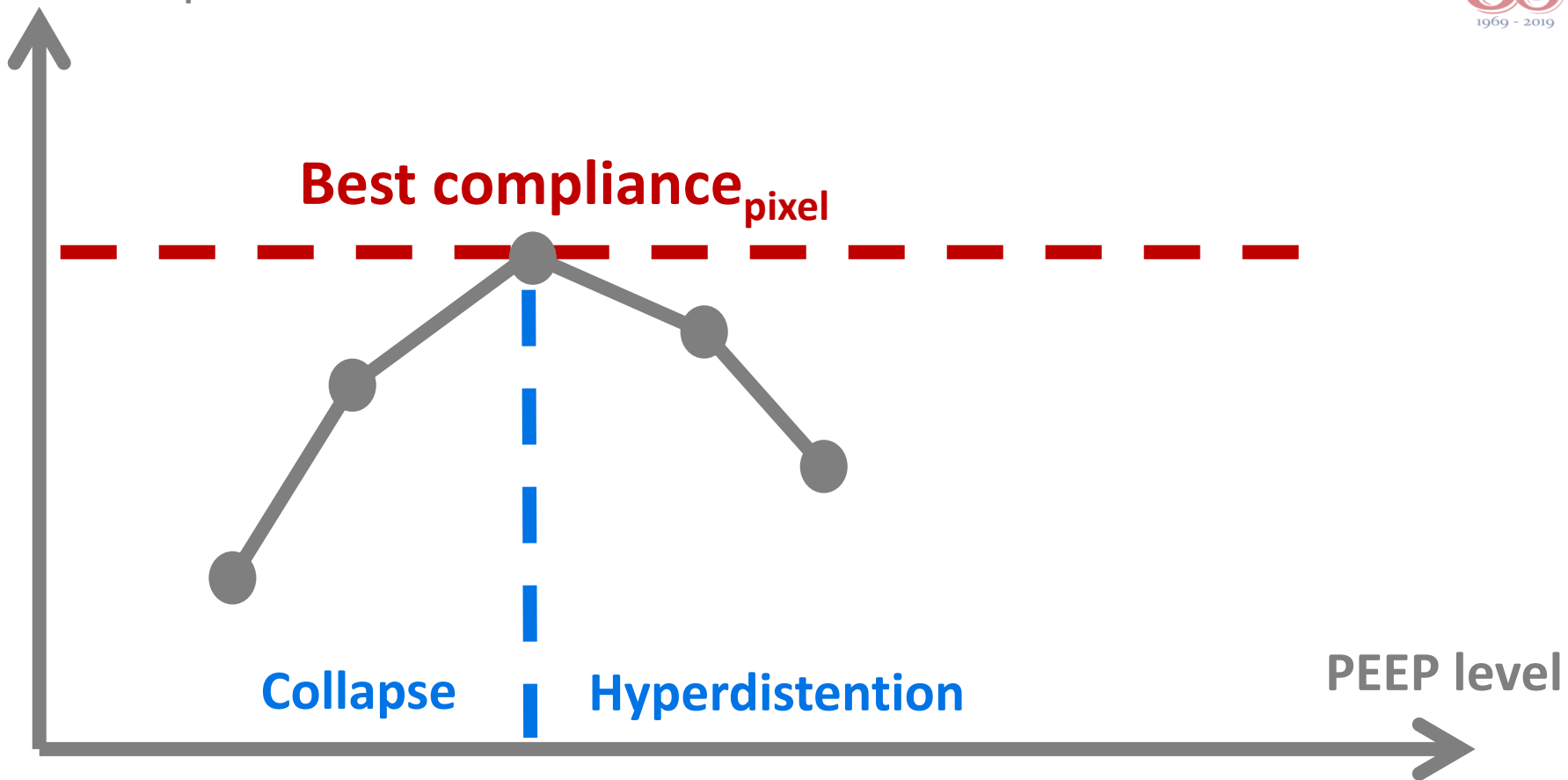
Only 8 case in $PEEP_{upper}$ and 6 cases when $PEEP_{lower}$ has stress index in the recommended range ($0.9 < SI < 1.1$)

Stress index

EIT-based measurement

Collapsibility/Hyperdistention

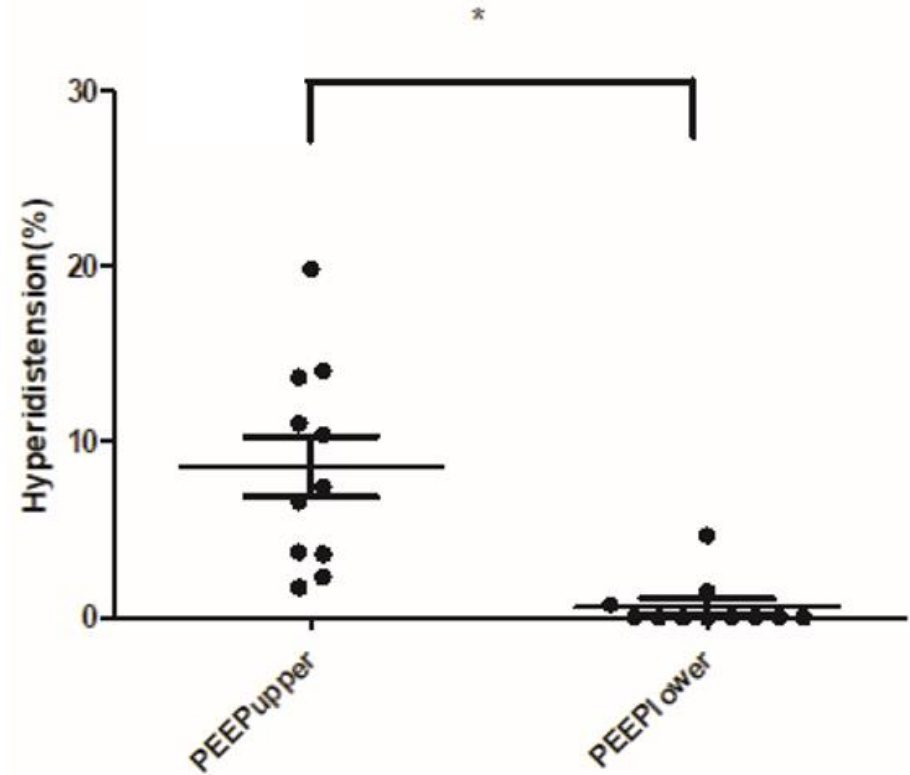
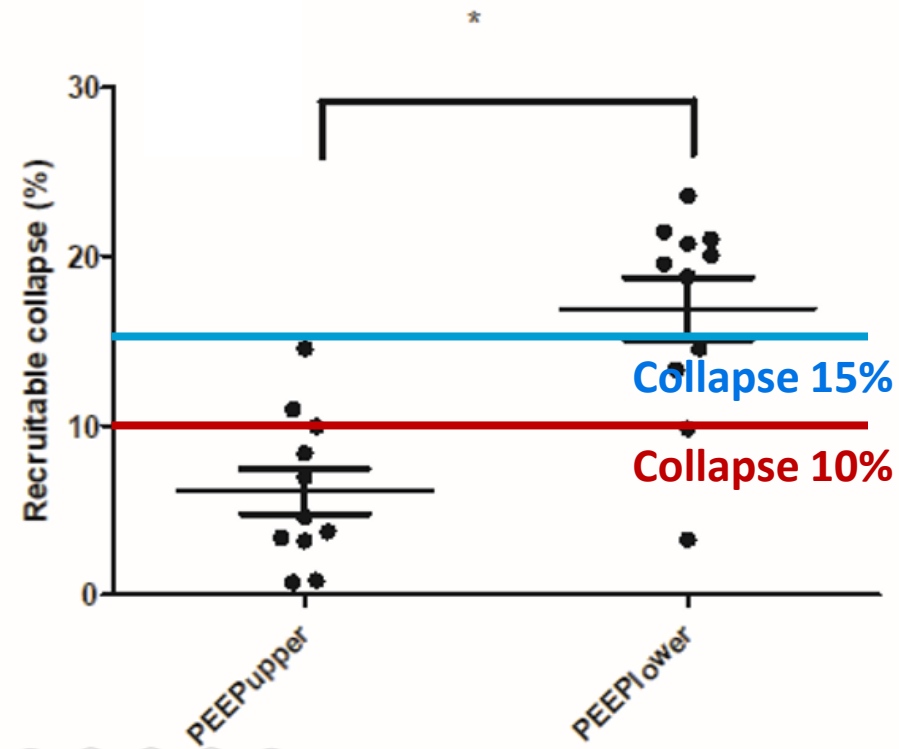
$$\text{compliance}_{\text{pixel}} = \Delta Z / \Delta P$$



$$\sum \text{Collapse}_{\text{pixel}}(\%) = \frac{\sum (\text{Best compliance}_{\text{PIXEL}} - \text{Current compliance}_{\text{pixel}})}{\sum \text{Best compliance}_{\text{pixel}}}$$

$$\sum \text{Hyperdistention}_{\text{pixel}}(\%) = \frac{\sum (\text{Best compliance}_{\text{PIXEL}} - \text{Current compliance}_{\text{pixel}})}{\sum \text{Best compliance}_{\text{pixel}}}$$

Bedside Contribution of Electrical Impedance Tomography to Setting Positive End-Expiratory Pressure for Extracorporeal Membrane Oxygenation-treated Patients with Severe Acute Respiratory Distress Syndrome



PEEP_{upper} has higher hyperdistention and lower collapse

When selected PEEP_{lower}

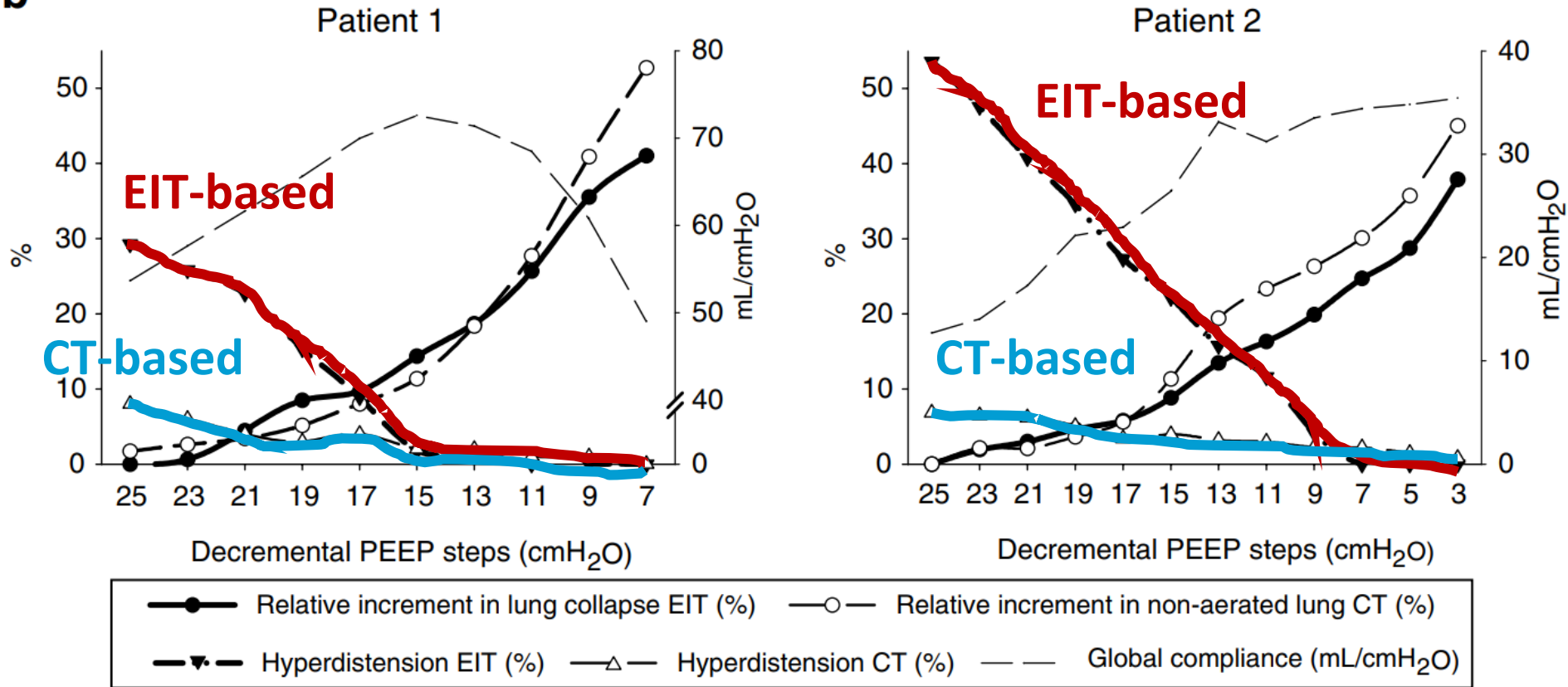
75% cases have a recruitable lung collapse above 10%

58% cases have a recruitable lung collapse above 15%

Costa EL et al, Intensive Care Med, 2009.

Franchineau G et al. Am J Respir Crit Care Med, 2017.

b



EIT-based hyperdistention usually overestimate CT-based hyperdistention

Stress index

EIT-based measurement

Collapsibility/Hyperdistention

Tidal recruitment/derecruitment

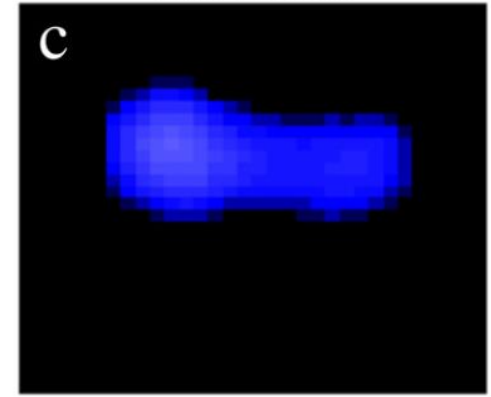
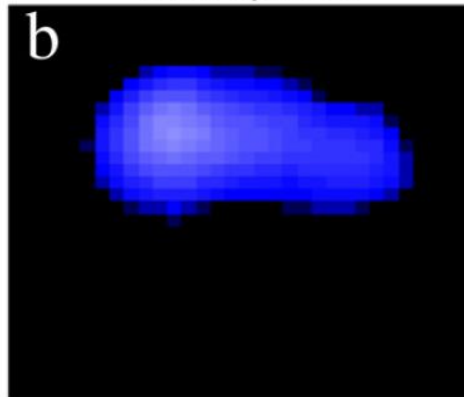
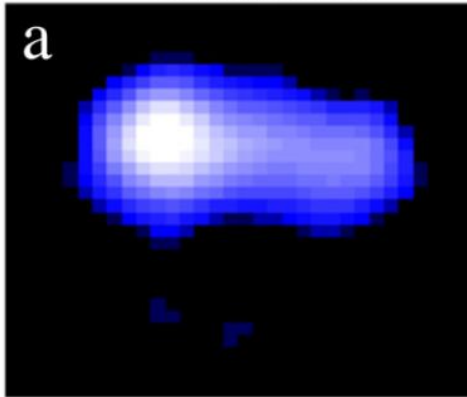
Dynamic Image

End Inspiration

End Expiration

Status Image

Tidal Variation



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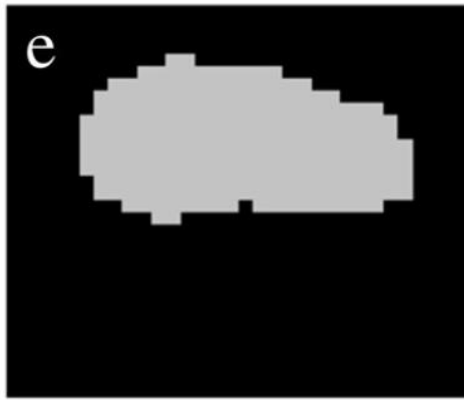
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Lung Regions

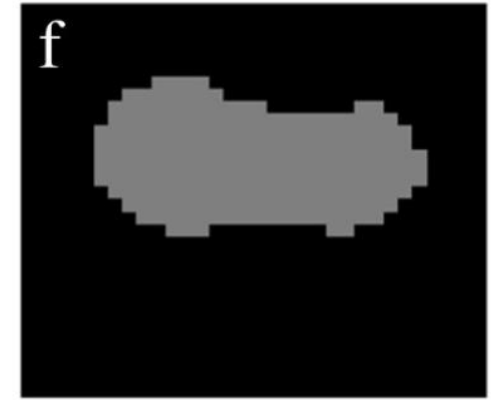
Ref. PEEP Level; End Expiration



> 25% of Max.



> 20% of Max.

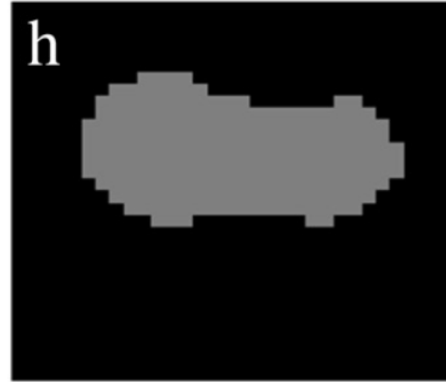


Arbitrary PEEP Level

End Expiration



Tidal Variation



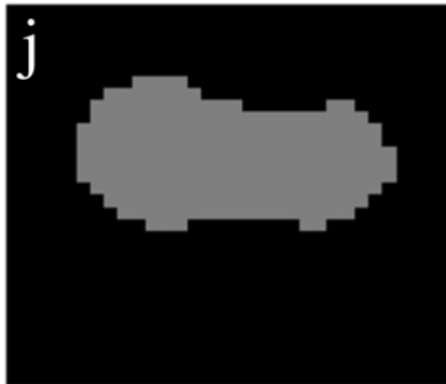
Overdistension



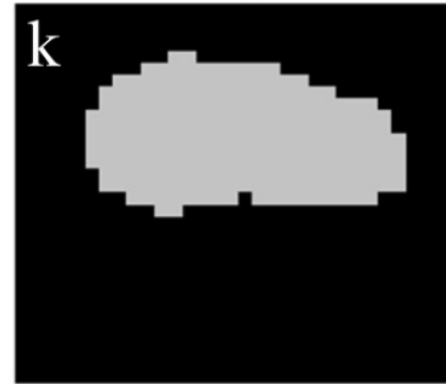
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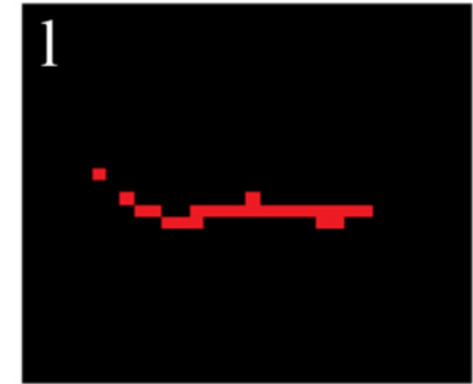
Tidal Variation



End Expiration

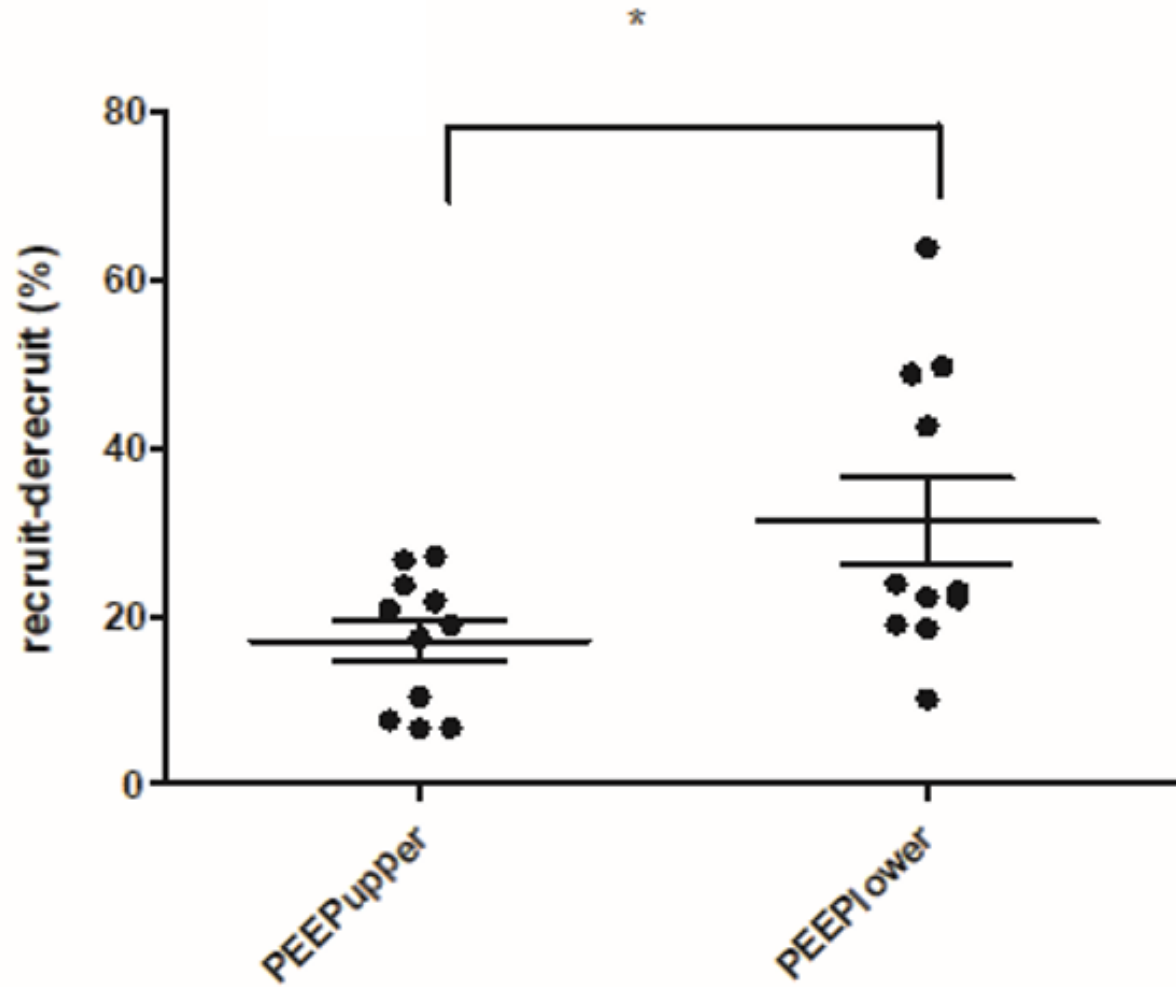


Tidal Recruitment / Derecruitment



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PEEP_{lower} has significantly higher tidal recruitment/derecruitment

Case	1	2	3	4	5	6	7	8	9	10	11
Gender/Age	M/65	F/40	M/30	M/73	F/64	F/67	M/36	M/41	M/70	M/74	M/60
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3 patients with similar compliance at PEEP_I and PEEP_H
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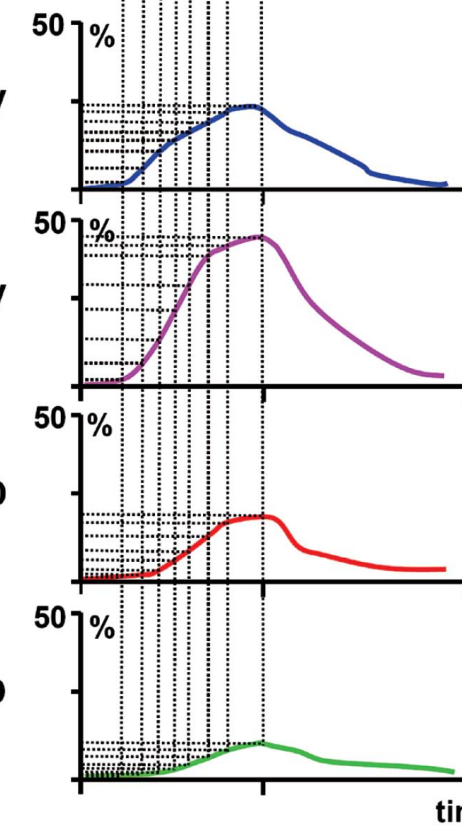
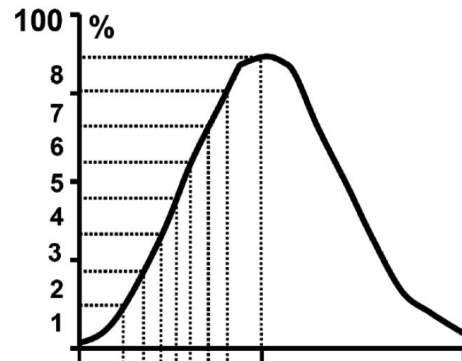
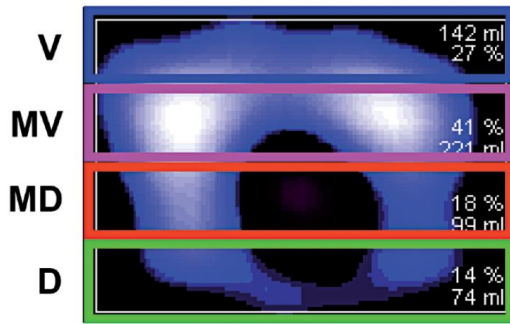
Stress index

EIT-based measurement

Collapsibility/Hyperdistention

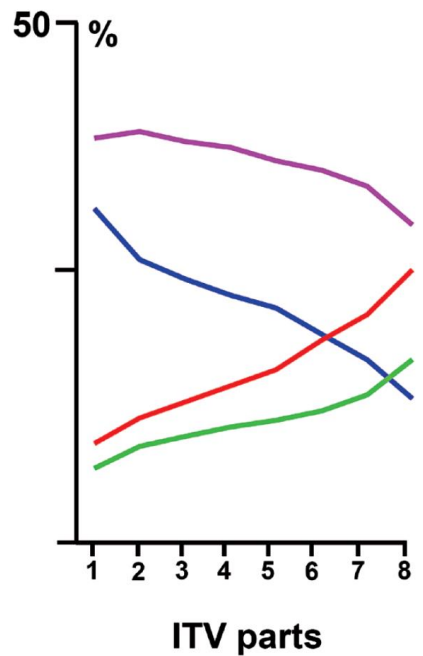
Tidal recruitment/derecruitment

Intratidal ventilation distribution



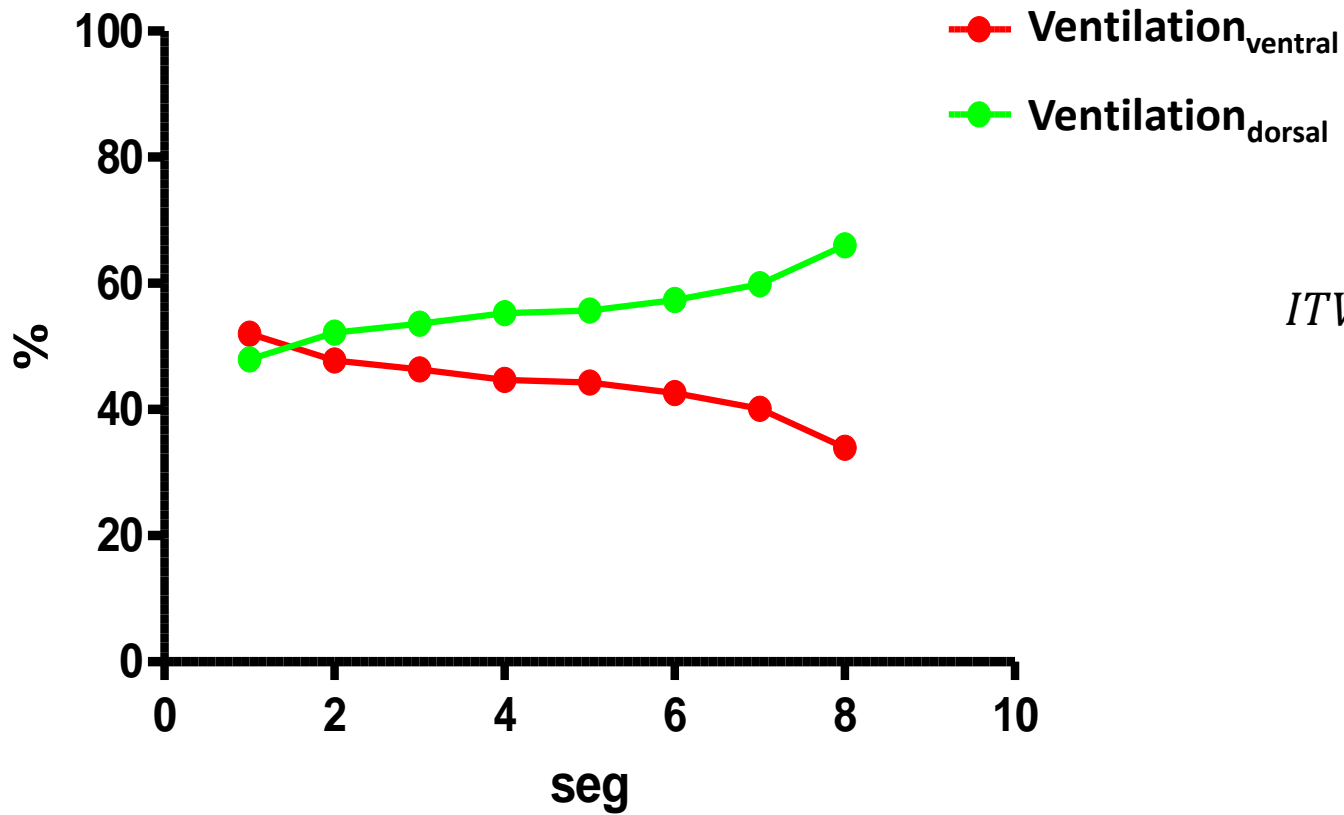
$$ITV = \frac{Ventilation_{ventral}}{Ventilation_{dorsal}}$$

A

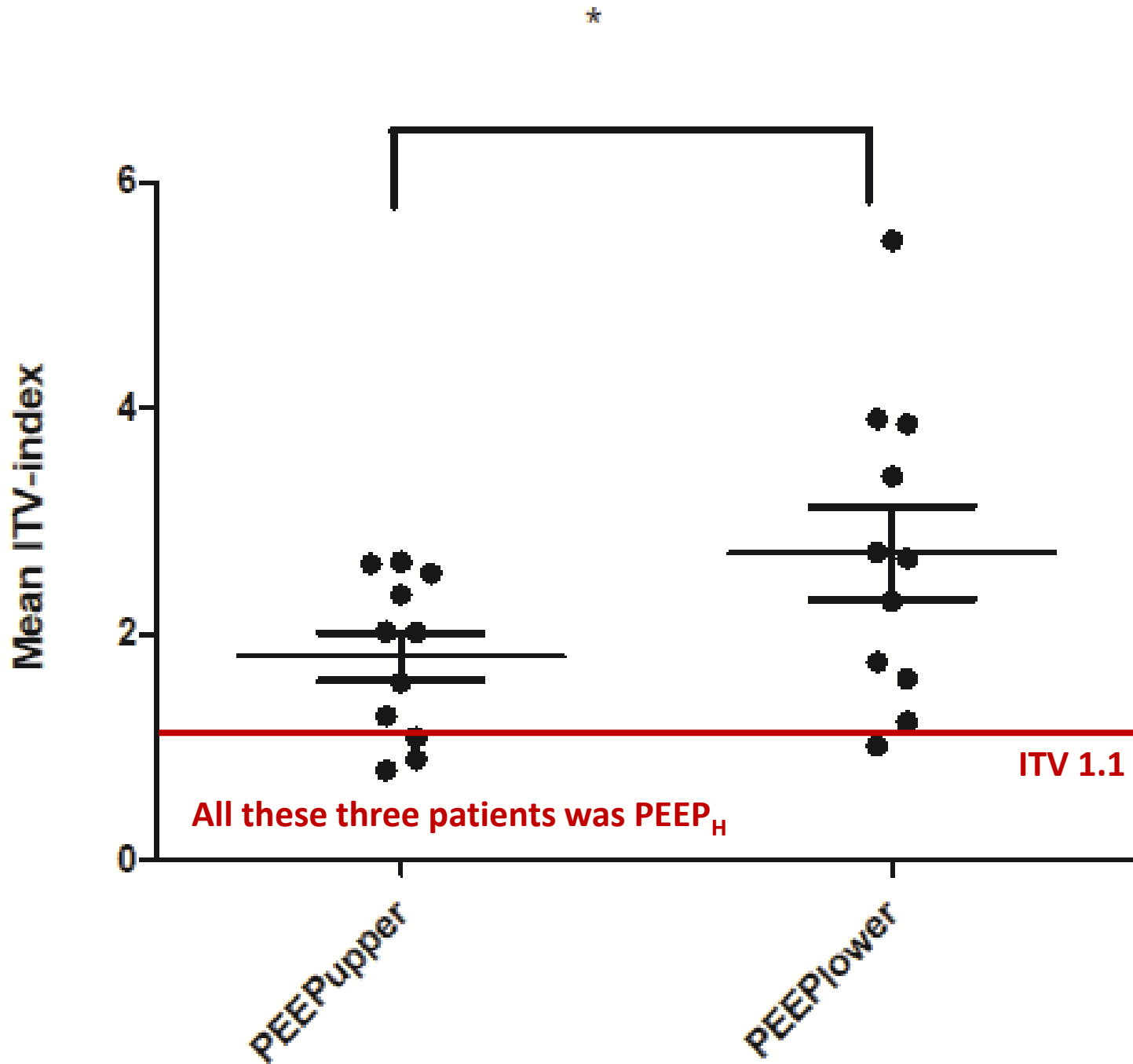


C

B



$$ITV = \frac{Ventilation_{ventral}}{Ventilarion_{dorsal}}$$



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3 patients with similar compliance at PEEP_I and PEEP_H
8 patients with similar compliance at PEEP_L and PEEP_I

Summary

- $PEEP_{upper}$ is recommended for ARDS patients with two similar best Crs but different PEEP levels
- $PEEP_{upper} > 11$ cm H₂O could present a potential risk of lung hyperdistension
- Addition of 2 cm H₂O over $PEEP_{upper}$ was not supported in the current study.

Protocol

- Define airway opening pressure with low flow pressure volume curve
- Set PEEP 15 cmH₂O then 5 cmH₂O, each 30 mins
- Delta P 15 cmH₂O

- Center of ventilation
- Intra-tidal ventilation distribution
- Collapsibility-Hyperdistention
- Regional compliance
- Transpulmonary driving pressure

Gas Exchange, Hemodynamics, and Ventilation Data

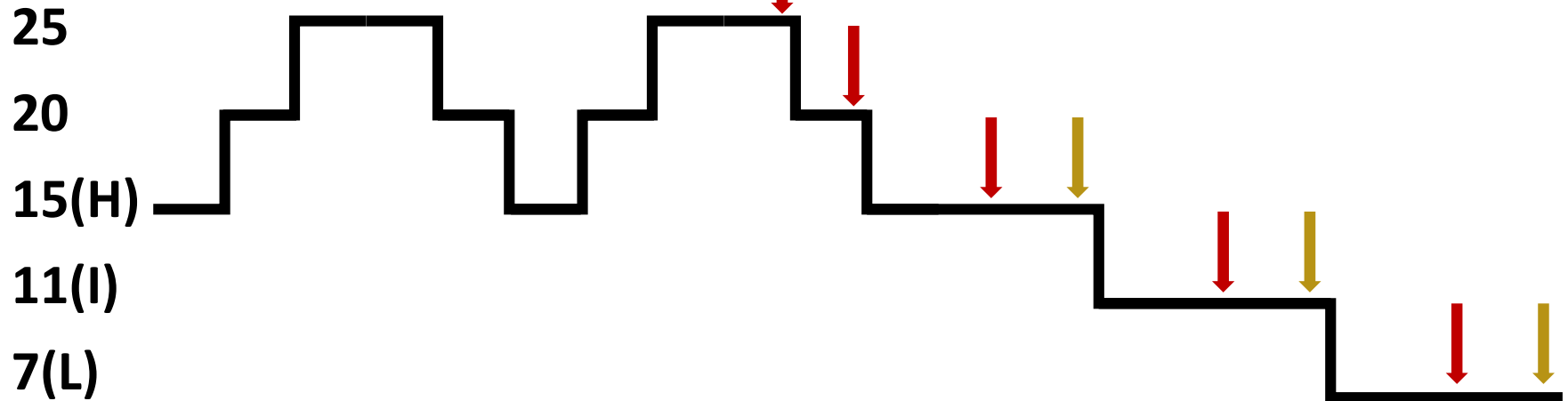
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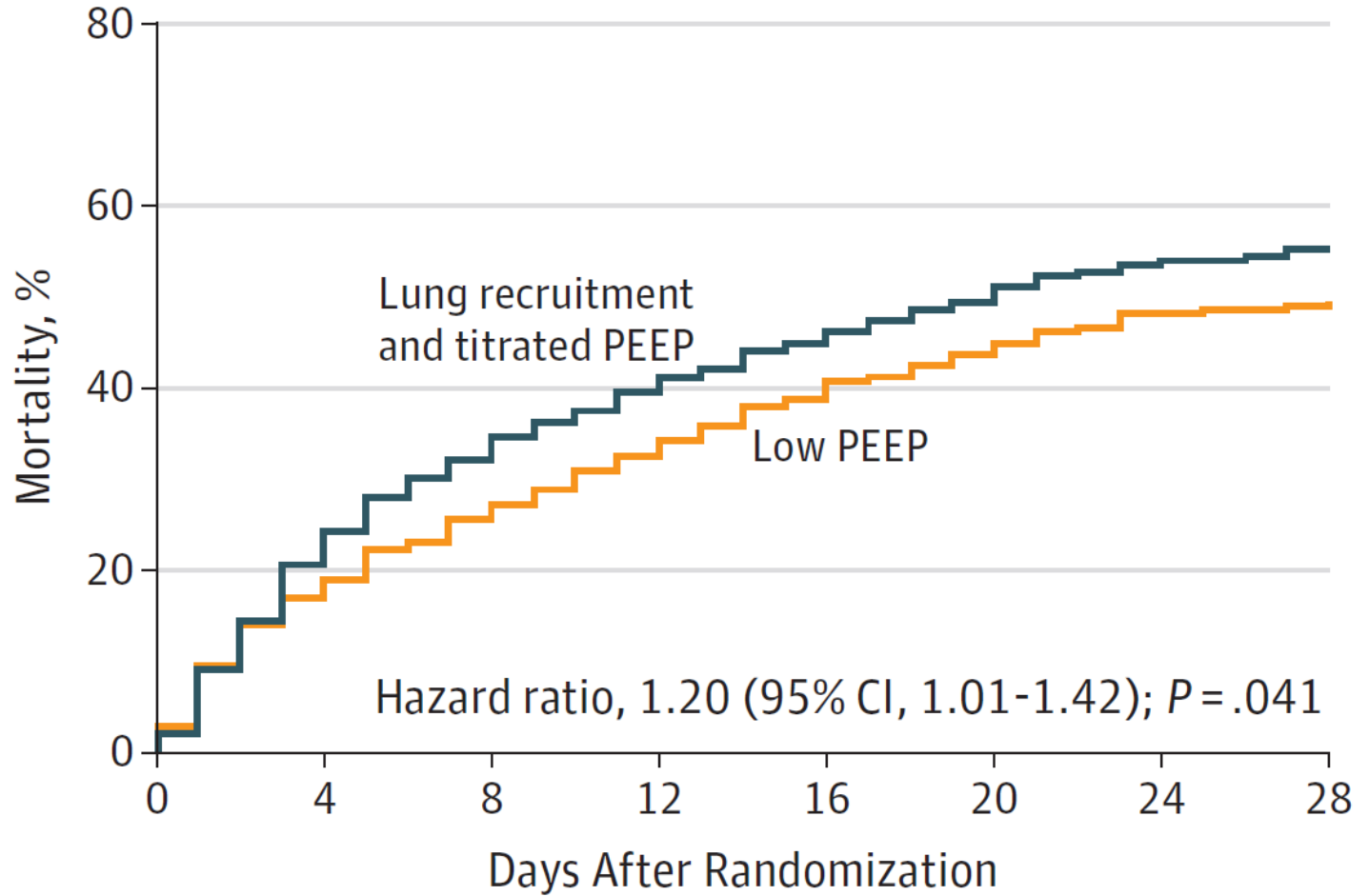
Arterial blood gas at PEEP level 15, 11, 7 cmH₂O

PEEP level



Lim CM et al, Crit Care Med, 2003.

Dellamonica J et al, Intensive Care Med, 2011.



No. at risk

Lung recruitment and titrated PEEP	501	397	340	303	276	254	233	225
Low PEEP	509	423	378	343	312	286	264	260

