Lung Recruitment in ALI/ARDS

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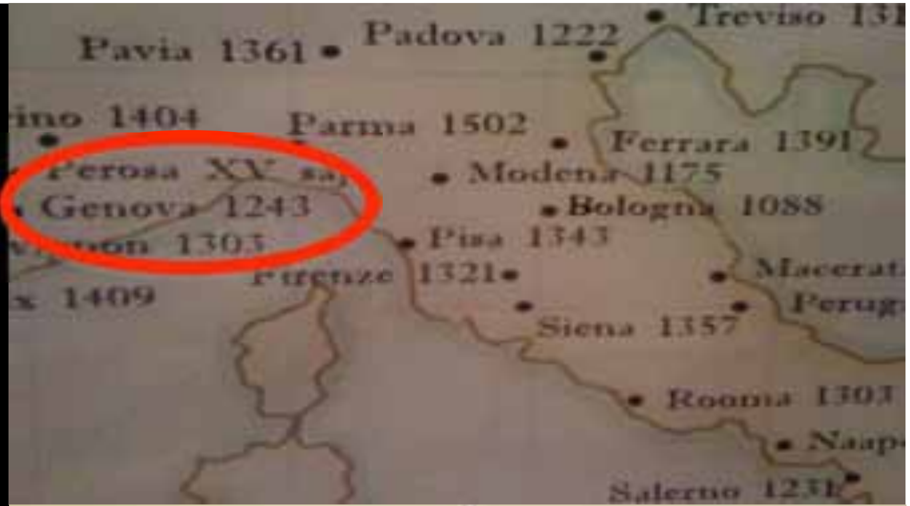
JRUR, Marseille, France, 2012



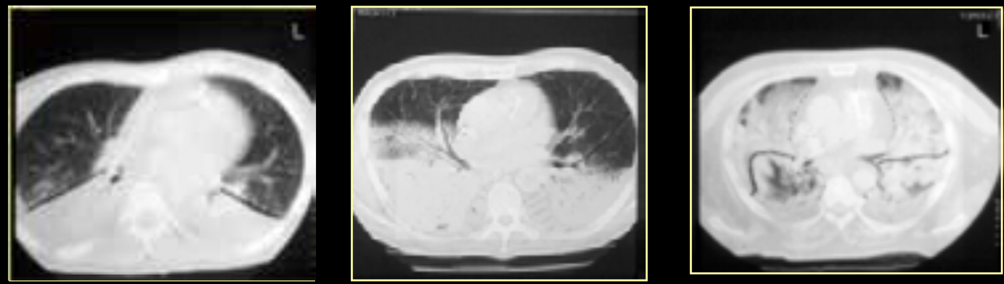

OASIS BAR
BELFAST 785 km
AMSTERDAM 1152 km
CARDIFF 848 km
ROME 1926 km
CAPE WRATH 18km
NEW YORK 4695 km
BRUSSELS 1,101 km
LAND'S END 1,018km
Düsseldorf 1158

AGENDA

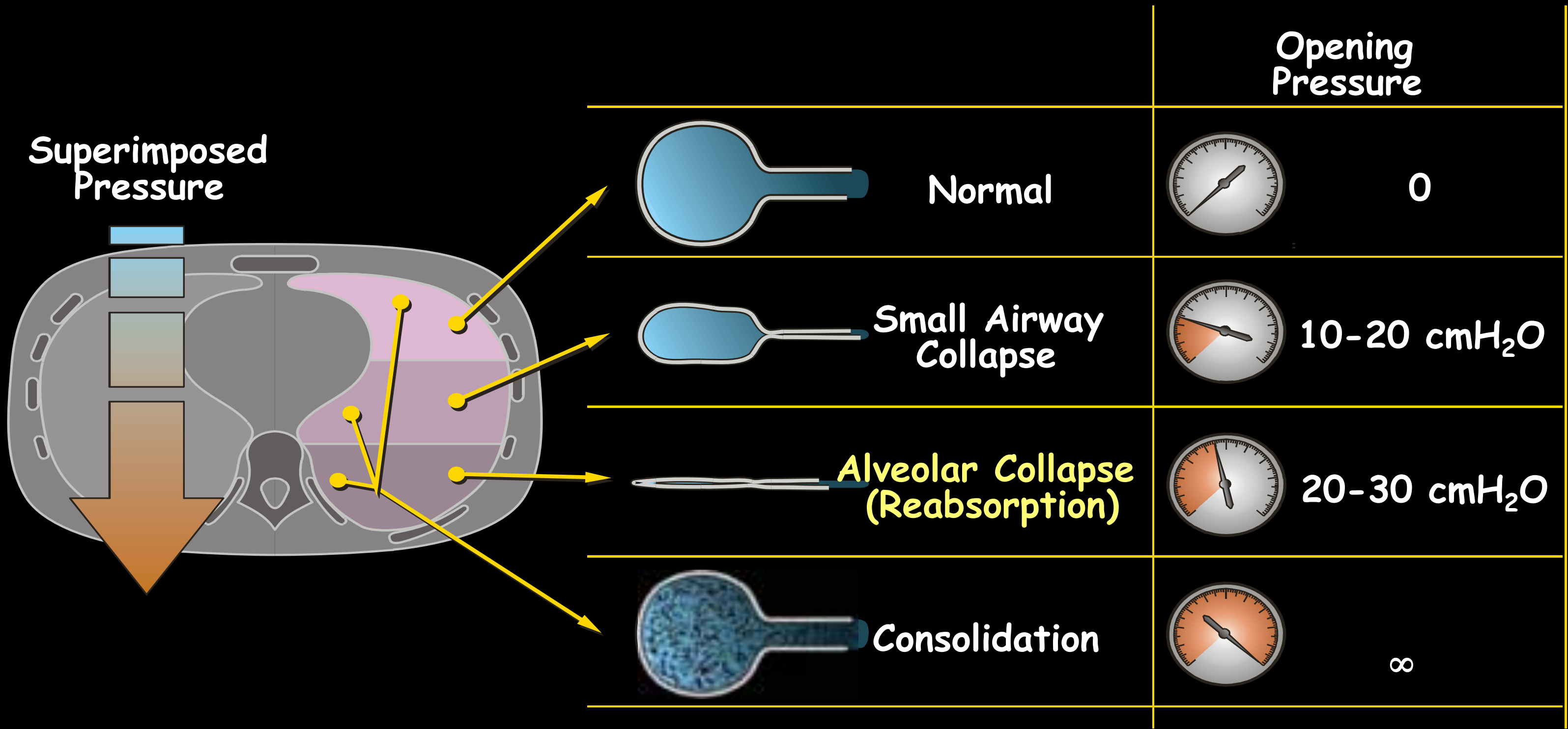
- ARDS: principles of treatment
- Recruitment in ARDS:
  - The rationale
  - Experimental data
  - “New” recruitment maneuvres
- Clinical data
- Recruitment and prone position
- How to set PEEP after Recruitment
- Conclusions

The ARDS Lung

Gattinoni JAMA 1993, Pelosi AJRCCM 1994, Gattinoni AJRCCM 2002, Gattinoni ICM 2005

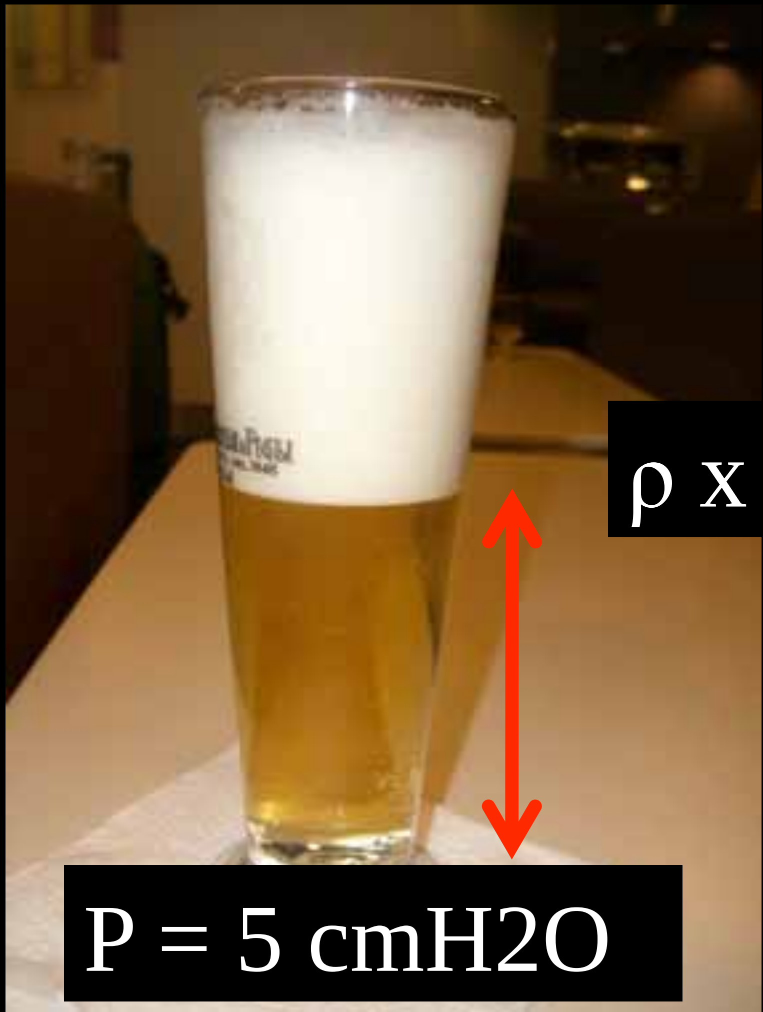


Rouby Intensive Care Med 2000

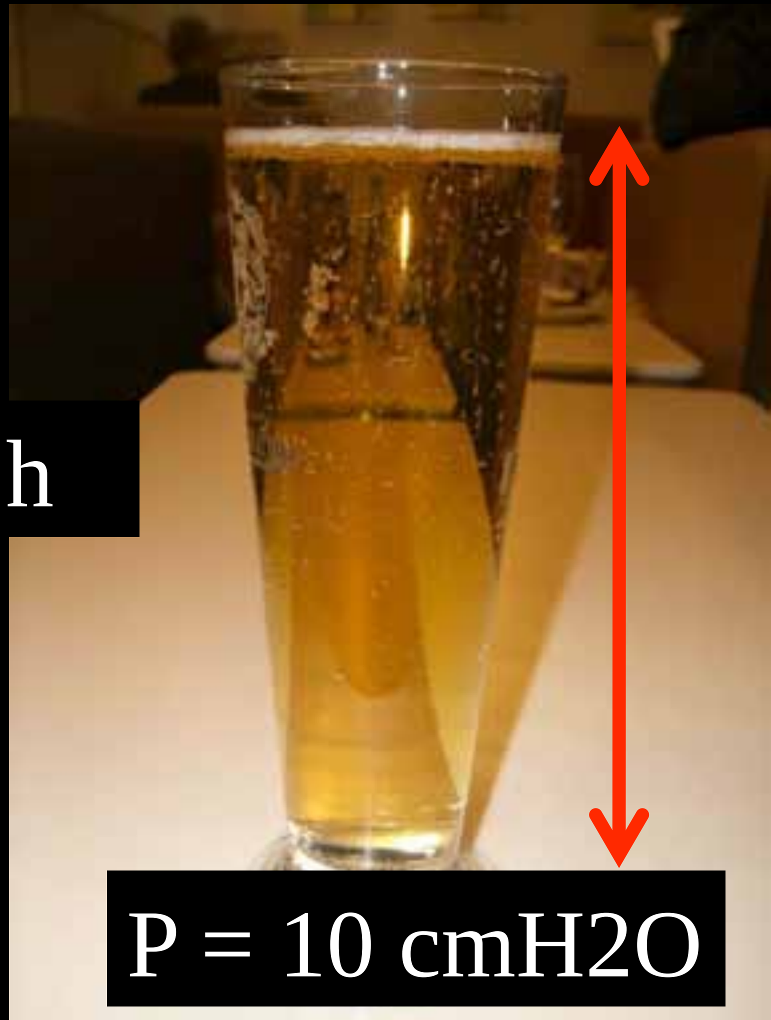


EDEMA – ATELECTASIS IN ALI/ARDS

$\rho \times g \times h$



LESS EDEMA-ATELECTASIS
LOWER PEEP – LOWER MORTALITY



HIGHER EDEMA-ATELECTASIS
HIGHER PEEP – HIGHER MORTALITY

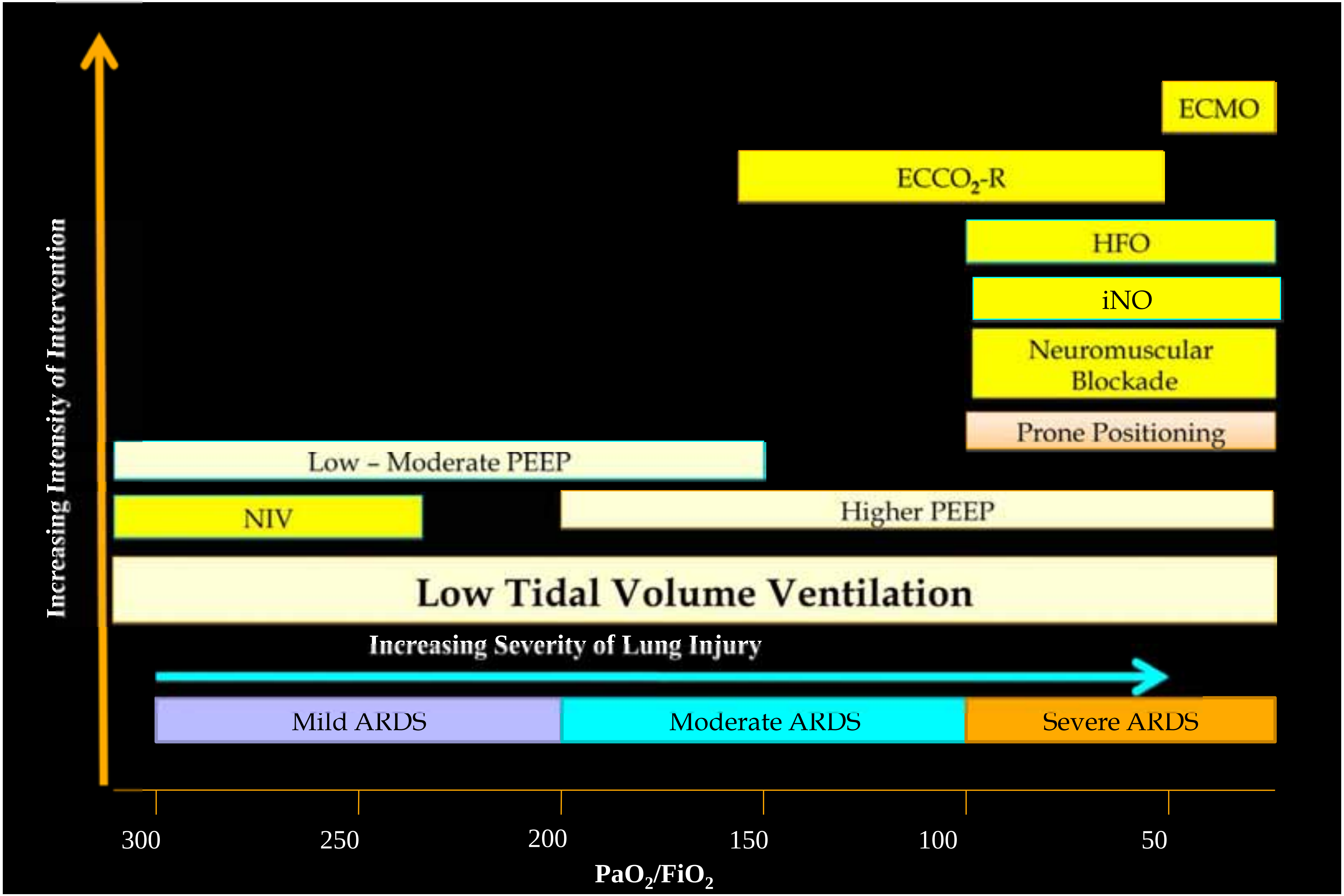
ARDS

	Mild	Moderate	Severe
Timing	Acute onset within 1 week of a known clinical insult or new/worsening respiratory symptoms		
Hypoxemia	PaO_2/FiO_2 201-300 with PEEP/CPAP ≥ 5	$PaO_2/FiO_2 \leq 200$ with PEEP ≥ 5	$PaO_2/FiO_2 \leq 100$ with PEEP ≥ 10
Origin of Edema	Respiratory failure not fully explained by cardiac failure or fluid overload**		
Radiological Abnormalities	Bilateral opacities*	Bilateral opacities*	Opacities involving at least 3 quadrants*
Additional Physiological Derangement	N/A	N/A	$V_{E\ Corr} > 10$ L/min or $C_{RS} < 40$ ml/cmH_2O

*Not fully explained by effusions, nodules, masses, or lobar/lung collapse; use training set of CXRs

**Need objective assessment if no risk factor present (See table)

$V_{E\ Corr} = V_E \times PaCO_2/40$



ECMO
ECCO2-R
HFO
iNO
Neuromuscular Blockade
Prone Positioning
Low – Moderate PEEP
NIV
Higher PEEP
Low Tidal Volume Ventilation
Increasing Severity of Lung Injury
Mild ARDS
Moderate ARDS
Severe ARDS
Increasing Intensity of Intervention
300
250
200
150
100
50
PaO2/FiO2

SURVIVING SEPSIS CAMPAIGN GUIDELINES 2012

R. Phillip Dellinger and Rui Moreno
On behalf of the SSC Committee (SCCM-ESICM)

Mechanical Ventilation of Sepsis-Induced Acute Respiratory Distress Syndrome (ARDS)

We suggest recruitment maneuvers in patients with severe refractory hypoxemia (Grade 2C).

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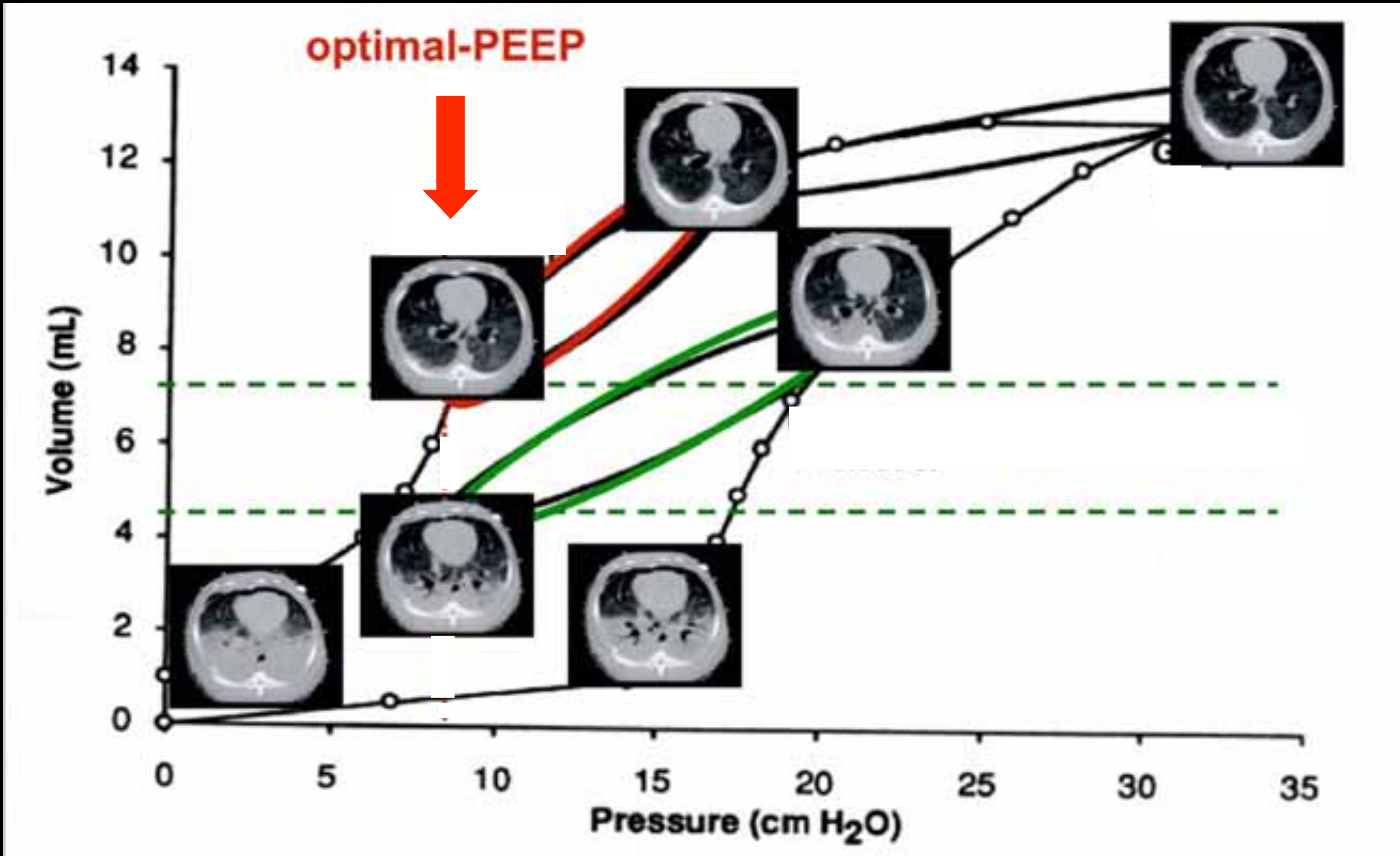
The concept of PEEP and Recruitment

Pelosi P, De Abreu G, Rocco PR Crit Care. 2010 Mar 9;14(2):210.



Recruitment in ALI/ARDS ?

Pelosi P, De Abreu G, Rocco PR Crit Care. 2010 Mar 9;14(2):210.

WHY NOT ?

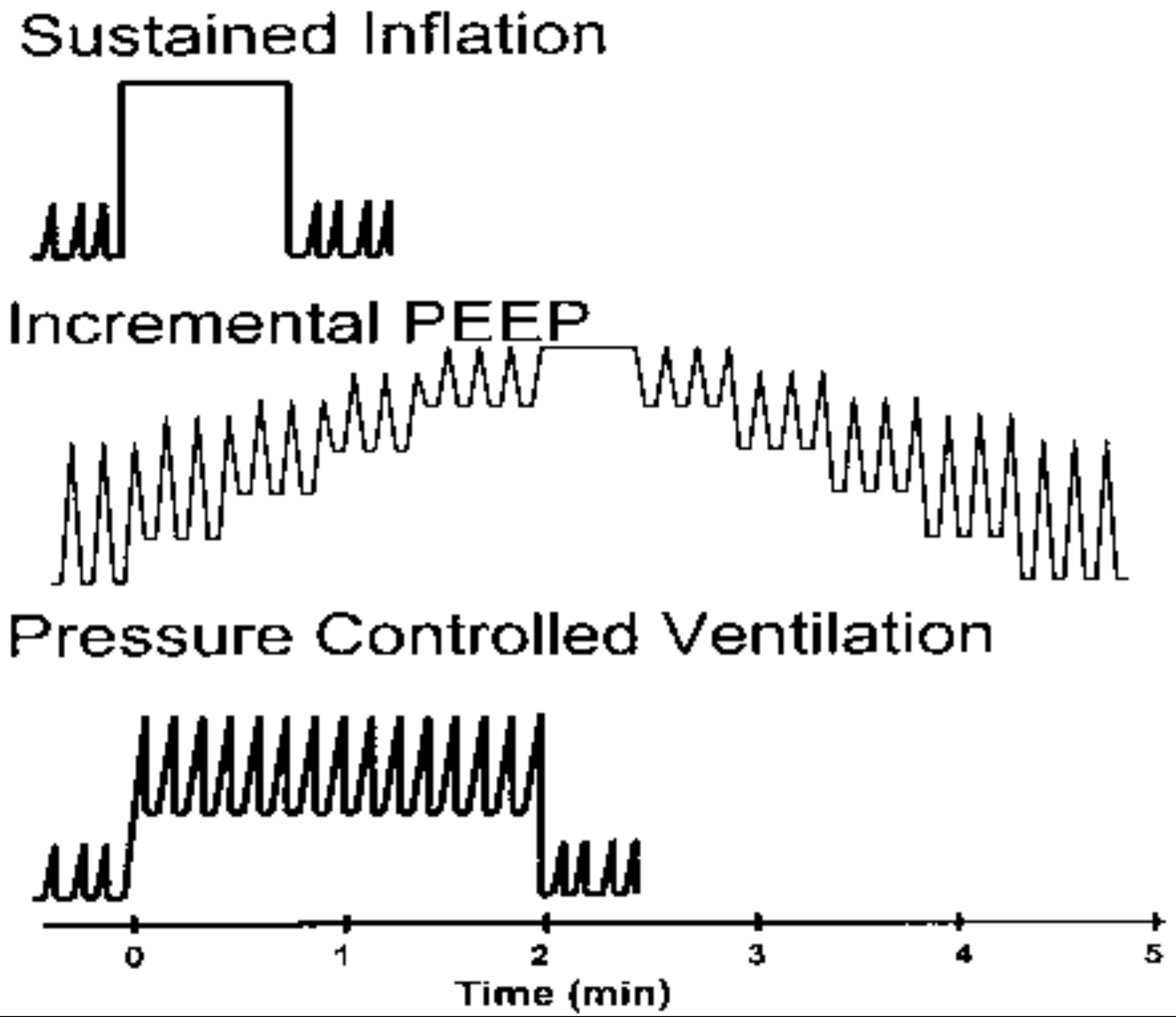
- Improves oxygenation
- Improves respiratory mechanics
- Increases lung volume/reduces atelectasis
- Not associated with major adverse effects

WHEN ?

- Before PEEP setting
- After dysconnection from MV or suctioning
- Rescue maneuvre

Recruitment Maneuvers for Acute Lung Injury: A Systematic Review

Fan E et al. Am J Respir Crit Care Med Vol 178. pp 1156–1163, 2008



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20%

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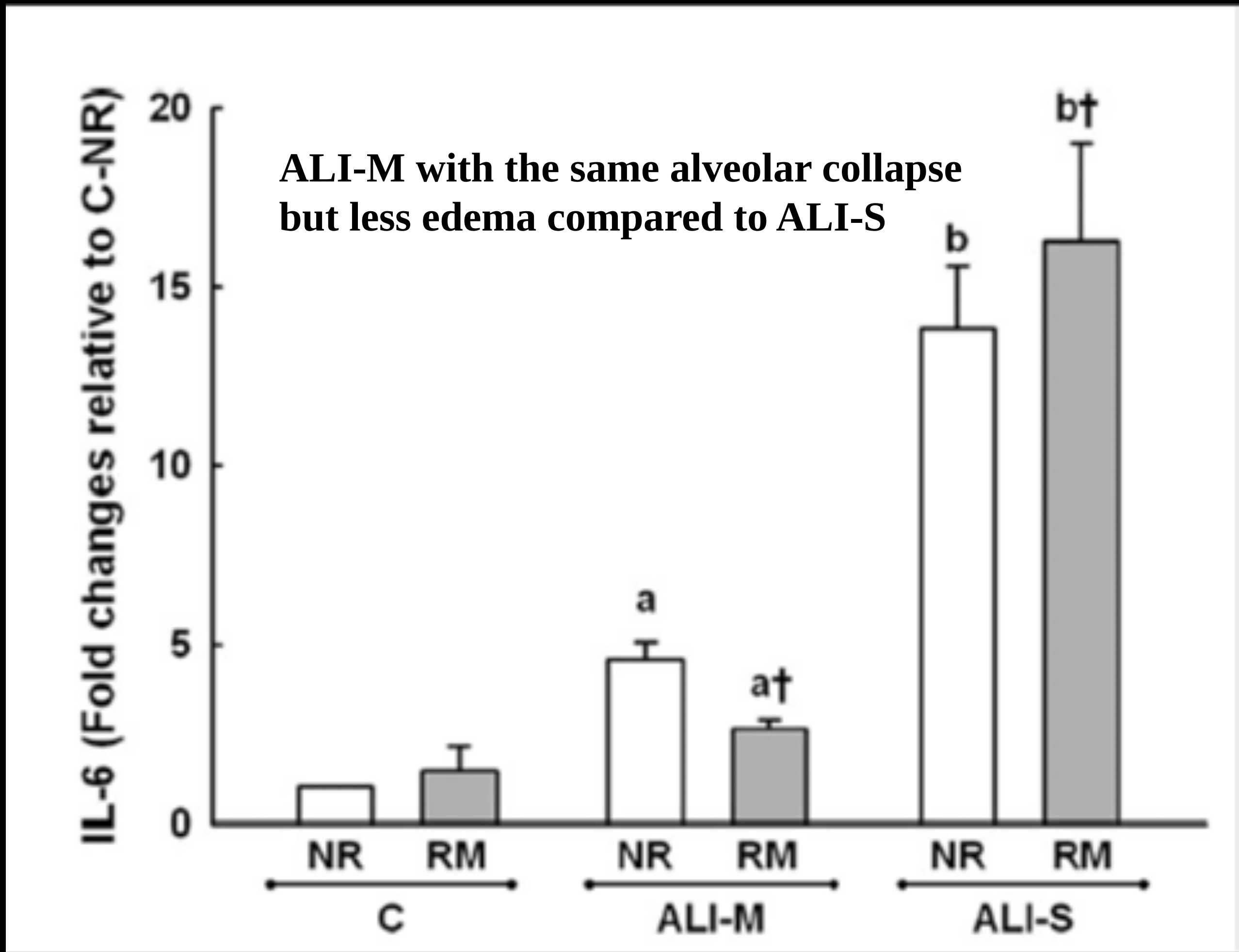
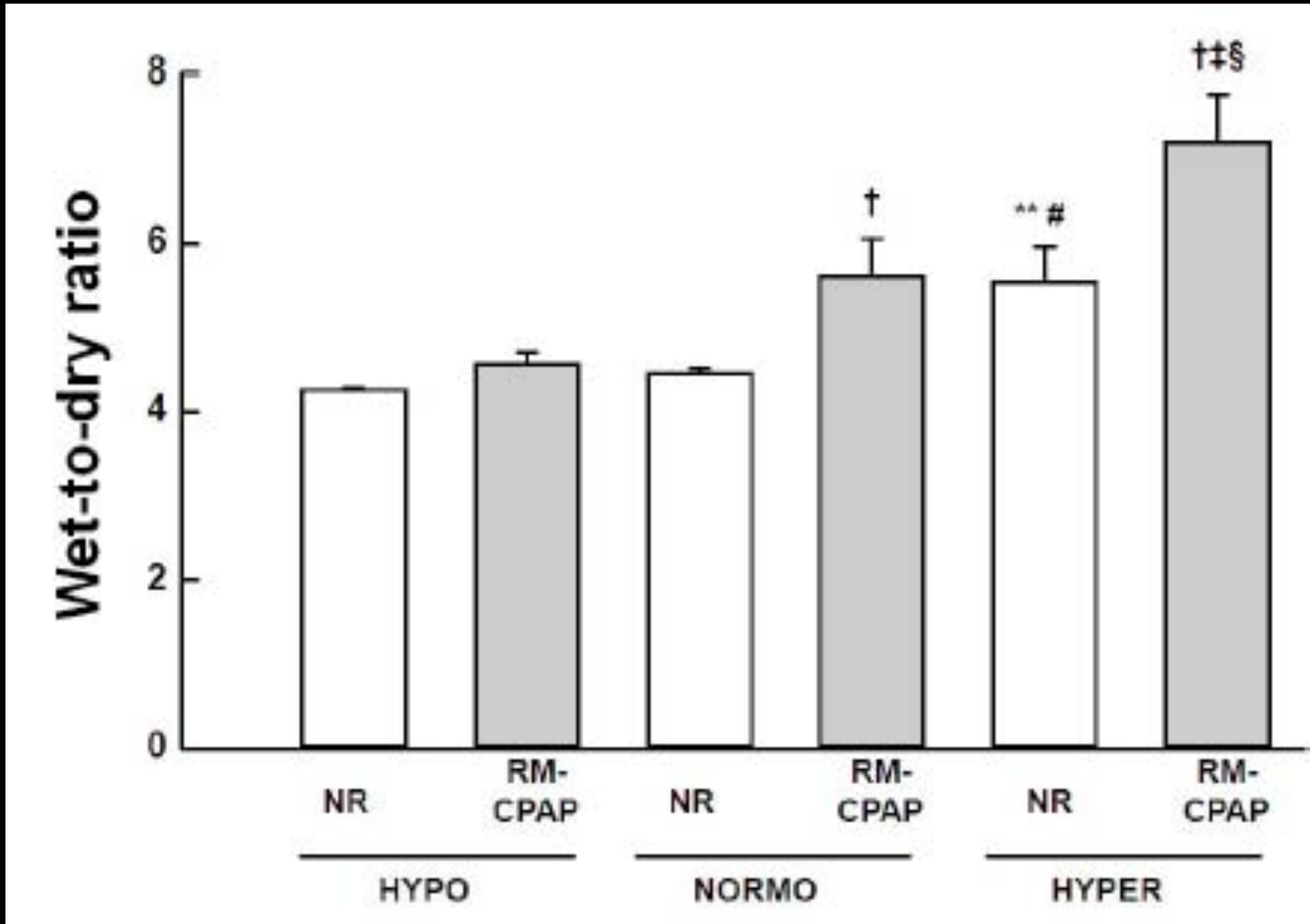
Recruitment maneuver in experimental acute lung injury: the role of alveolar collapse and edema

Santiago VR et al Crit Care Med. 2010 Nov;38(11):2207-14.



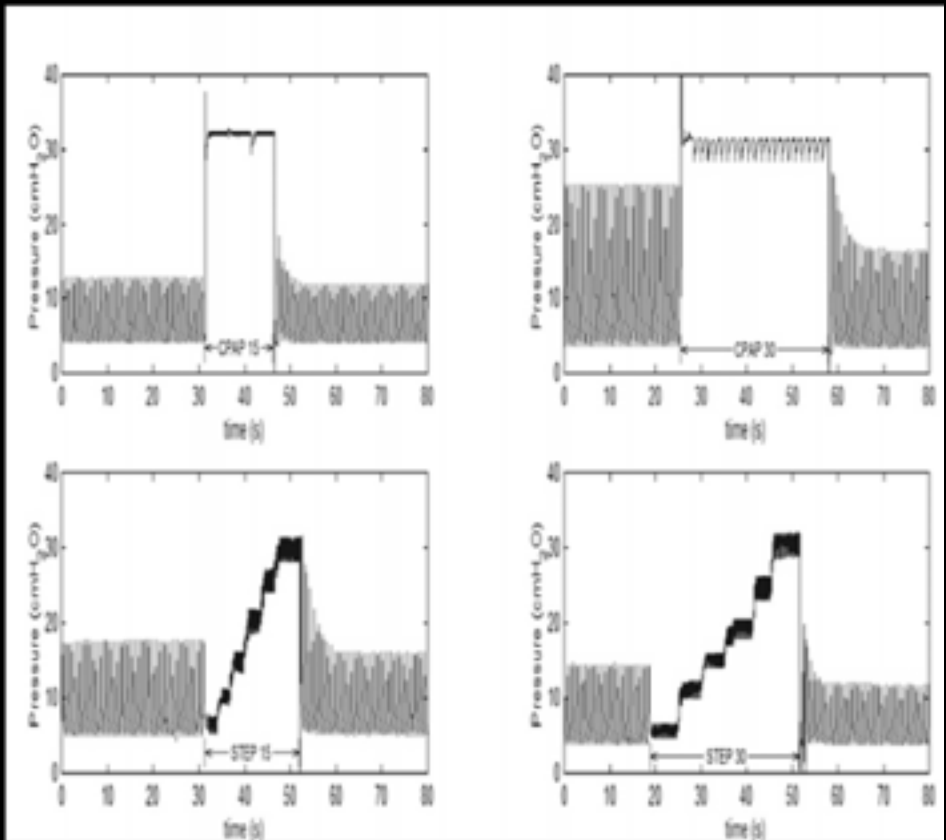
Hypervolemia induces and potentiates lung damage after RM in a model of sepsis-induced ALI

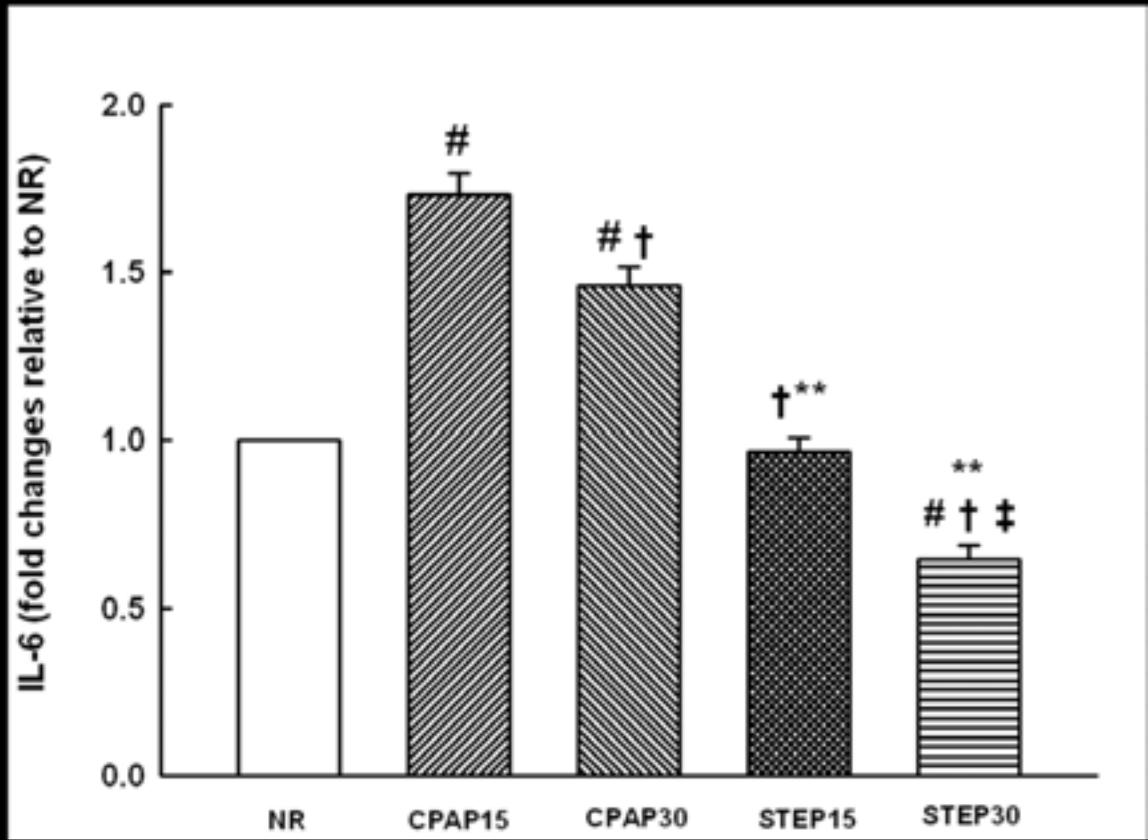
Silva PL et al. Critical Care 2010, 14:R114



Effects of pressure profile and duration of RM on lung morpho-functional and biological impact in experimental lung injury

Silva PI et al Crit Care Med. 2011 May;39(5):1074-81.





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"New" recruitment Maneuvres:

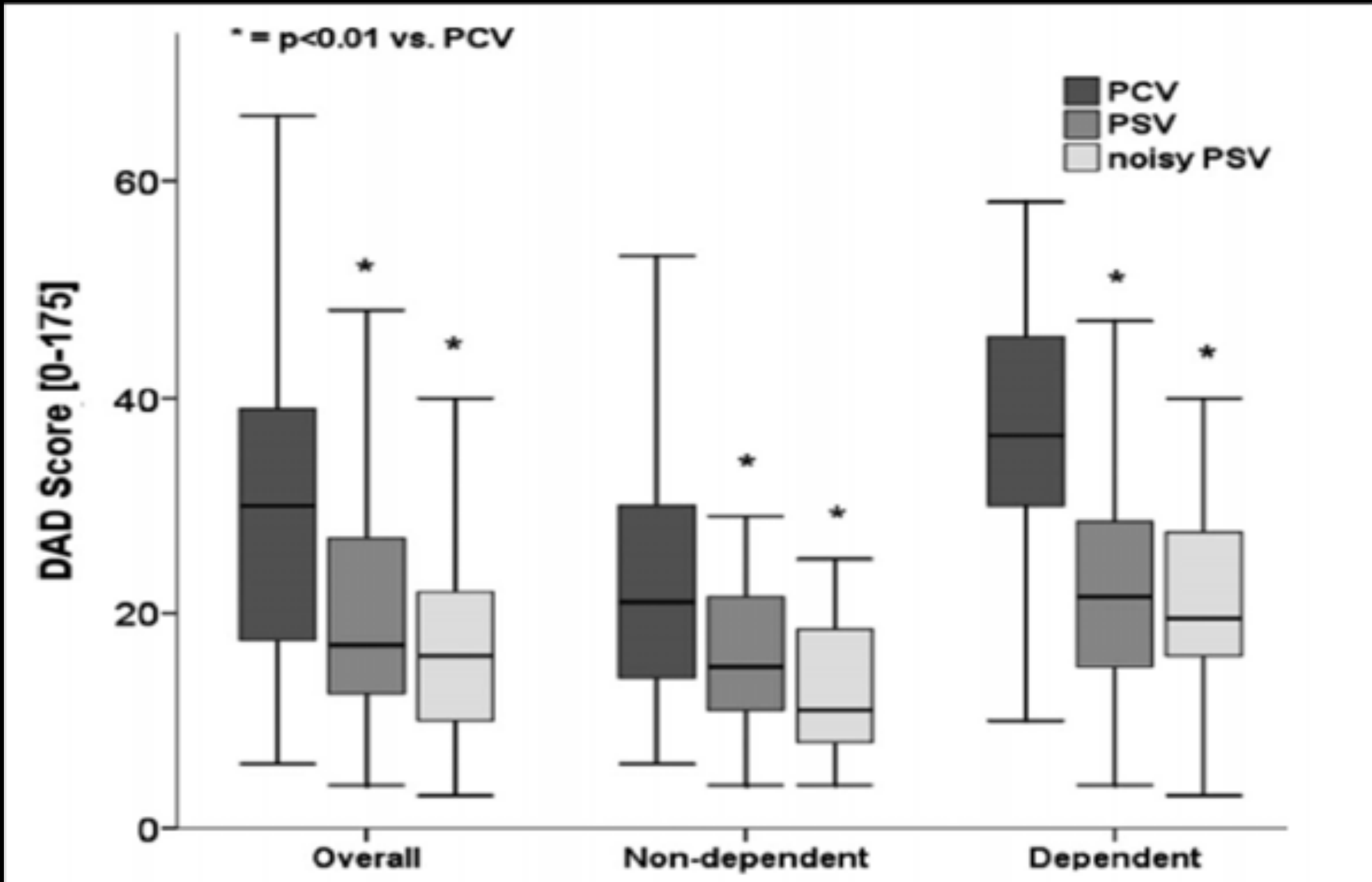
Assisted Ventilation

Sigh

Variable Ventilation

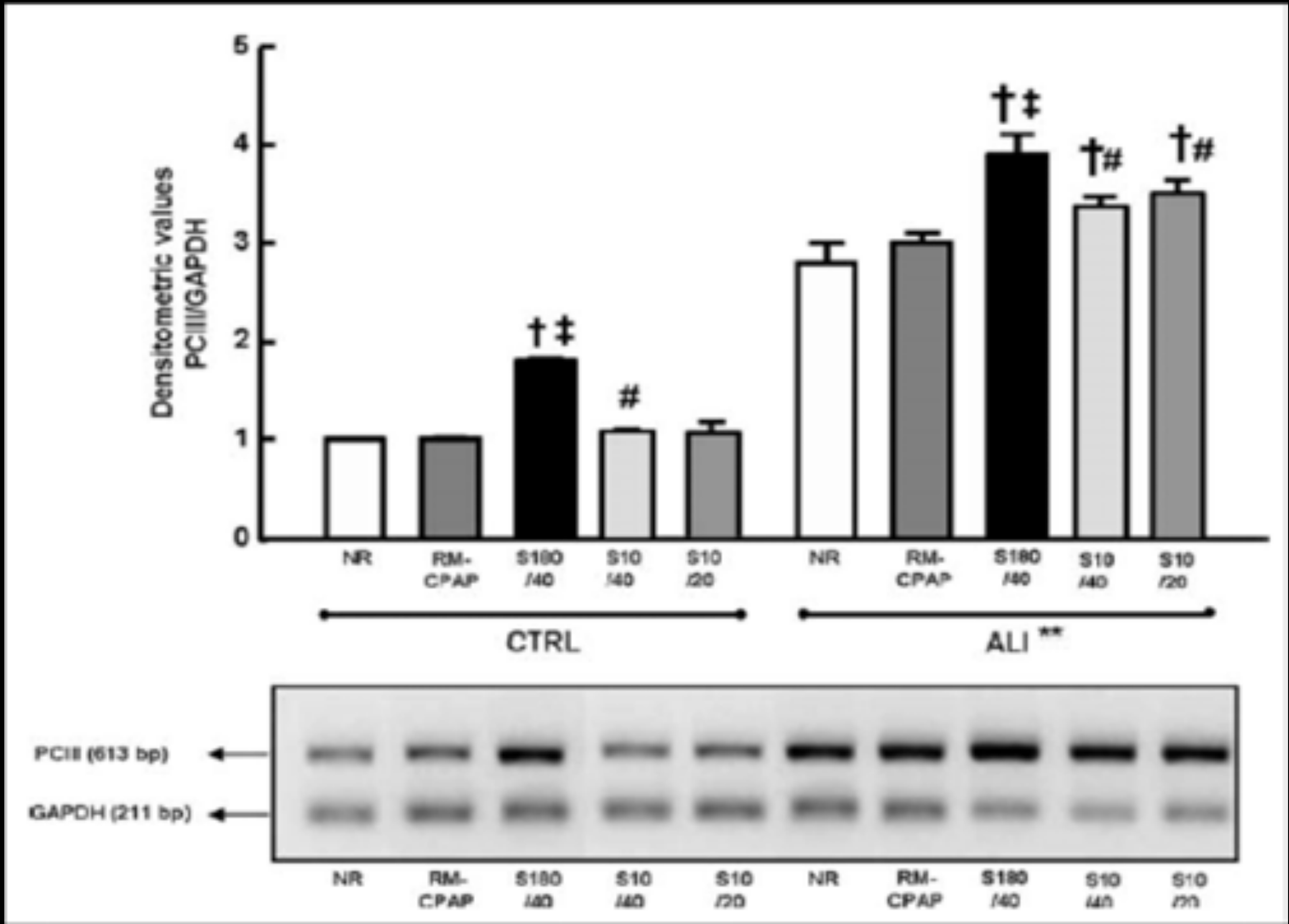
Ventilator Induced Lung Injury

Spieth P et al. Crit Care Med. 2011 Apr;39(4):746-55



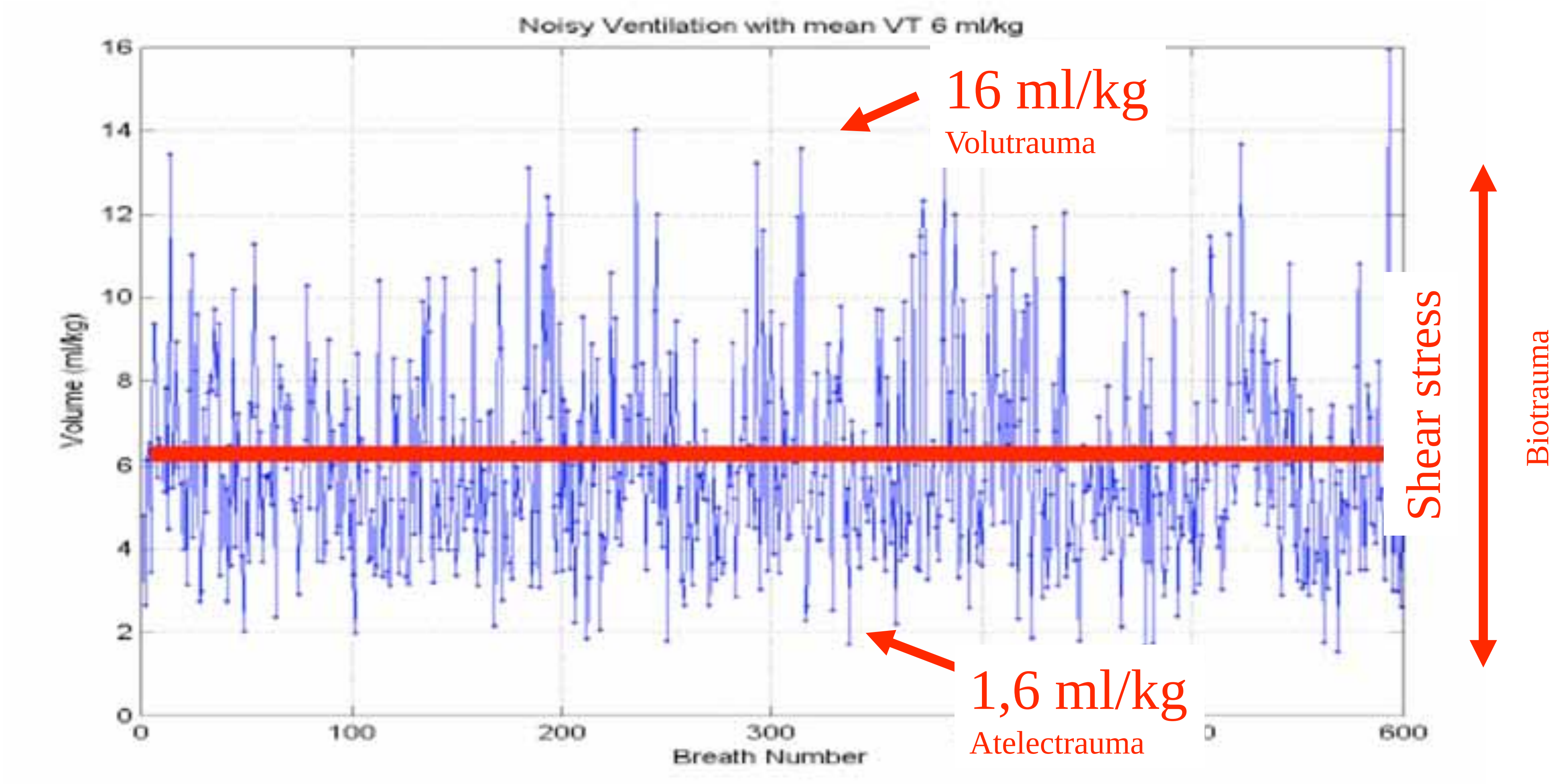
Effects of frequency and inspiratory plateau pressure during recruitment manoeuvres on lung and distal organs in acute lung injury

Steimback PW et al Intensive Care Med 35:1120-1128, 2009



Variable VTs improve different lung protective ventilation strategies in experimental ALI

Spieth PM et al Am J Respir Crit Care Med 2009 15;179(8):684-93



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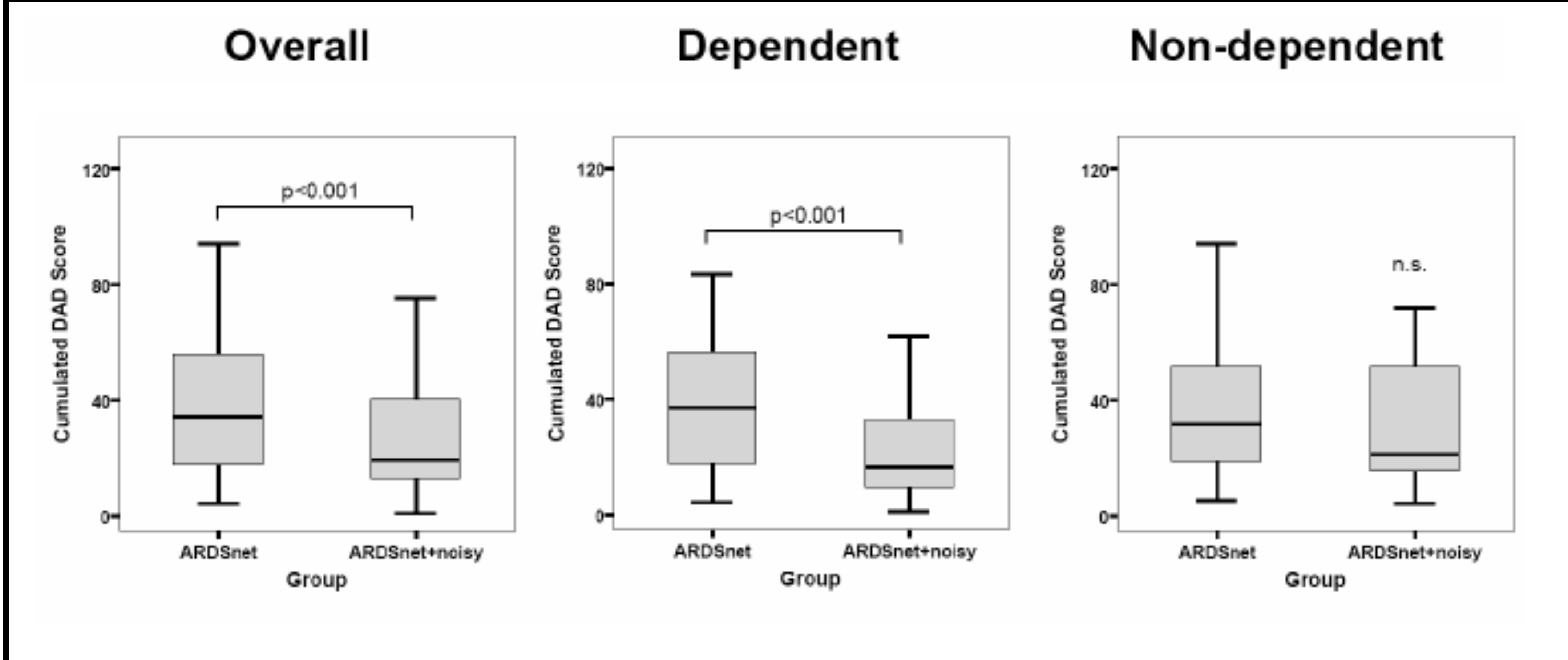

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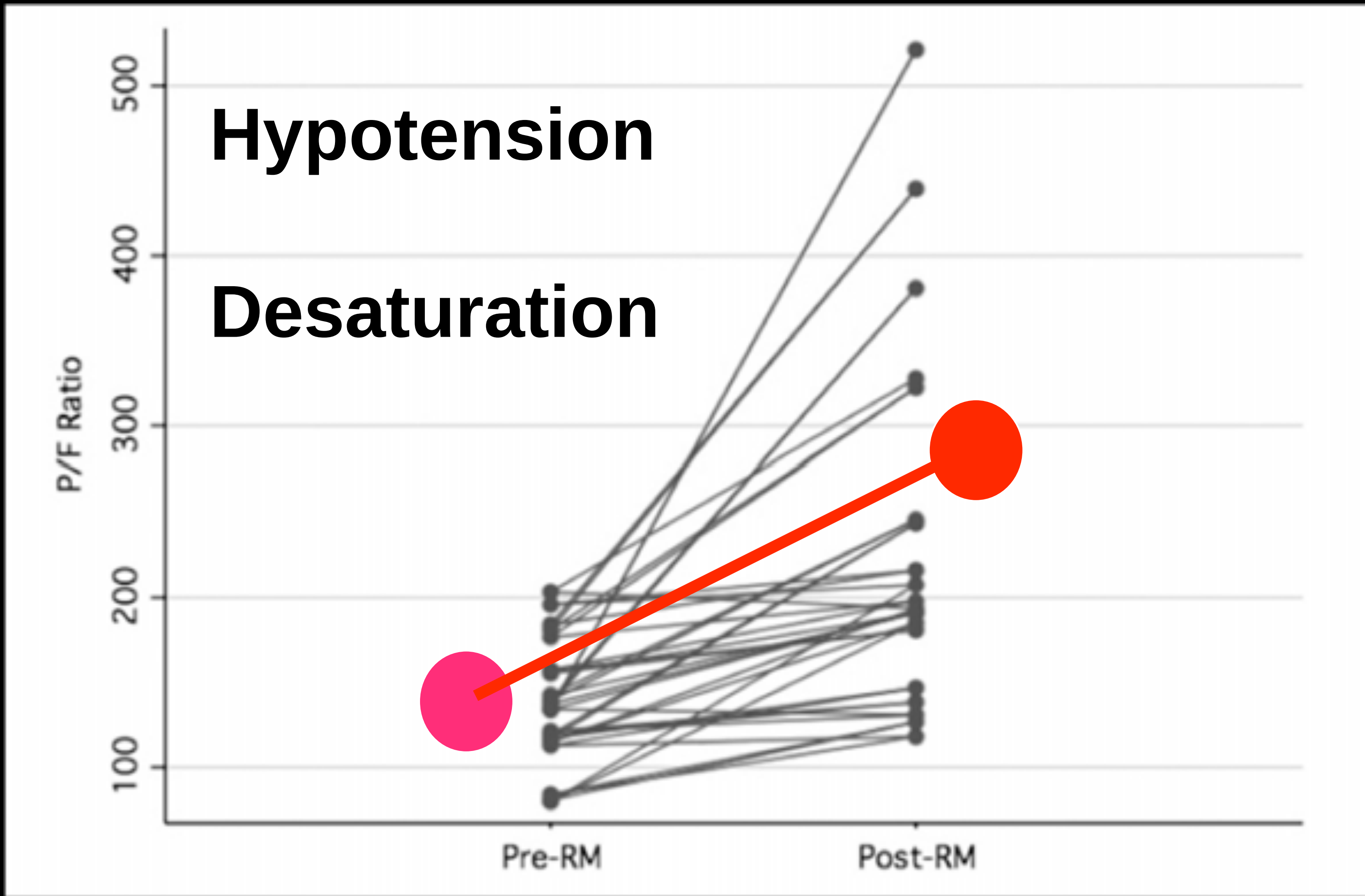
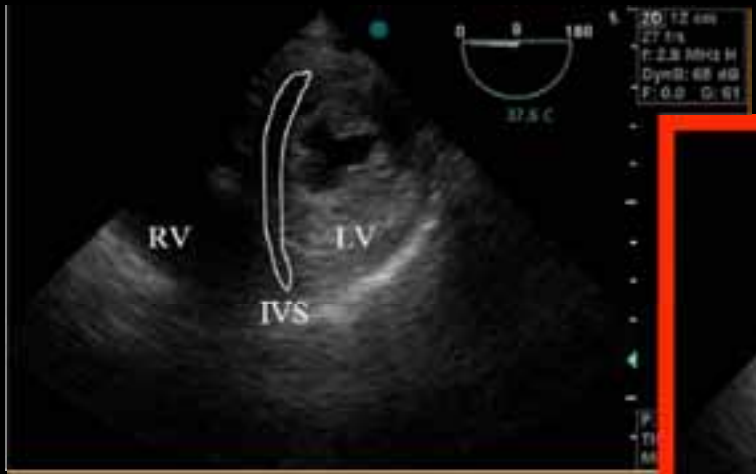


Respiratory and hemodynamic changes during decremental open lung PEEP titration in ARDS

Gernoth W et al Critical Care 2009, 13:R59; Epub 2009 Apr 17

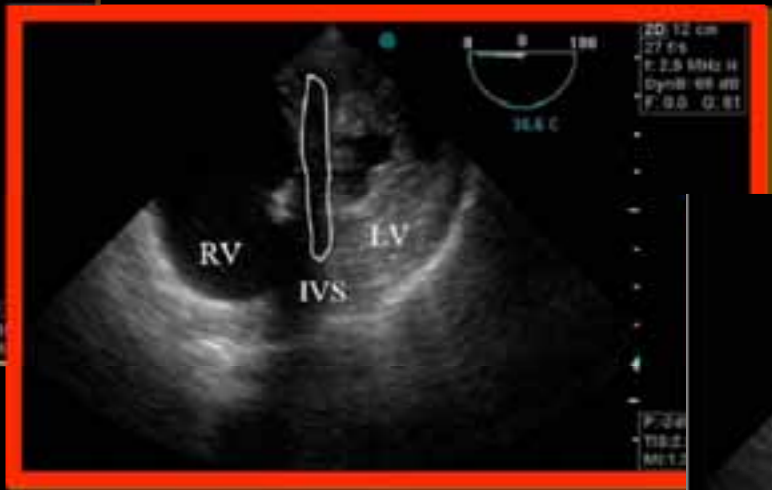
Right ventricular Tei index [%]

Before



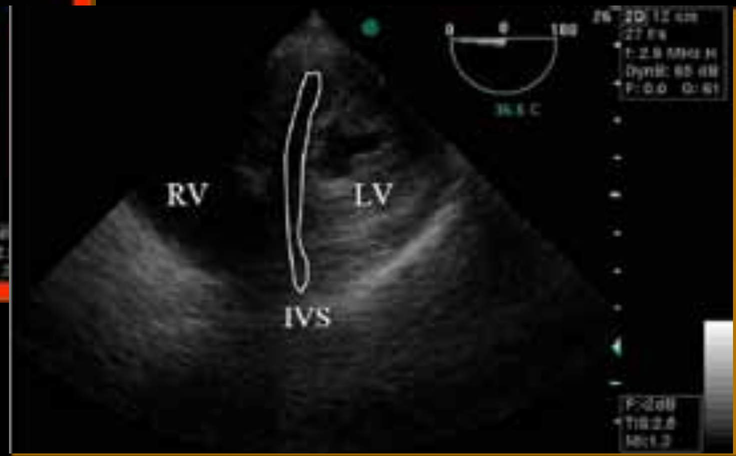
39±11

During RM



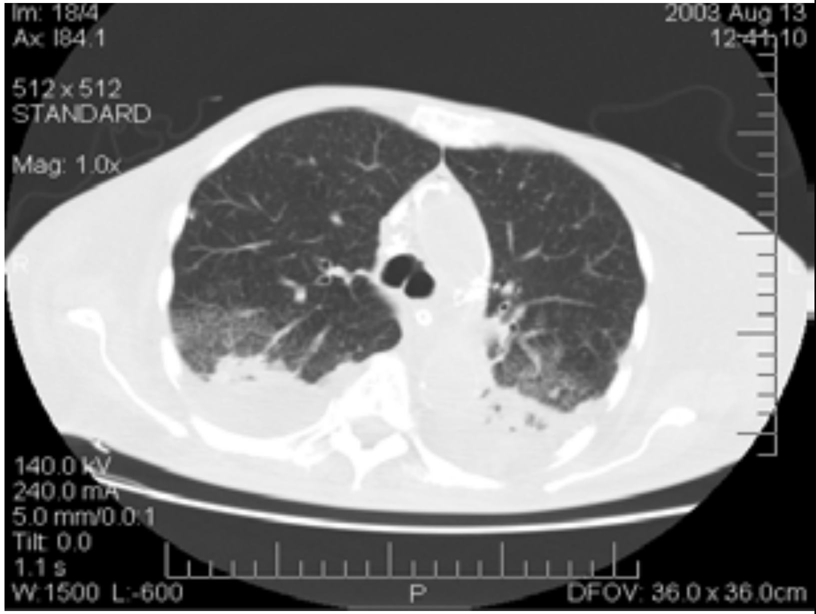
42±10

After

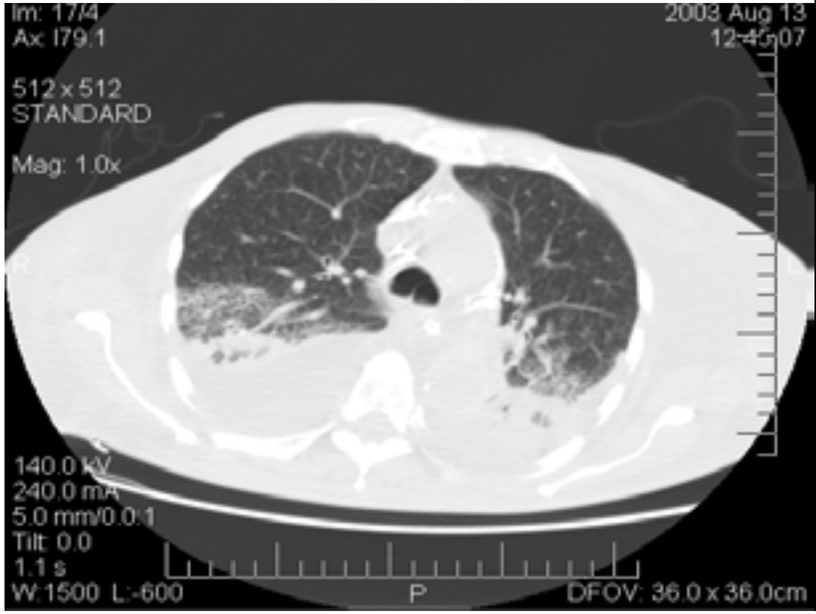


36±11

Paw $45 cmH_2O$

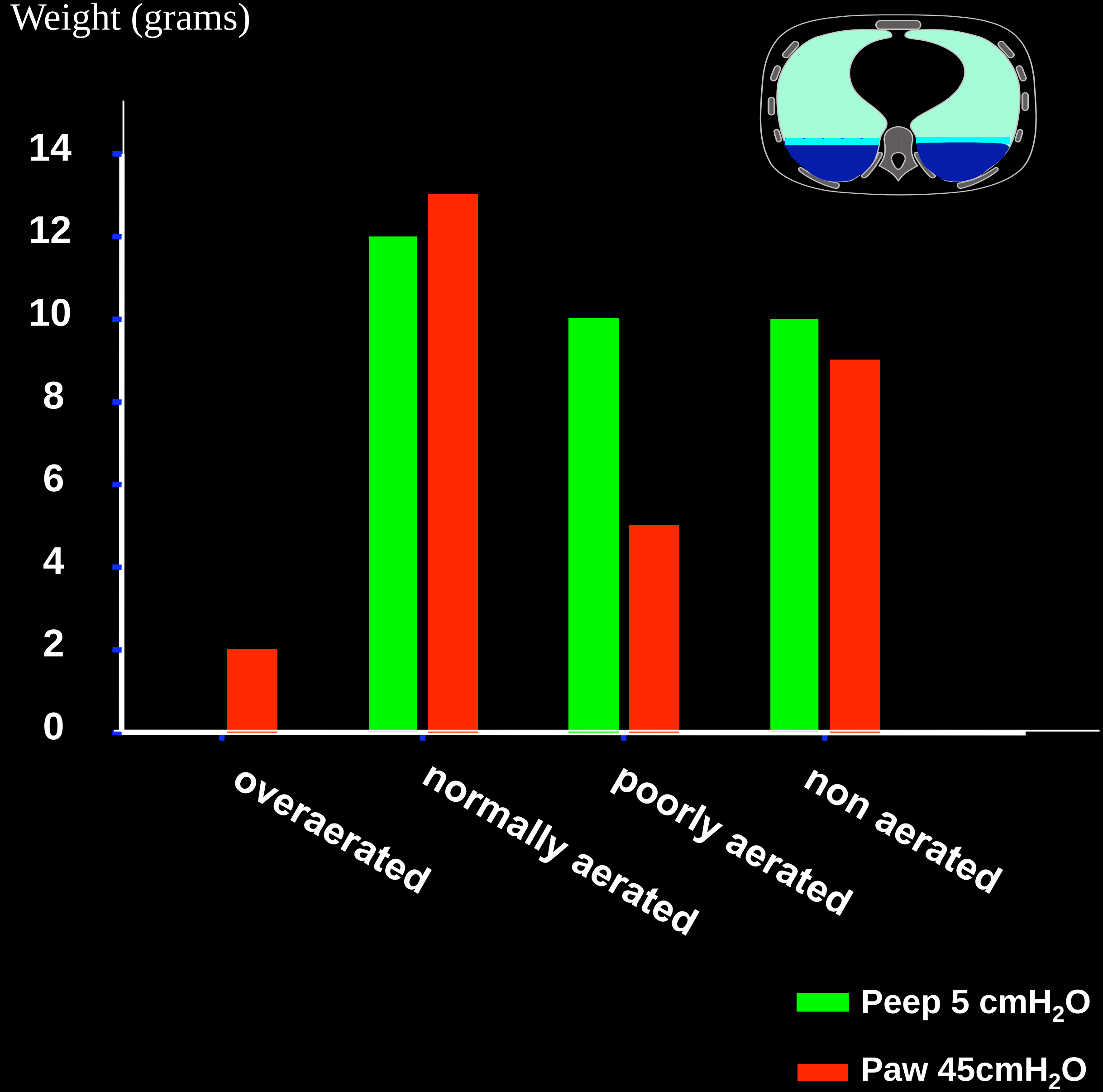


Peep 5 cmH_2O

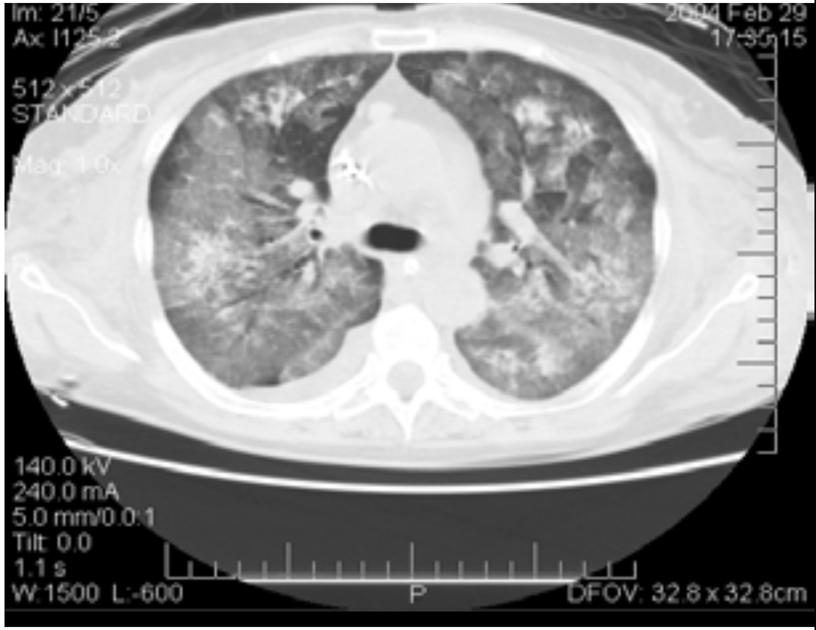


Gattinoni et al NEJM 2006, 354(17):1775-86

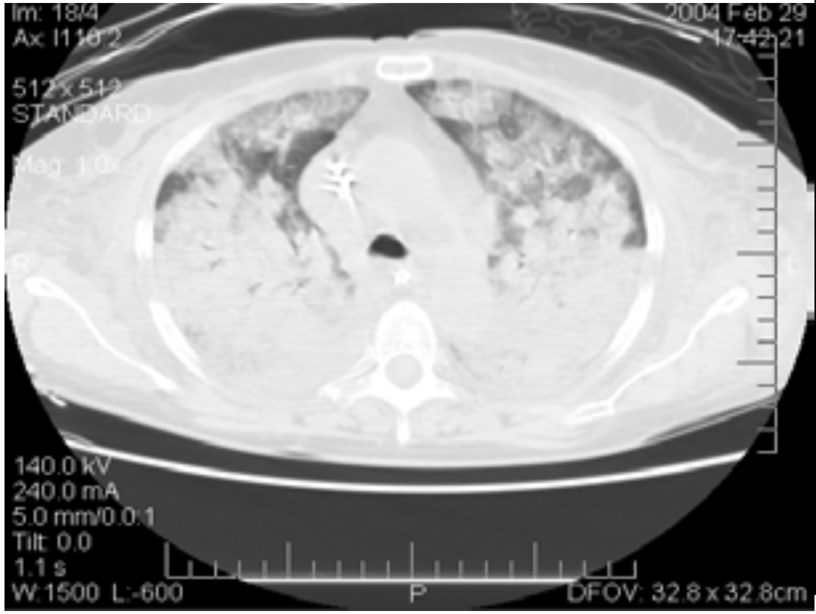
Non recruiter



Paw 45cmH_2O

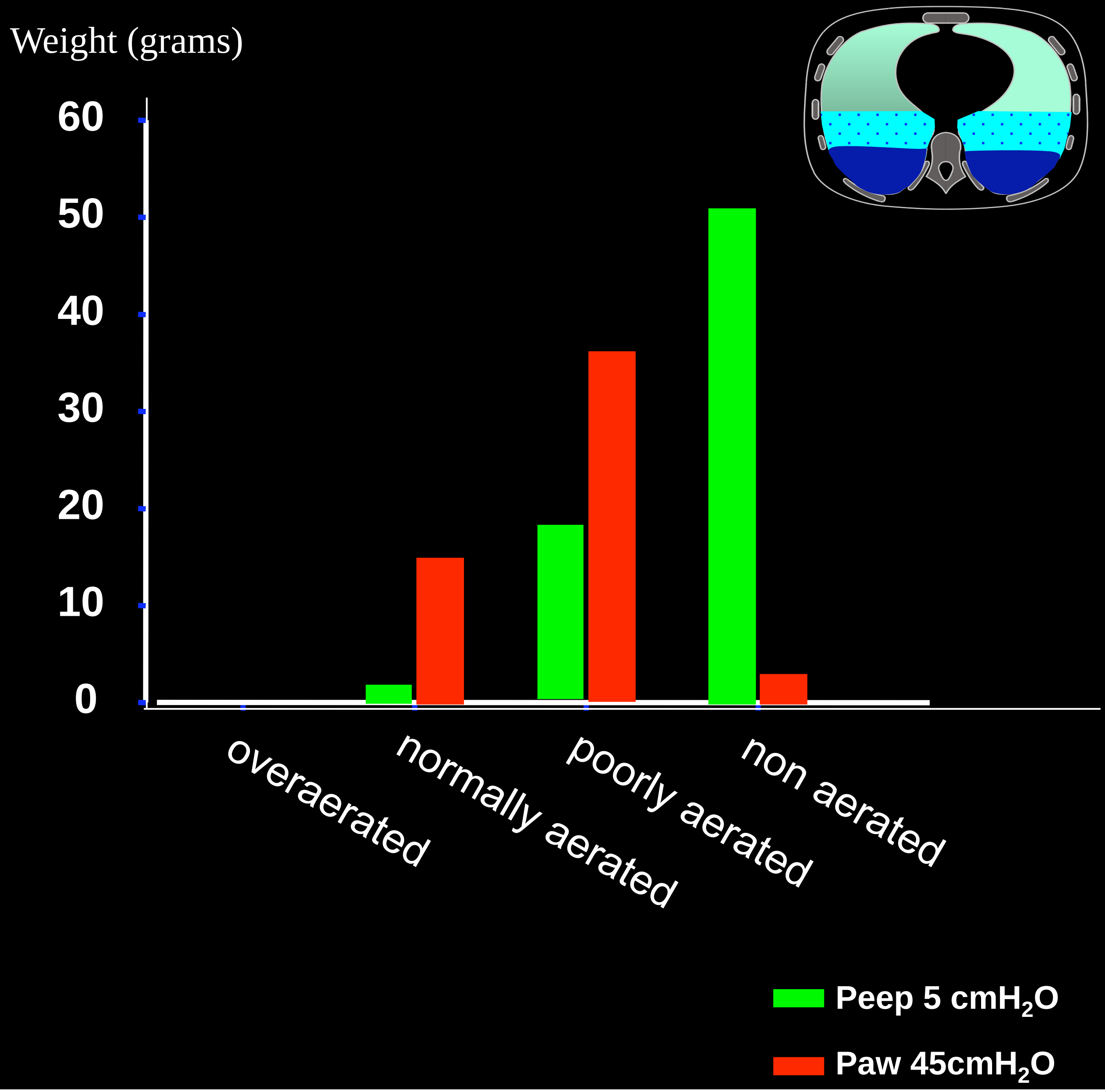


Peep 5 cmH_2O



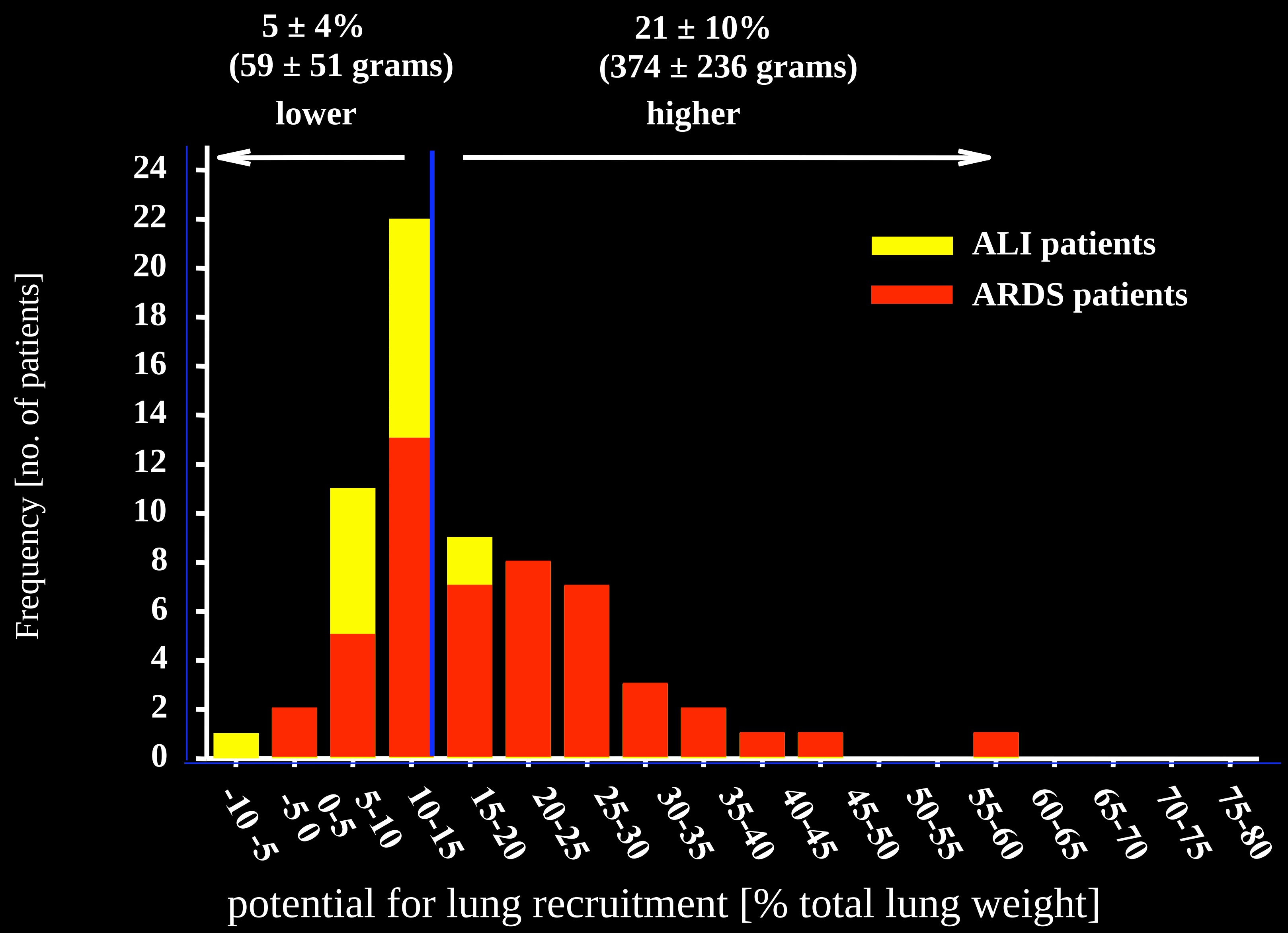
Gattinoni et al NEJM 2006, 354(17):1775-86

Recruiter



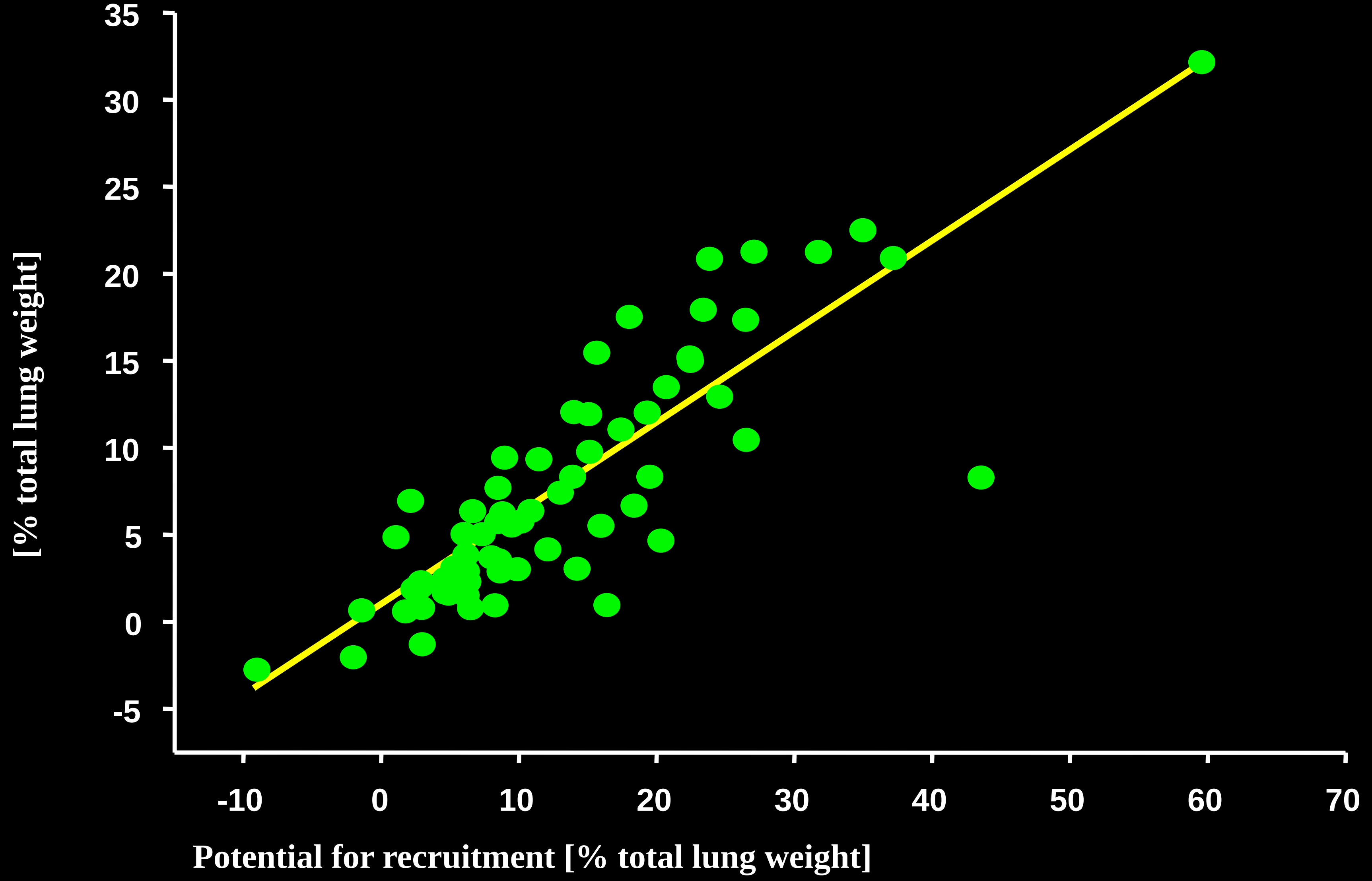
Potential for lung recruitment

Gattinoni et al NEJM 2006, 354(17):1775-86



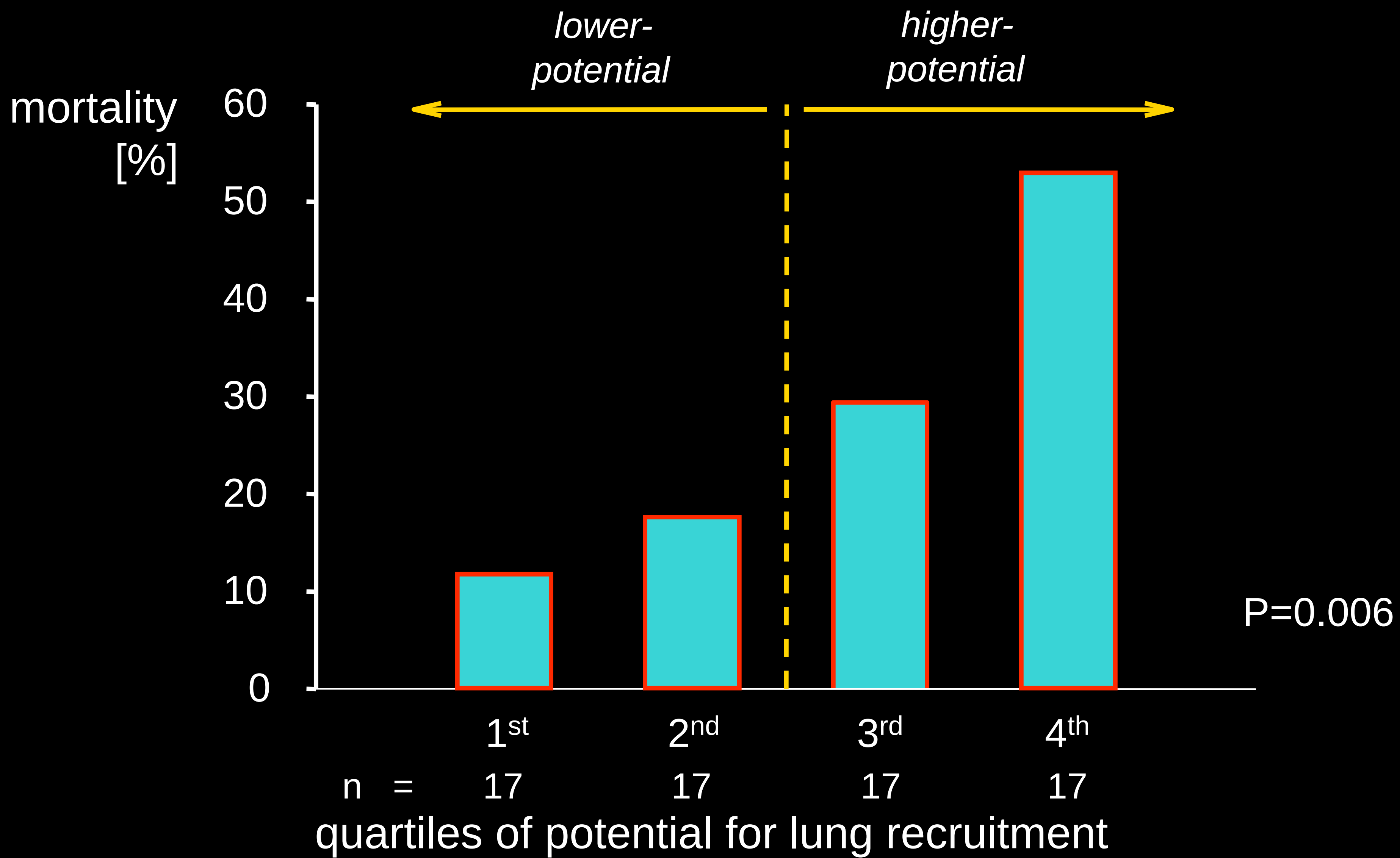
Recruitment is a function of lung weight

Gattinoni et al NEJM 2006, 354(17):1775-86



Mortality at ICU-discharge

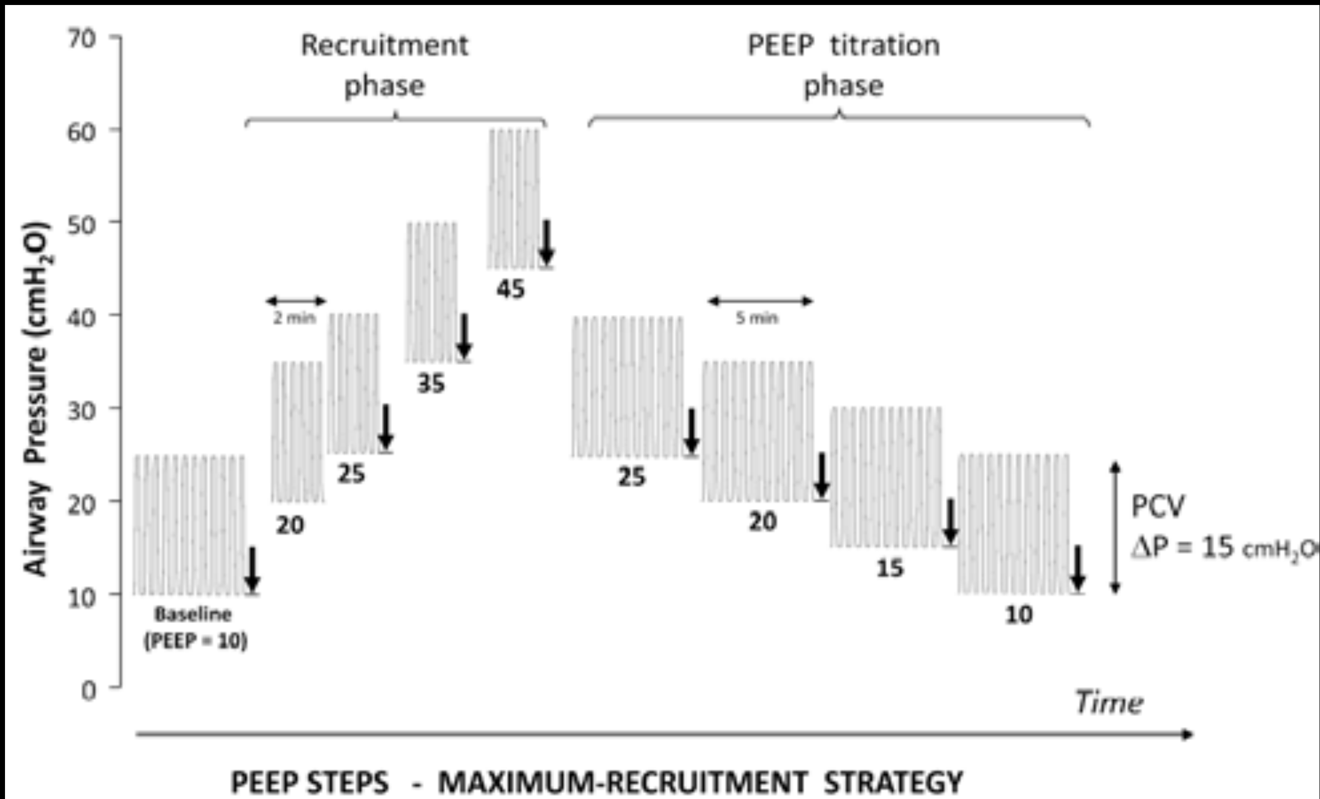
Gattinoni et al NEJM 2006, 354(17):1775-86



How large is the lung recruitability in early ARDS: a prospective case series of patients monitored by CT

De Matos GFJ et al Critical Care 2012, 16:R4

- Less than 72 hours onset
- $PaO_2/FIO_2 < 200$, with PEEP ≥ 10 cmH_2O, FIO_2 of 1.0 and pressure-controlled ventilation with driving pressure set at 15 cmH_2O



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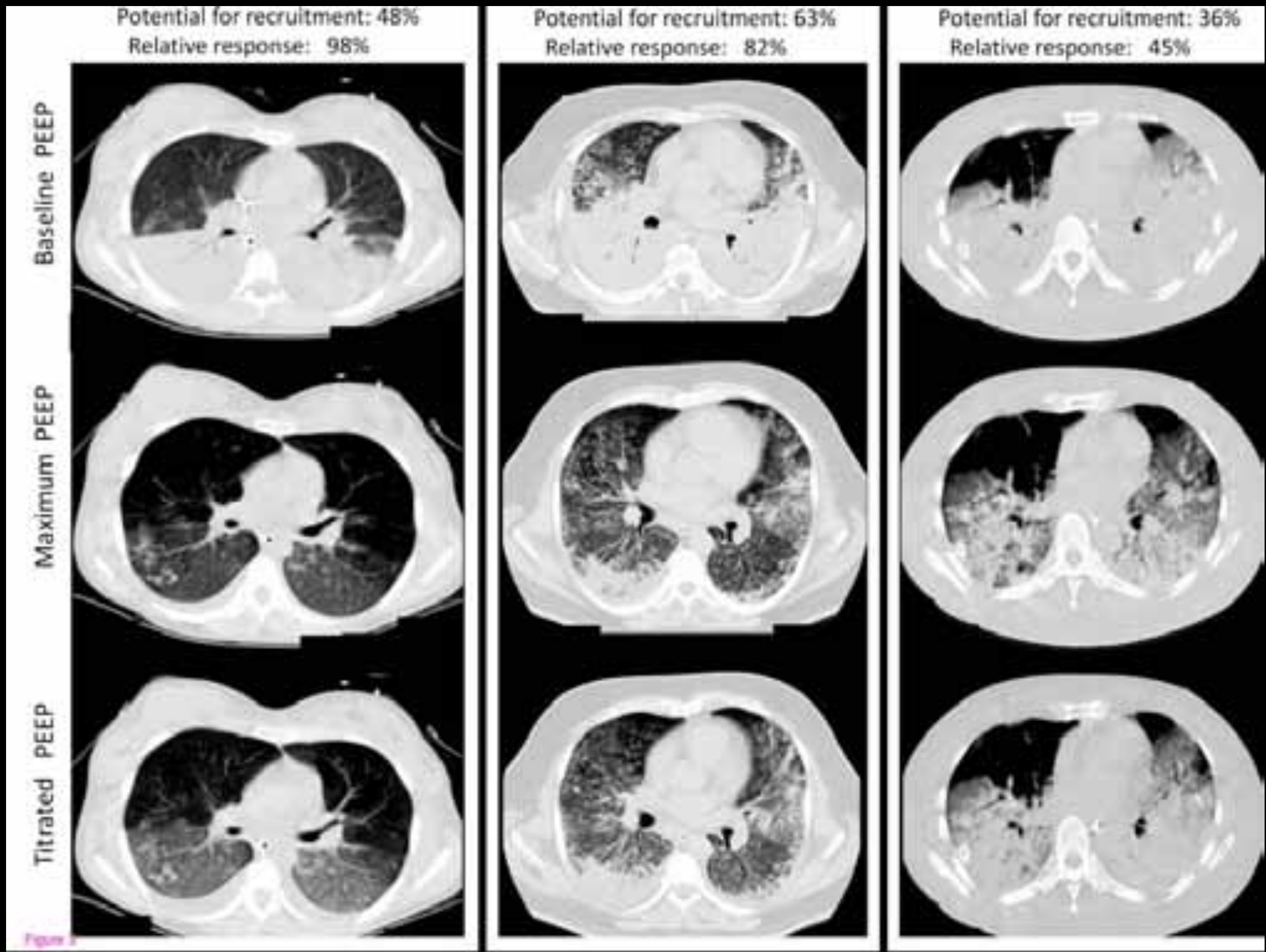

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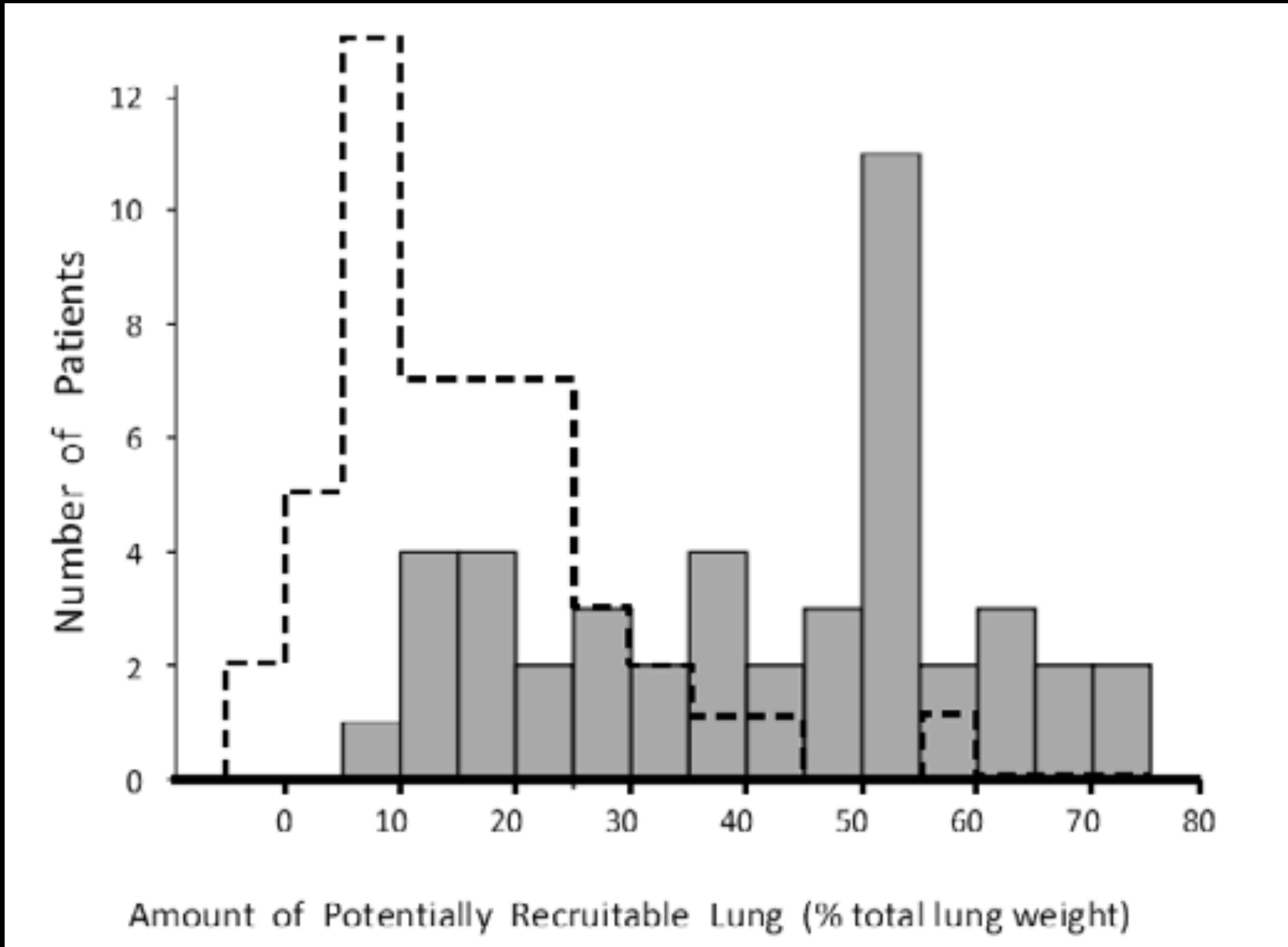

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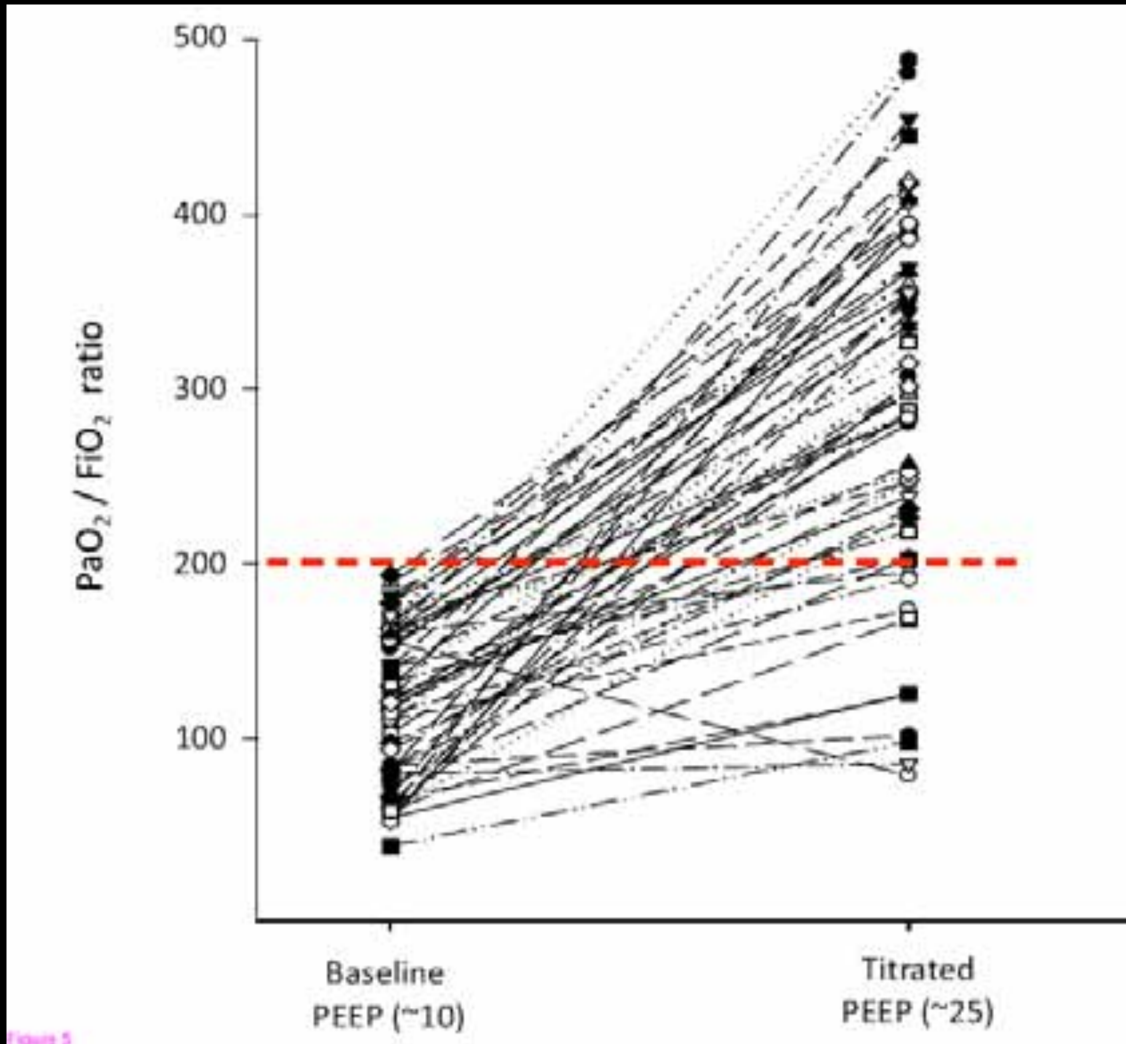

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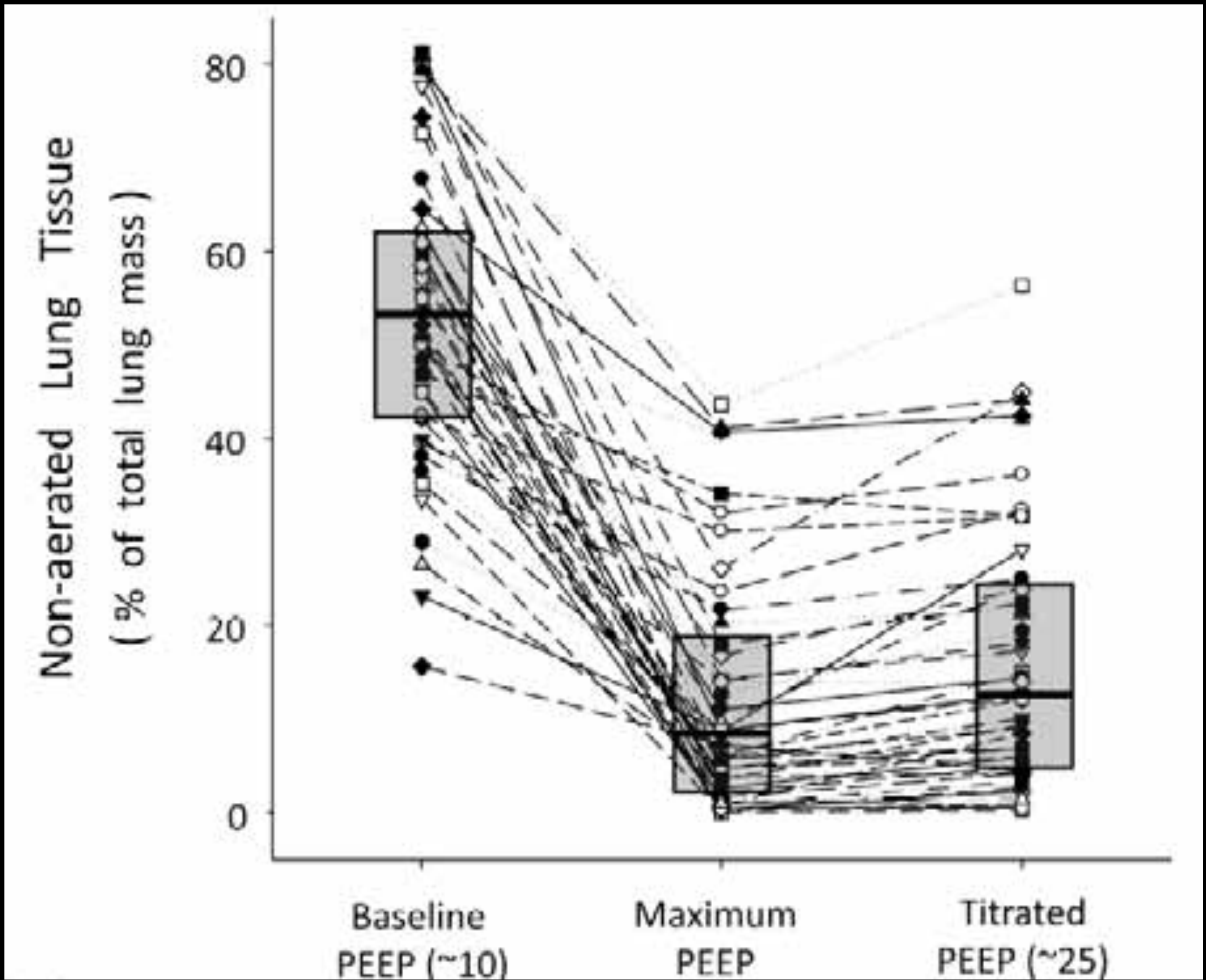

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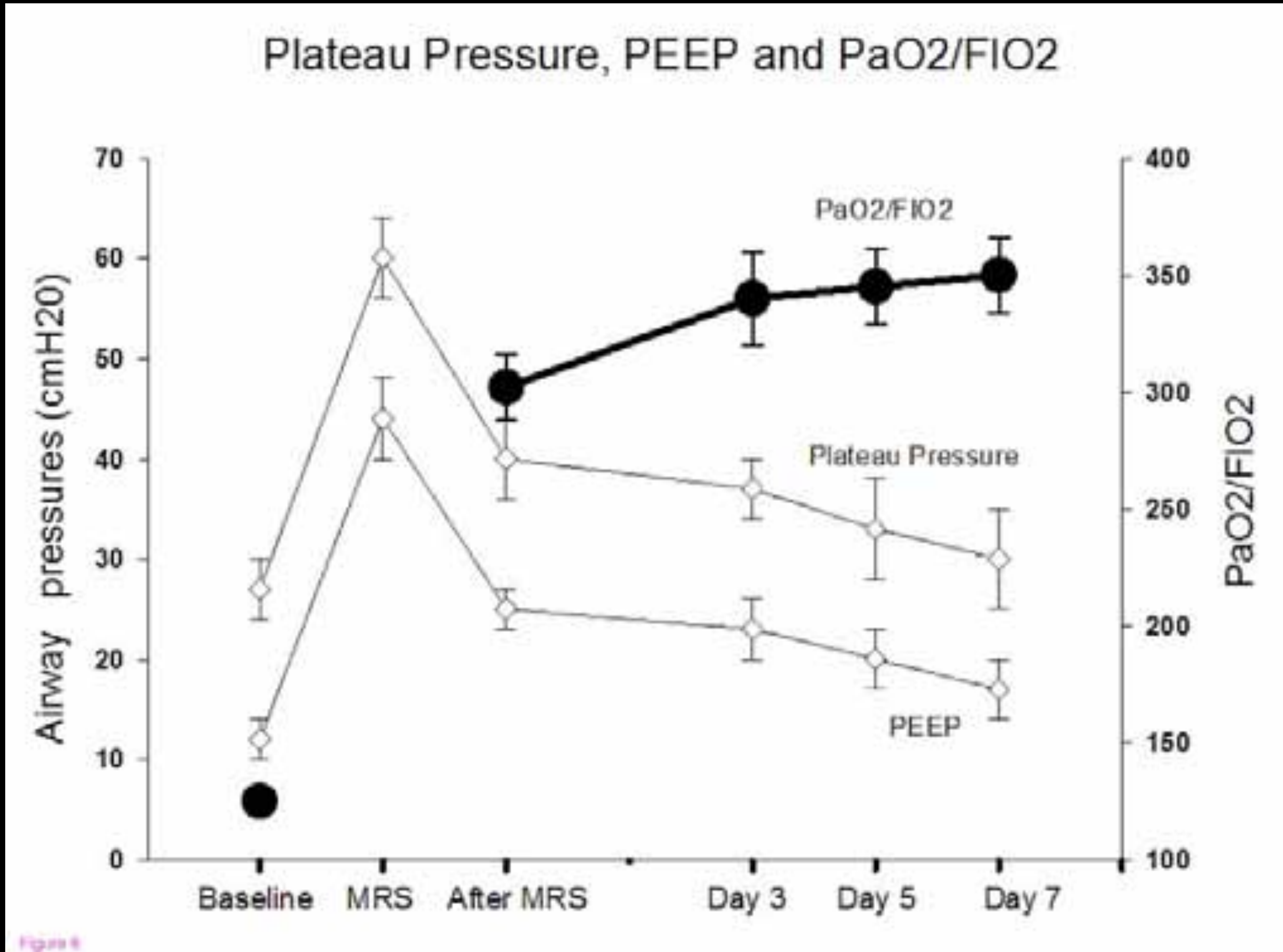
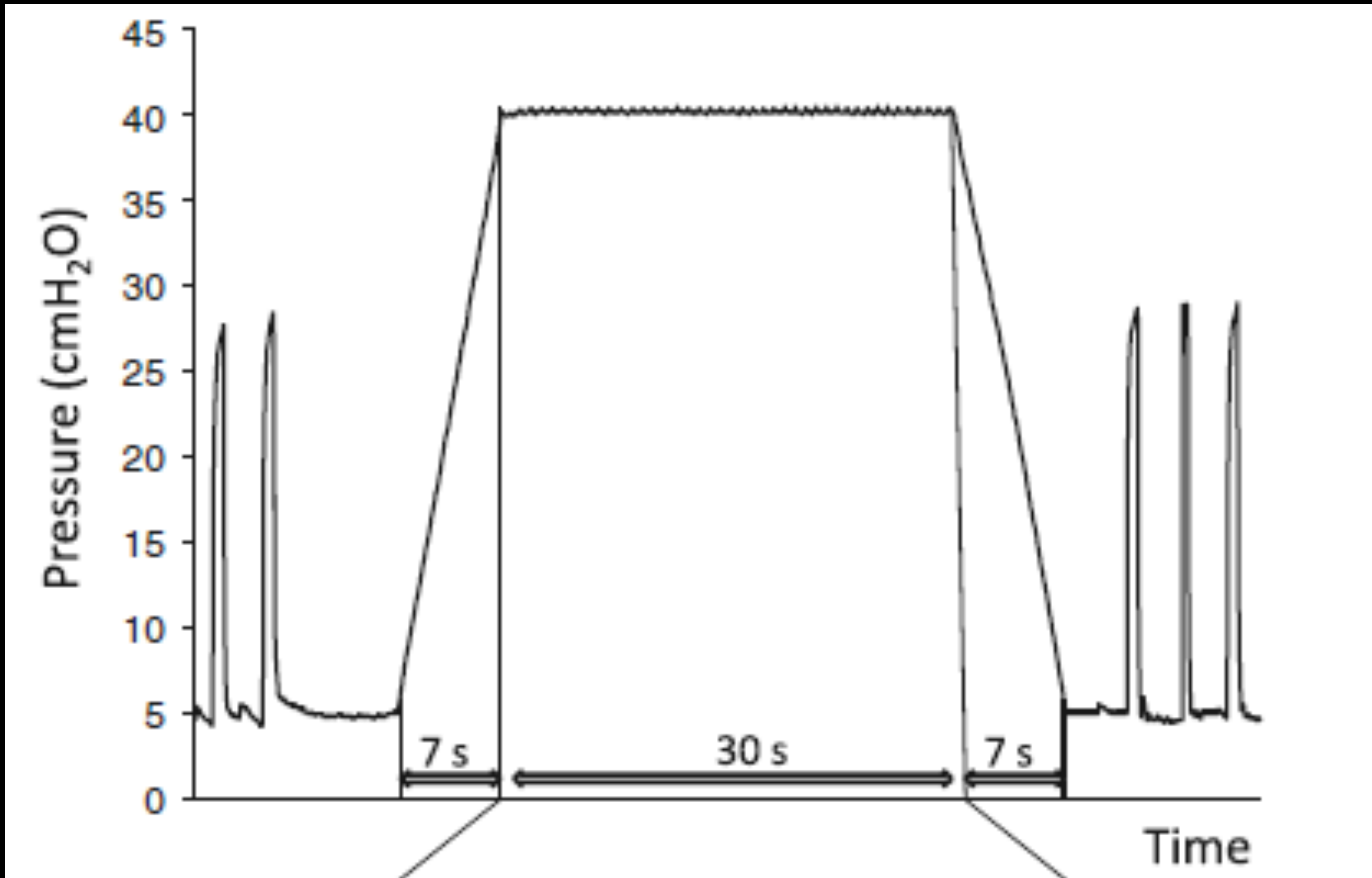


Optimal duration of a sustained inflation recruitment maneuver in ARDS patients

Arnal JM et al Intensive Care Med (2011) 37:1588–1594



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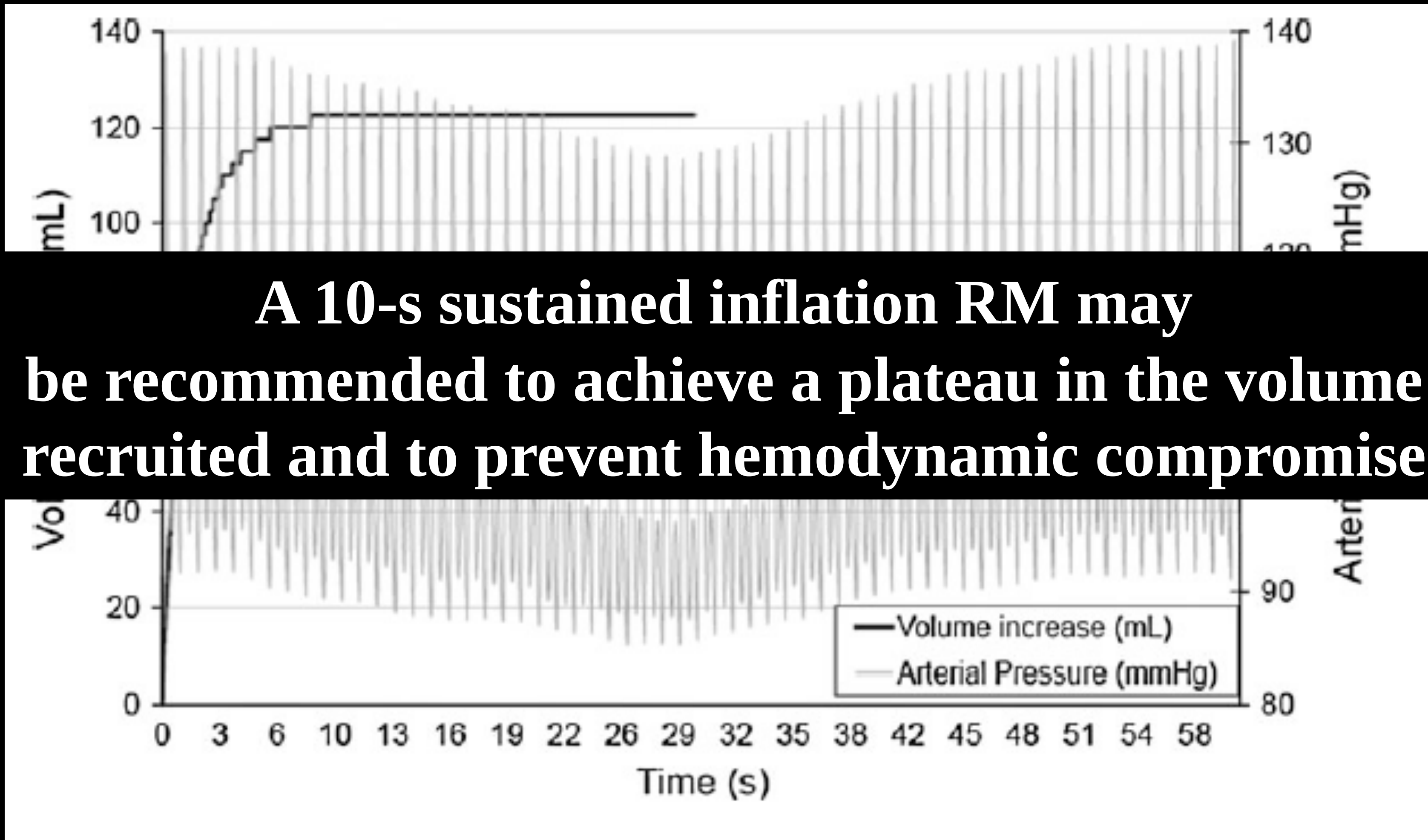
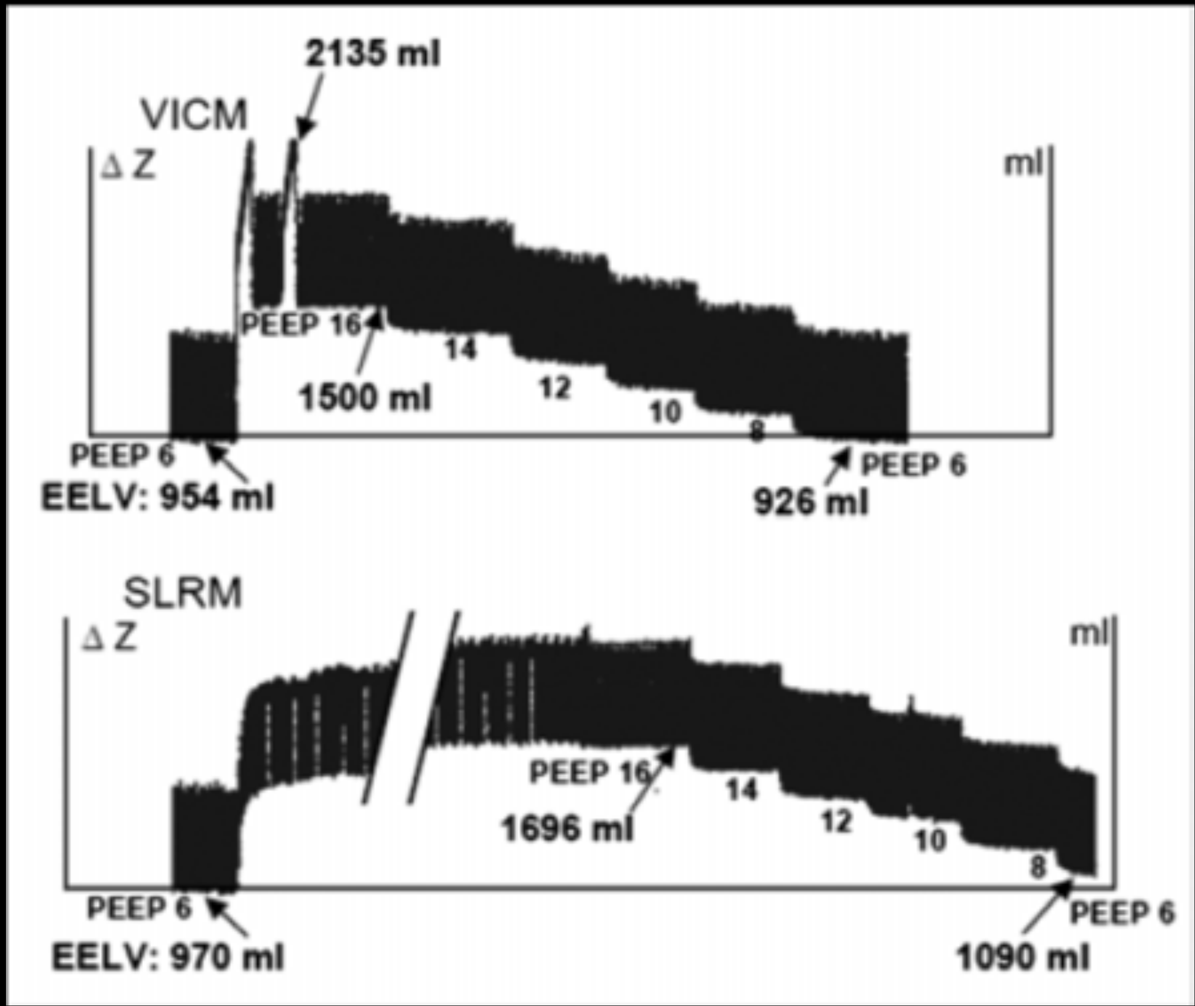


A 10-s sustained inflation RM may be recommended to achieve a plateau in the volume recruited and to prevent hemodynamic compromise

Prolonged moderate pressure recruitment manoeuvre results in lower optimal PEEP and plateau pressure

Lowhagen K et al Acta Anaesthesiol Scand 2011; 55: 175–184



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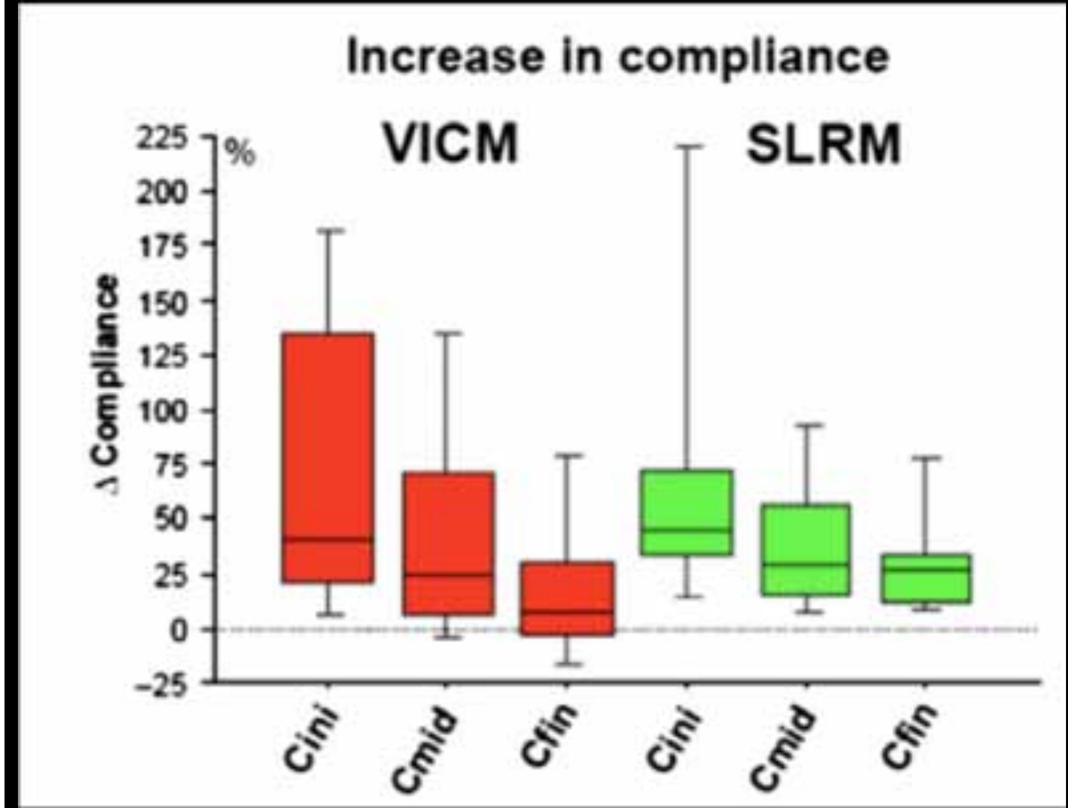
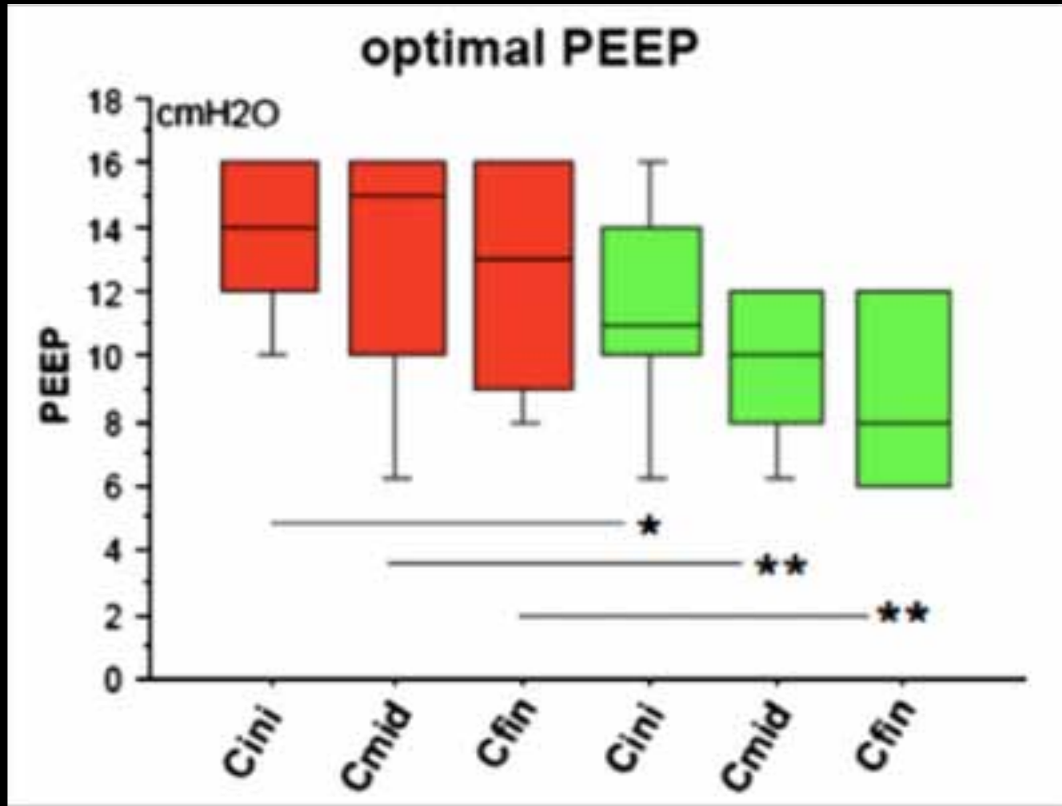




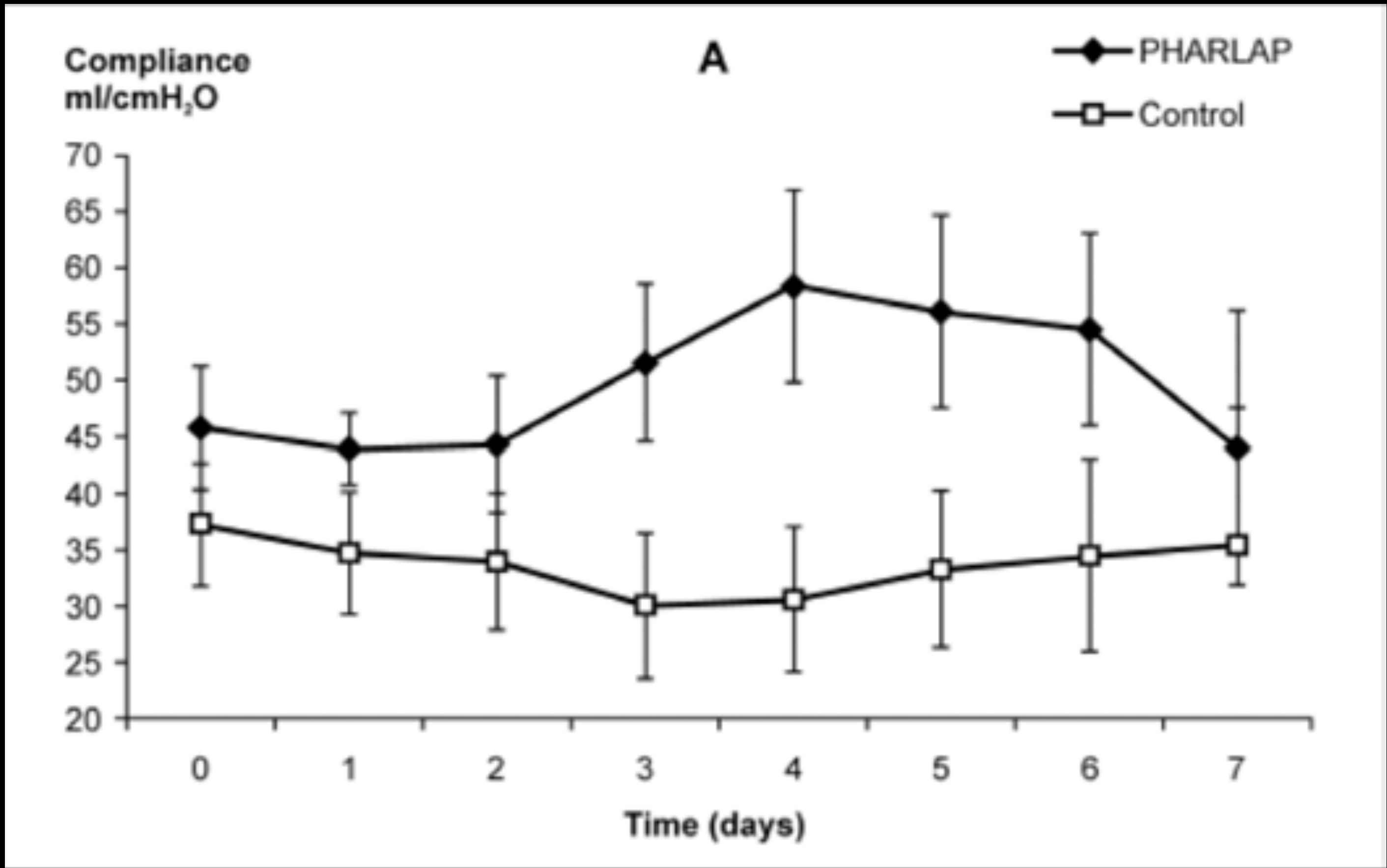
Randomised controlled trial of an open lung strategy with staircase recruitment, titrated PEEP and targeted low airway pressures in patients with ARDS

Hodgson et al. Critical Care 2011, 15:R133

	PHARLAP	Control
Number in group	10	10
Male, number	7	6
Age, years	60 ± 5	58 ± 4
APACHE 2 score	20.1 ± 3	20.1 ± 2
APACHE 3 score	66.3 ± 8	64.8 ± 7
SOFA score	8.6 ± 0.9	8.4 ± 0.5
PaO_2/F_iO_2, mmHg	155 ± 8	149 ± 12
Diagnostic group	5 pneumonia	6 pneumonia
	2 AAA	2 AAA
	1 necrotising fasciitis	1 burn
	2 trauma	1 sepsis
Static lung compliance, ml/cm H_2O	45.8 ± 5.4	37.3 ± 5.4
PEEP, cm H_2O	11.8 ± 0.7	14.2 ± 1.2

Randomised controlled trial of an open lung strategy with staircase recruitment, titrated PEEP and targeted low airway pressures in patients with ARDS

Hodgson et al. Critical Care 2011, 15:R133



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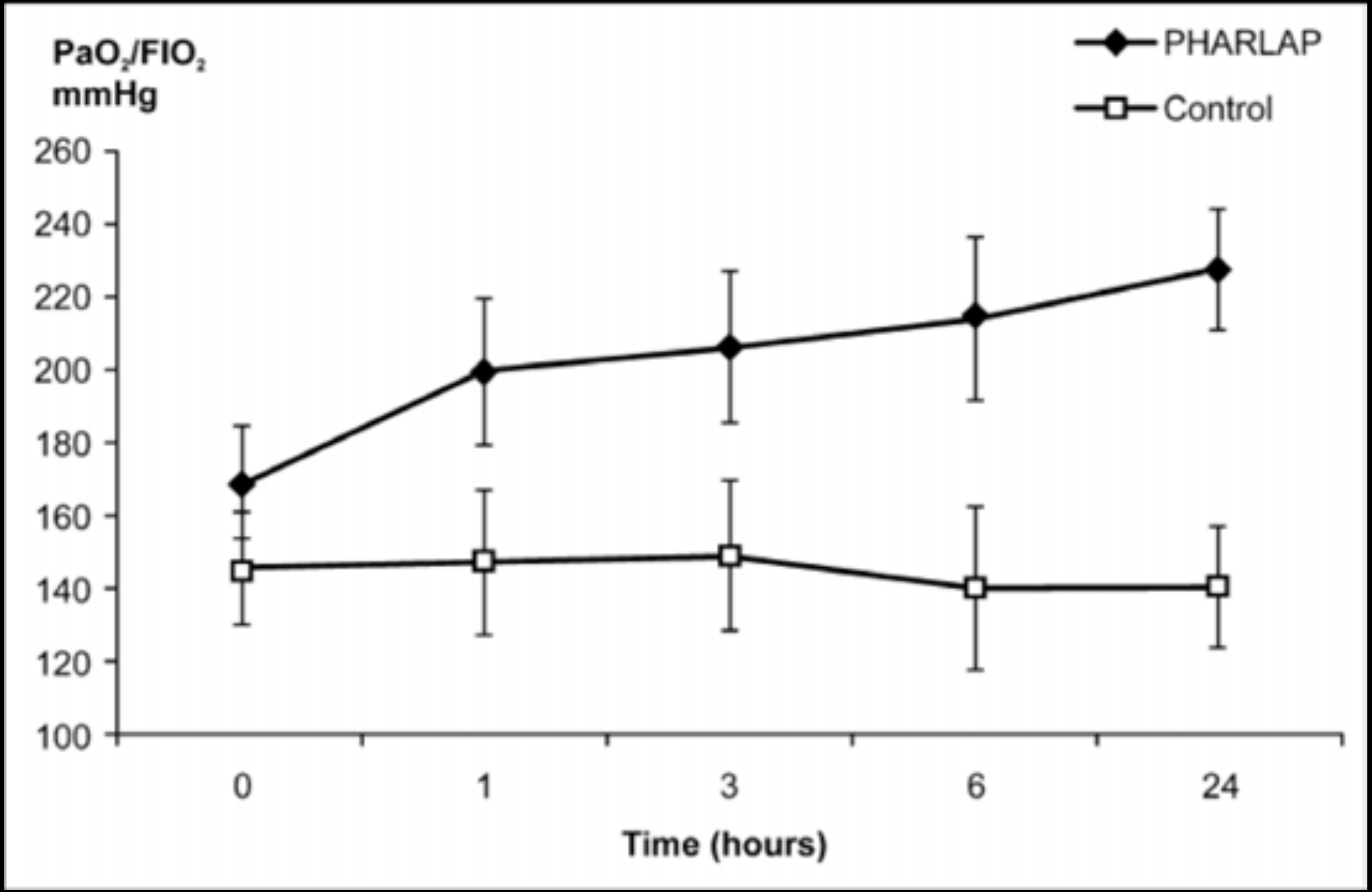

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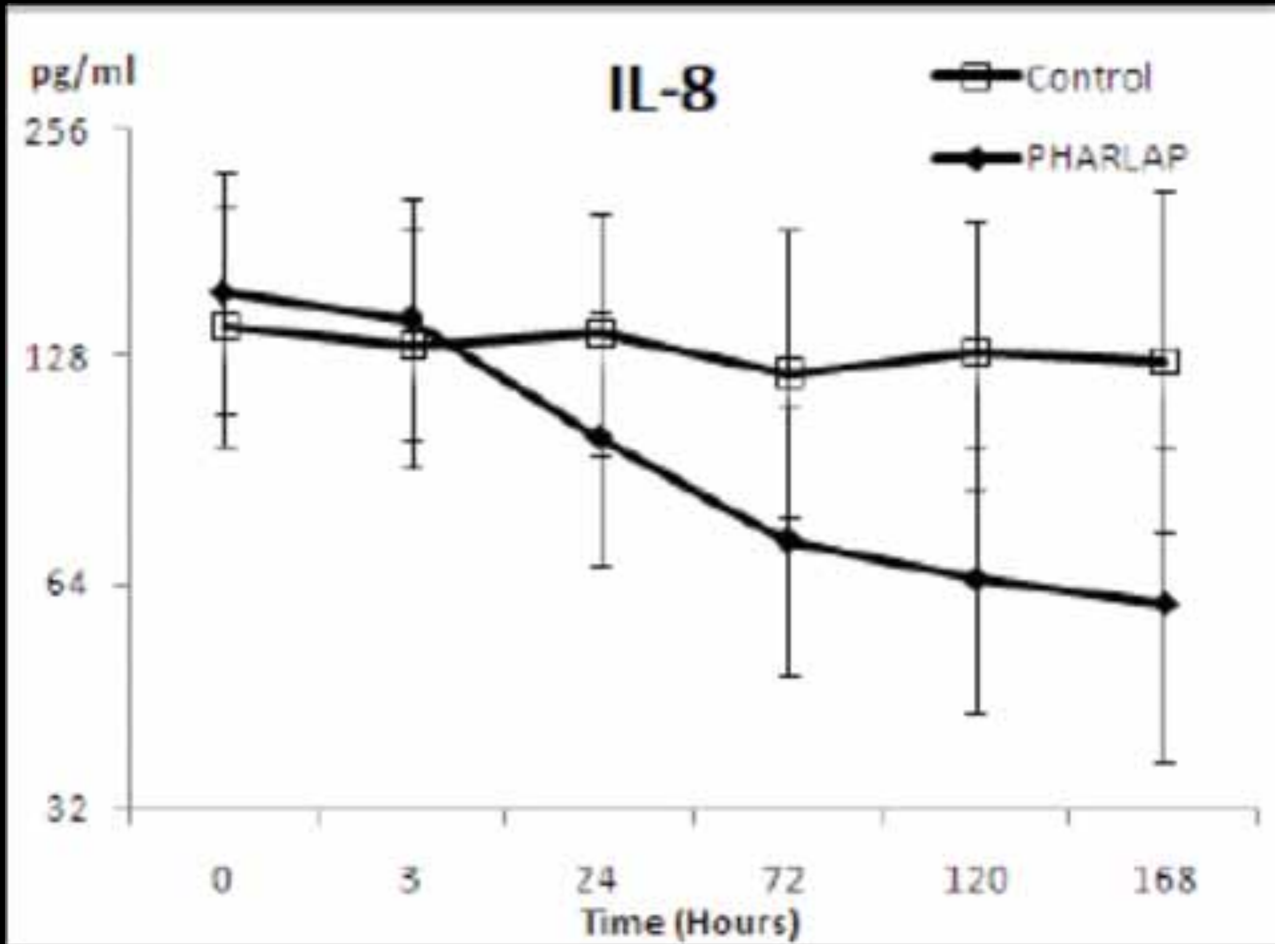

Clinical efficacy and safety of recruitment maneuver in patients with acute respiratory distress syndrome using low tidal volume ventilation: a multicenter randomized controlled clinical trial

Xiu-Mimg XI et al Chin Med J 2010;123(21):3100-3105

Characteristics	RM group (n=55)	Control group (n=55)	P values
Age (year)	62.2±16.0	65.5±15.2	0.28
Male (n (%))	38 (69.1)	40 (72.7)	0.68
APACHE II score	21.5±6.7	23.1±8.6	0.28
Tidal volume (ml/kg of PBW)	6.6±0.9	6.8±1.1	0.39
PEEP (cmH_2O)	10.5±3.2	9.7±2.4	0.18
Ppeak (cmH_2O)	28.0±5.9	27.9±6.8	0.94
Pplat (cmH_2O)	24.2±5.3	23.4±5.3	0.47
Respiratory rate (breaths/min)	27.3±8.0	26.5±9.1	0.39
PaO_2/FiO_2	93.8 (68.7–150.0)	120.0 (88.3–140.0)	0.06
Causes of ARDS (n (%))			
Pneumonia	19 (34.5)	17 (30.9)	
Aspiration	6 (10.9)	4 (7.3)	
Sepsis	7 (12.7)	16 (29.1)	
Trauma	2 (3.6)	3 (5.5)	
Others	21 (38.2)	15 (27.3)	

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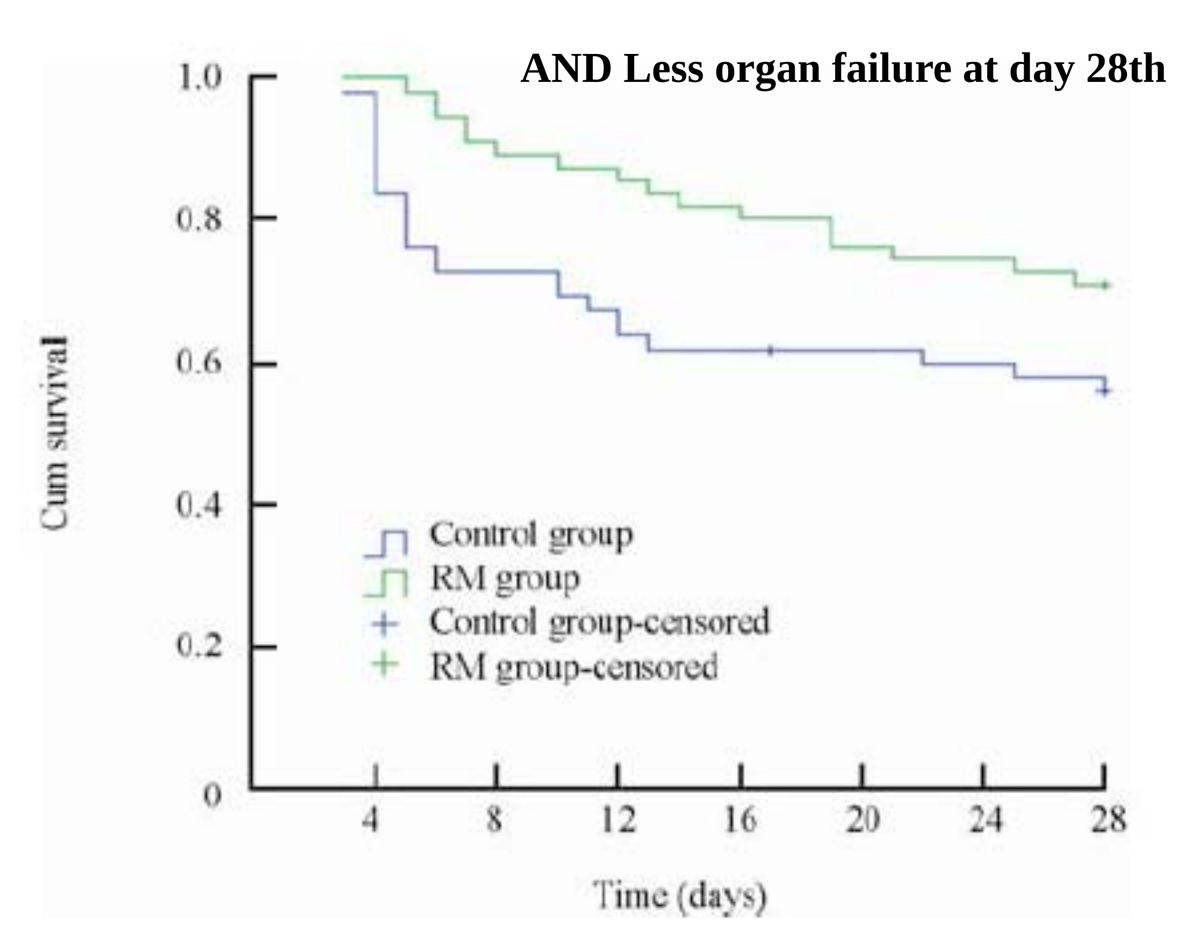

Open Lung Approach Study

Brazil
-Hospital das Clinicas, Dr.Marcelo Amato

Chile
-Clinica Alemana de Santiago, Dr.Vinko Tomicic

Korea
-Asan Medical Center, Ulsan College of Medicine, Dr.Younsuck Koh

Japan
-Tokushima University Hospital, Dr.Masaji Nishimura

Spain
-Hospital Fundacion Jimenez-Diaz, Dr.Fernando Suarez-Sipmann
-Hospital Clinico Universitario de Valencia, Dr.Javier Belda
-Hospital de Leon, Dr. Demetrio Carriedo
-Hospital Universitario Ntra. Sra. de Candeleria, Dr.Santiago Lubillo
-Hospital Universitario Rio Hortega, Dr.Jesus Blanco
-Hospital Morales Meseguer, Dr.Gumersindo Gonzalez
-Hospital Clinic de Barcelona, Dr.Elizabeth Zavala
-Hospital Universitario La Paz, Dr.Julia Lopez
-Hospital Universitario Txagorritxu, Dr.Nela Hernandez
-Hospital Virgen de la Salud, Dr.Maria del Mar Cruz Acquaroni
-Hospital Universitario Virgen de la Arrixaca, Dr. Domingo Martinez
-Hospital Virgen de la Luz, Dr Juan Bautista Arajuo
-Hospital Universitario de Valencia, Federico Aguar
-Hospital Galdakano, Dr. Higinio Martin
-Hospital de Navarra, Dr. Juan Pedro Tirapu
-Consorcio Hospitalario de Manresa, Dr. Rafael Fernandez
-Hospital Donostia, Dr. Pilar Marco
-Hospital Universitario Juan Canalejo, Dr.Miguel A. Solla
-Hospital Universitario Santiago de Compostela, Dr. Valentin Caruezo

Peru
- Hospital Nacional Edgardo Rebagliati Martins, Dr. Rollin Roldán Mori

USA
-Massachusetts General Hospital, Dr.Robert Kacmarek

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- ARDS: principles of treatment
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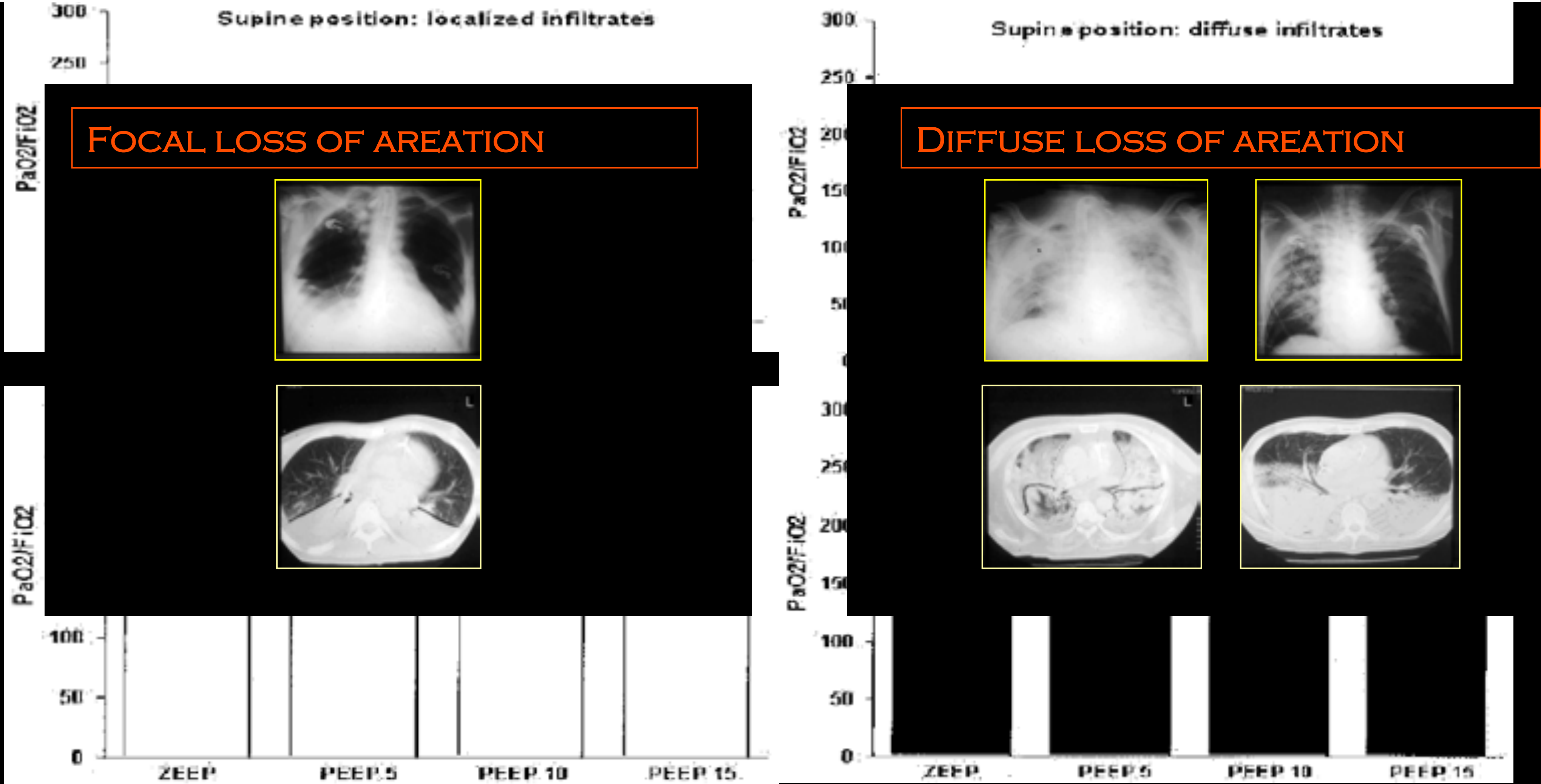
Prone position and positive end-expiratory pressure in acute respiratory distress syndrome*

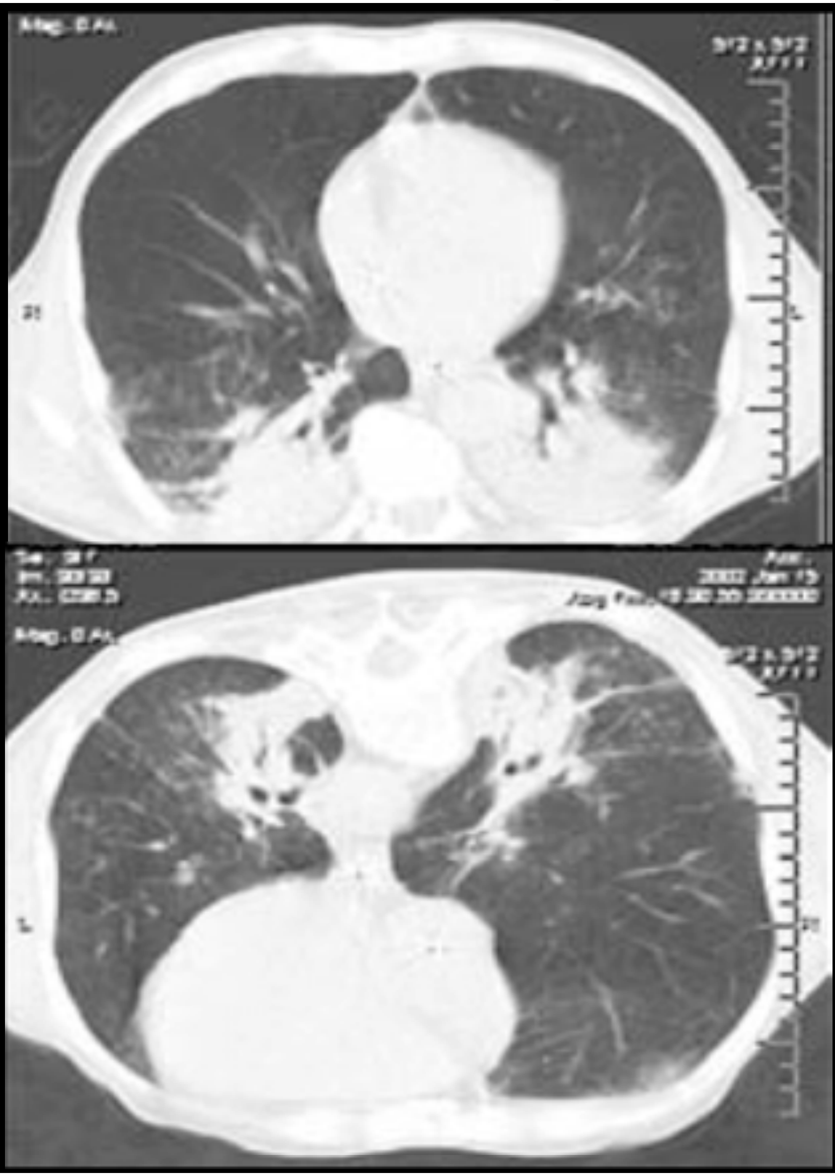
Crit Care Med 2003; 31:2719–2726

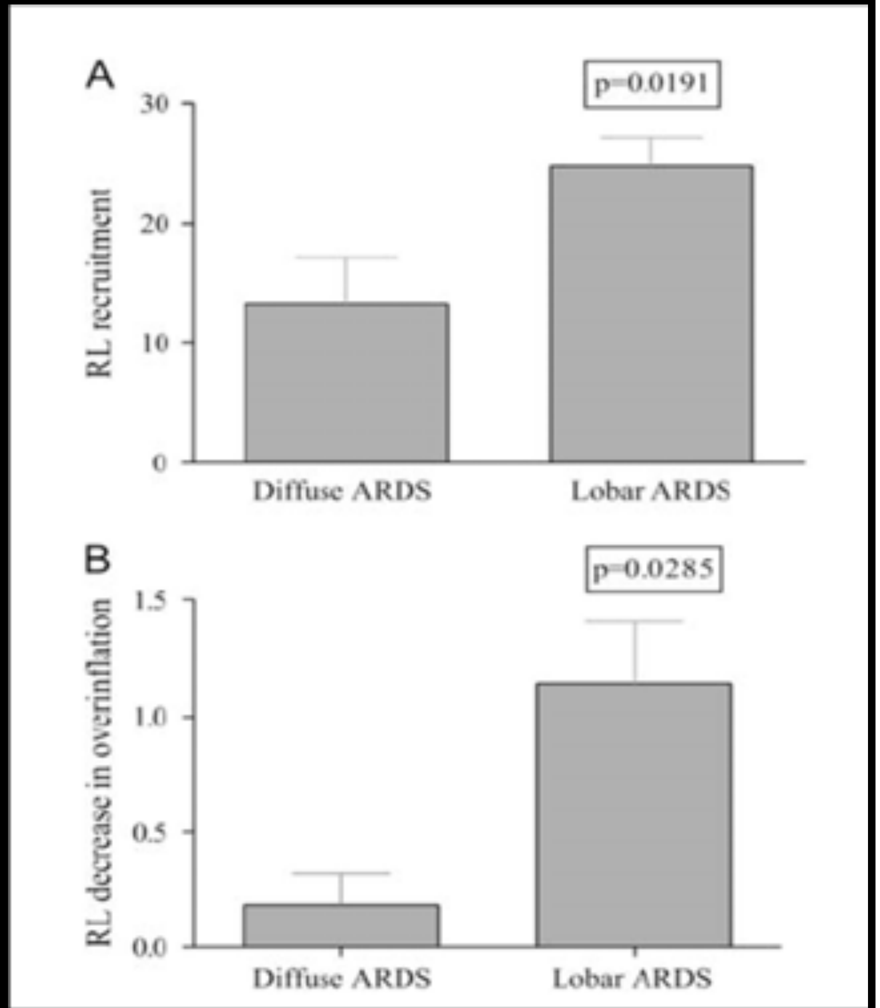
Marc Gainnier, MD; Pierre Michelet, MD; Xavier Thirion, MD; Jean-Michel Arnal, MD;
Jean-Marie Sainty, MD; Laurent Papazian, MD

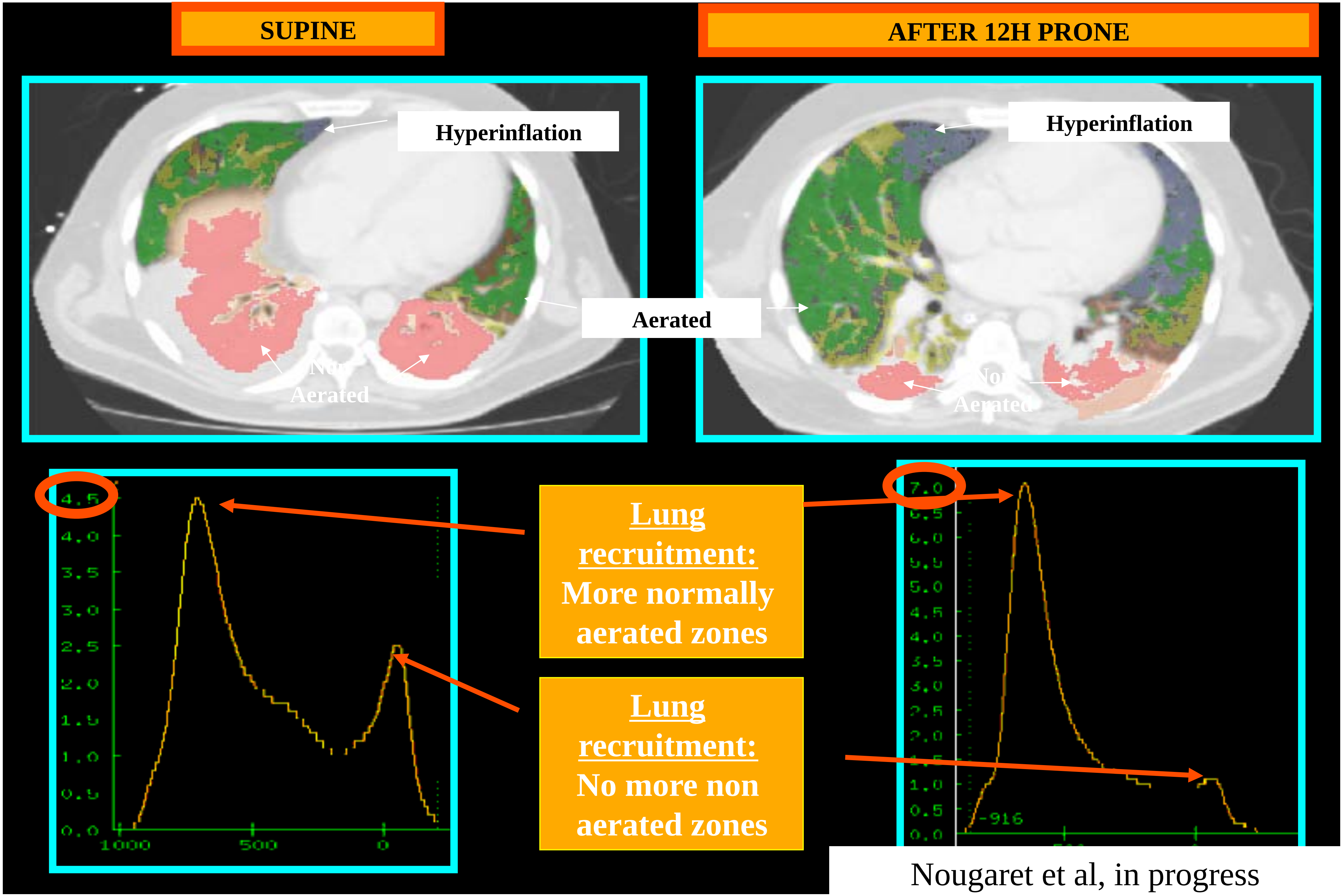


Prone Position Augments Recruitment and Prevents Alveolar Overinflation in Acute Lung Injury

Eftichia Galiatsou, Eleonora Kostanti, Eugenia Svarna, Athanasios Kitsakos, Vasilios Koulouras, Stauros C. Efremidis, and Georgios Nakos



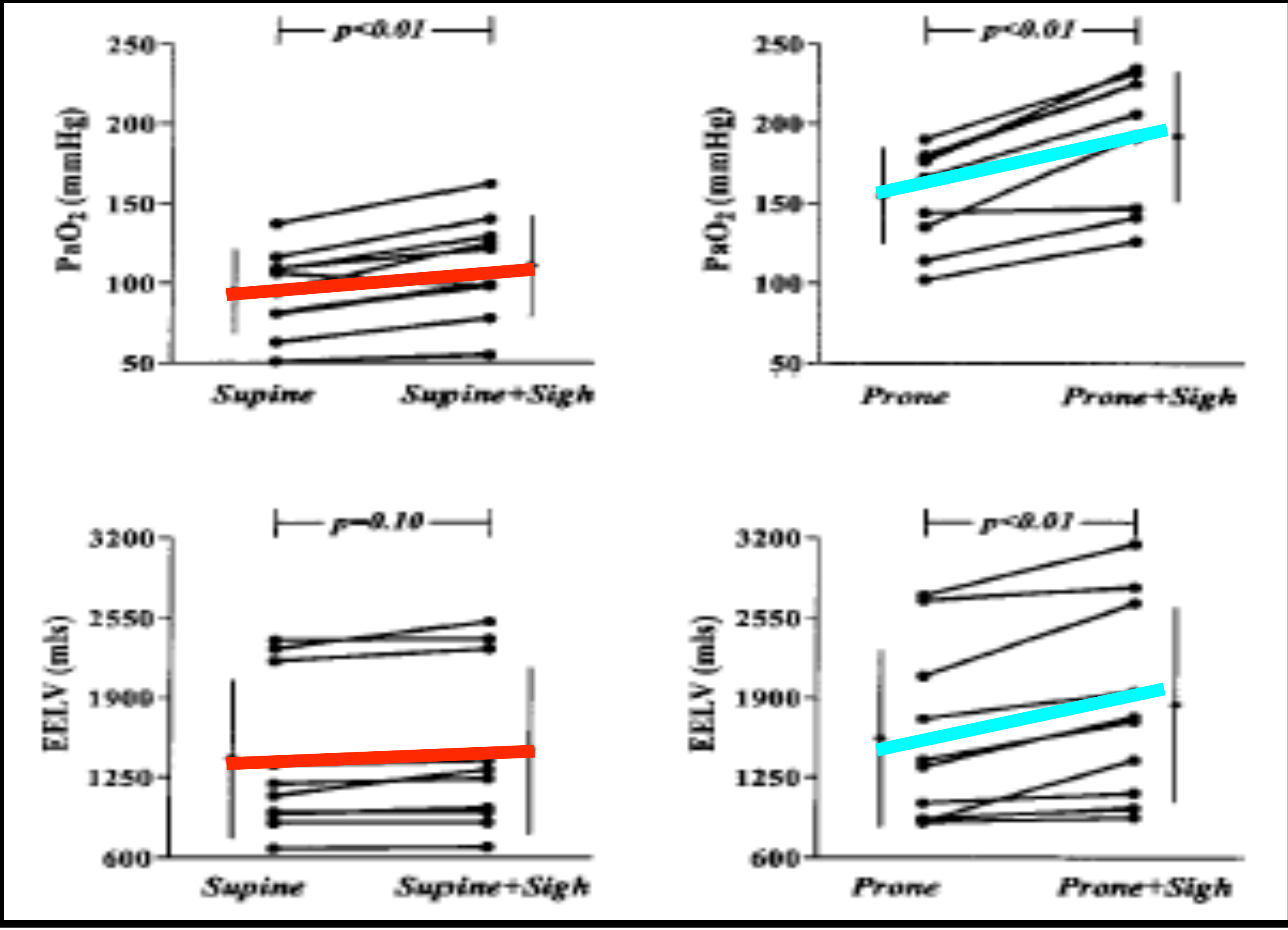




Nougaret et al, in progress

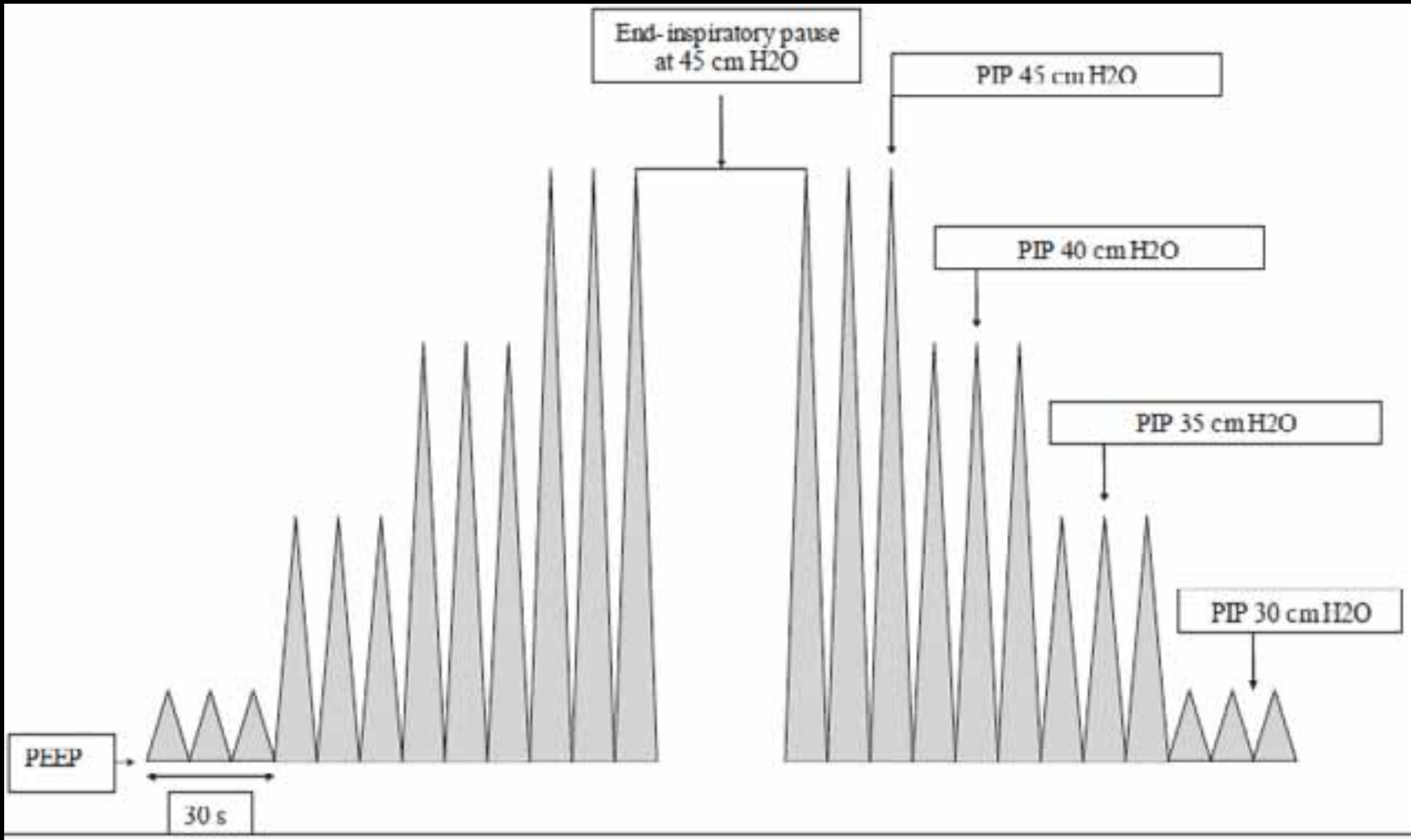
Sigh in supine and prone during ARDS

Pelosi P et al Am J Respir Crit Care Med 2003; 167: 521-527



Prone position and recruitment manoeuvre: the combined effect improves oxygenation

Rival G et al. Critical Care 2011, 15:R125



Prone position and recruitment manoeuvre: the combined effect improves oxygenation

Rival G et al. Critical Care 2011, 15:R125

	SP		
Gas exchanges	Time 0	Time 1 (RM1)	time 2
pH	7.37 ± 0.08	7.37 ± 0.07	7.40 ± 0.08[b]
PaO_2, mmHg	75.6 ± 19	85.4 ± 28	94.5 ± 39
$PaCO_2$, mmHg	39 ± 7	39 ± 7.7	35 ± 7.4[l]
PaO_2/FiO_2 ratio, mmHg	98.3 ± 28	111.4 ± 41.2	123 ± 52.3

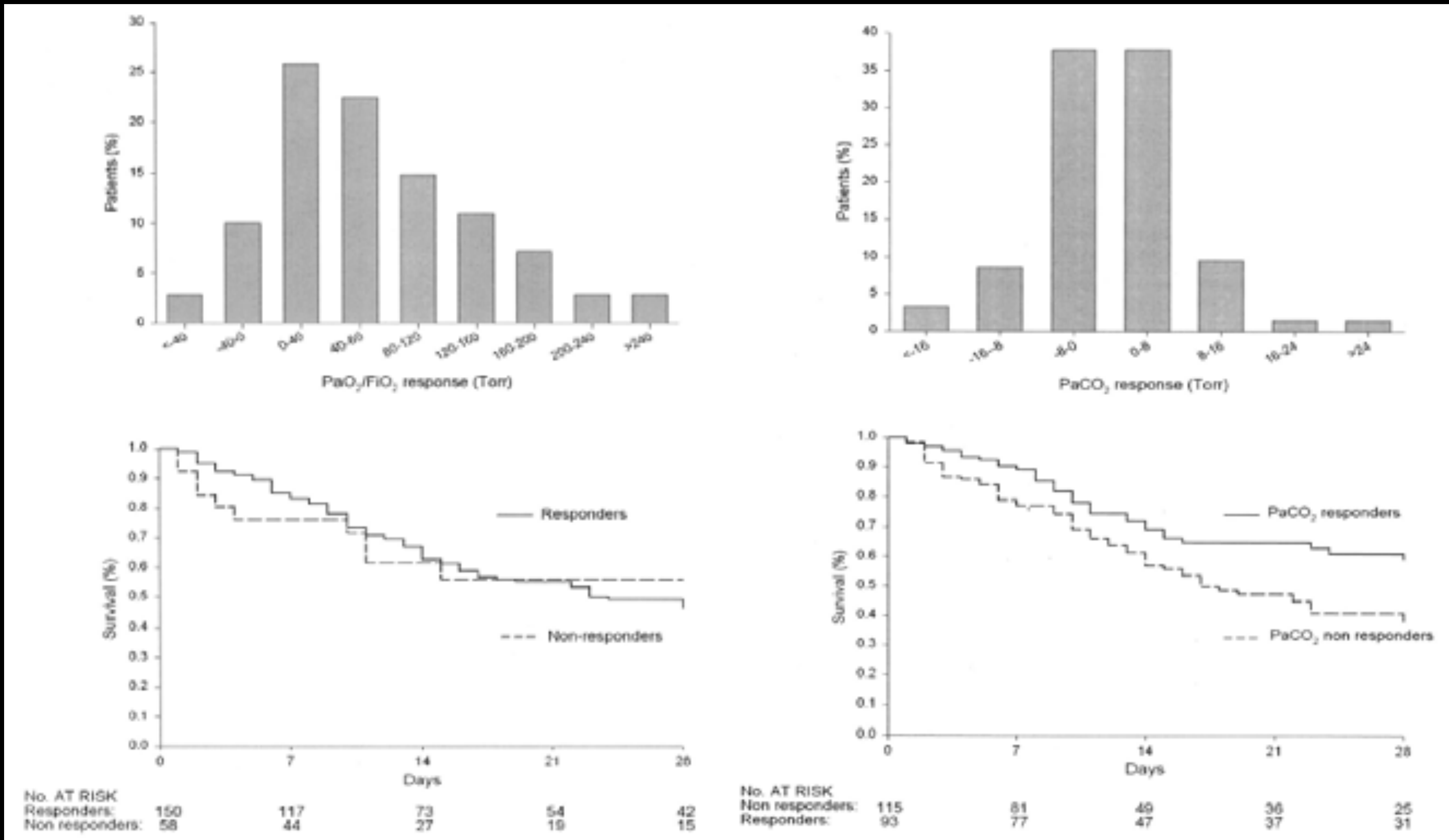
Prone position and recruitment manoeuvre: the combined effect improves oxygenation

Rival G et al. Critical Care 2011, 15:R125

	PP			
Gas exchanges	Time 4 (RM2)	time 5	Time 6 (RM3)	time 7
pH	7.39 ± 0.08	7.43 ± 0.08[d]	7.40 ± 0.09	7.47 ± 0.08[e]
PaO_2, mmHg	117 ± 63	138 ± 77	138.6 ± 70	171.5 ± 84[g]
$PaCO_2$, mmHg	37 ± 8.4	35 ± 7.7[k]	36.4 ± 8.4	31.5 ± 8.4[l]
PaO_2/FiO_2 ratio, mmHg	151.2 ± 75.7	178 ± 99	177 ± 75	218.2 ± 99.5[n]

Prone position: CO_2 and Survival

Gattinoni et al Crit Care Med 2003;31:2727



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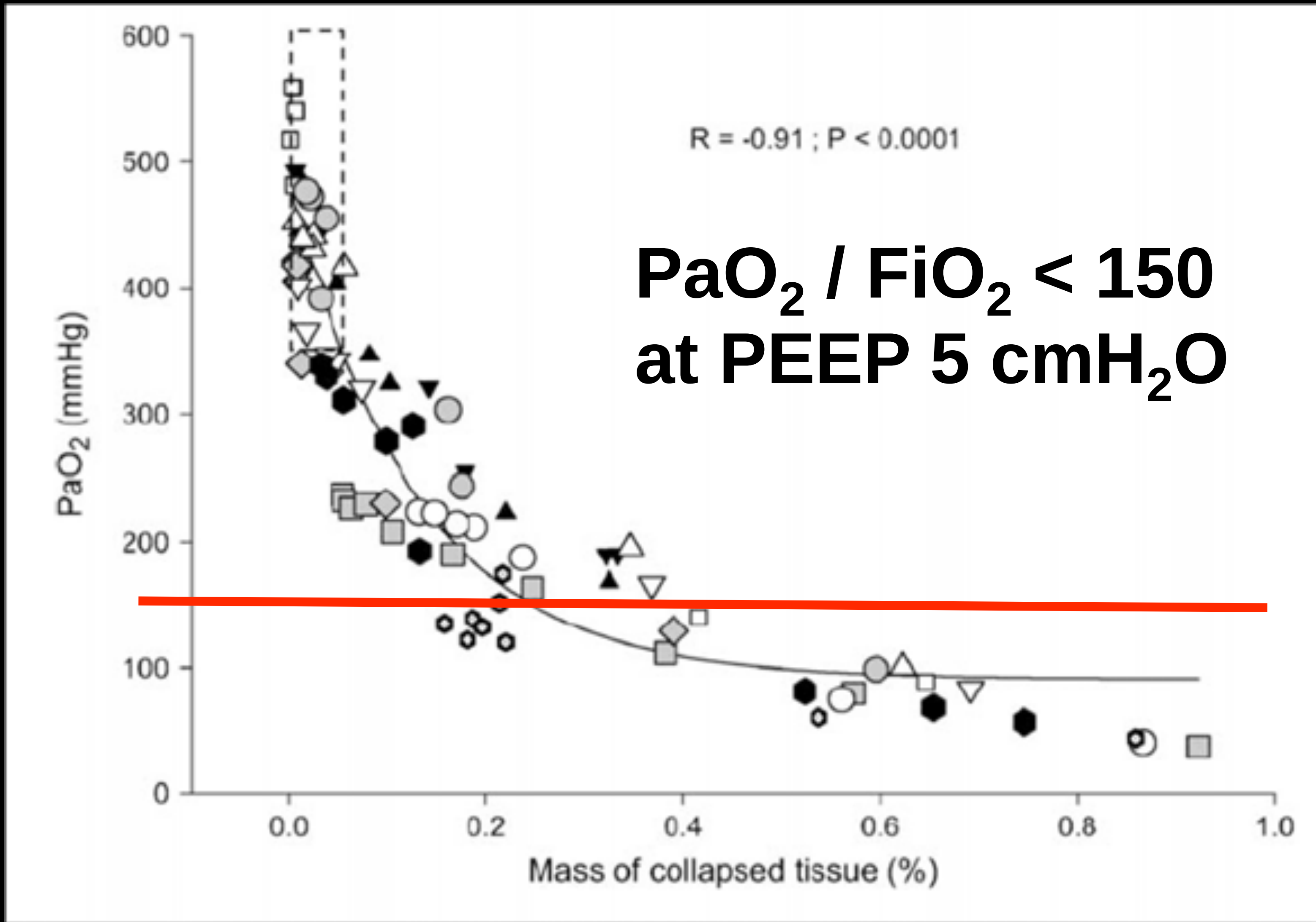
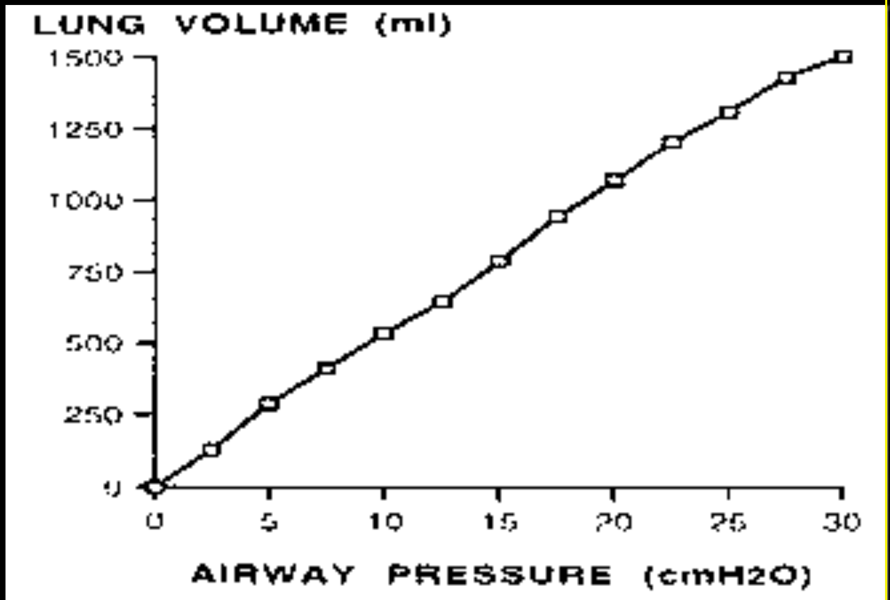
Oxygenation and collapsed tissue

Borges et al Am J Respir Crit Care Med 174; 268-278, 2006



Assessment of Pulmonary Morphology in ALI
Absence of Lower Inflection Point in the P-V Curve

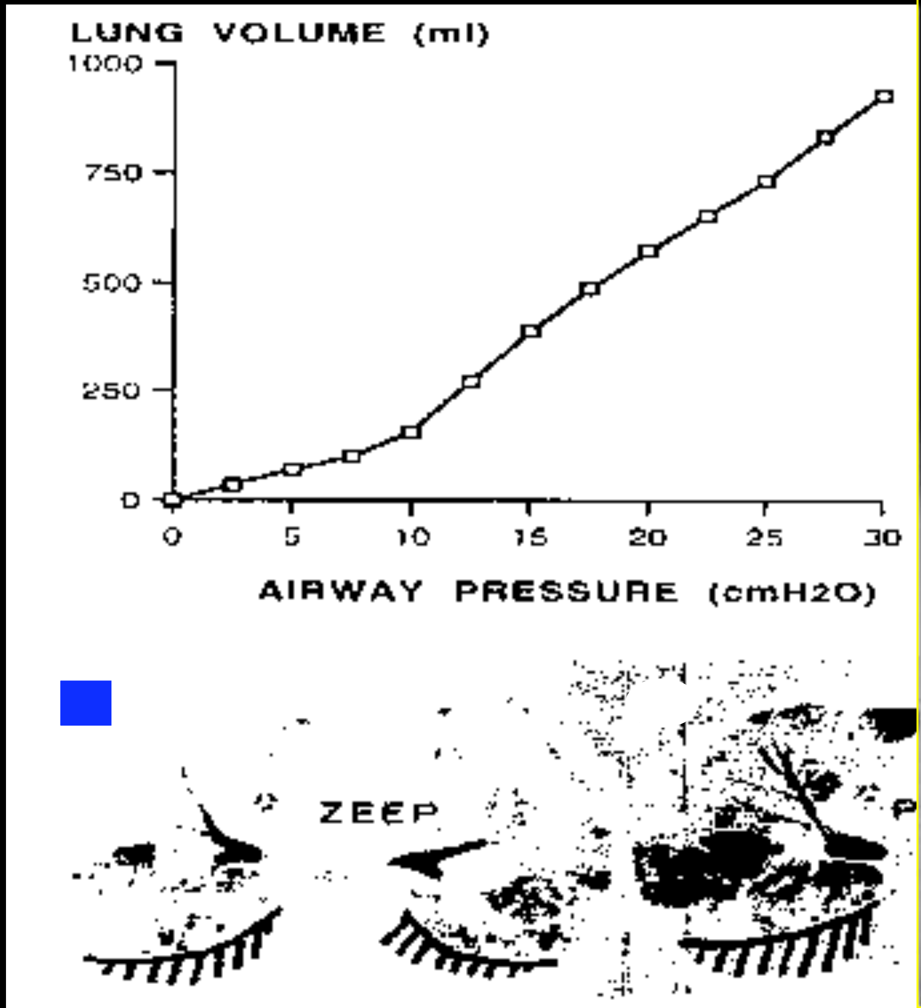
Vieira et al. Am J Resp Crit Care Med 1999; 159:1612-1623.



ZEEP **PEEP 10 cmH_2O** **PEEP 15 cmH_2O**

Assessment of Pulmonary Morphology in ALI
Significance of Lower Inflection Point in the P-V Curve

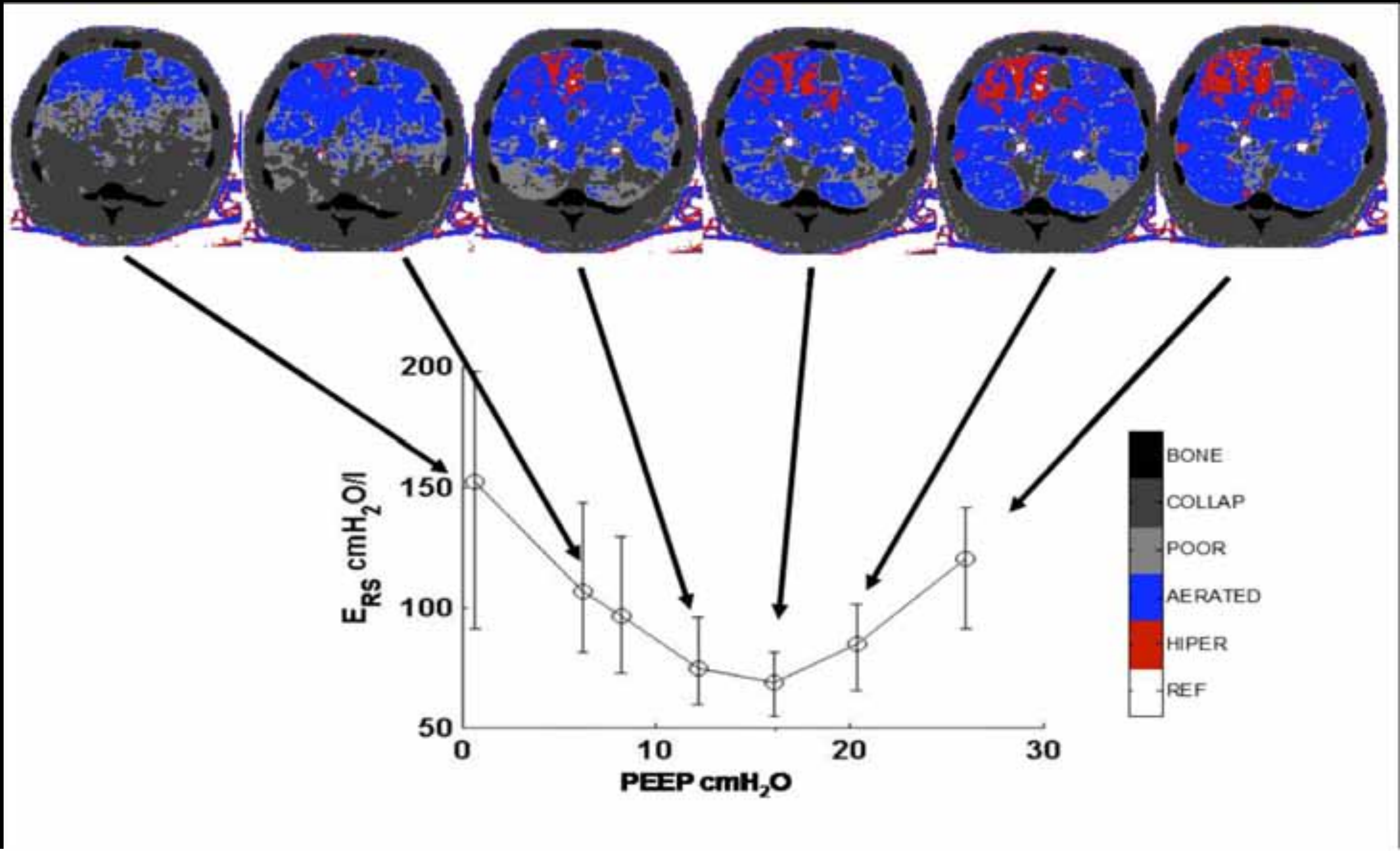
Vieira et al. Am J Resp Crit Care Med 1999; 159:1612-1623.



ZEEP LIP + 2 cmH_2O LIP + 7 cmH_2O

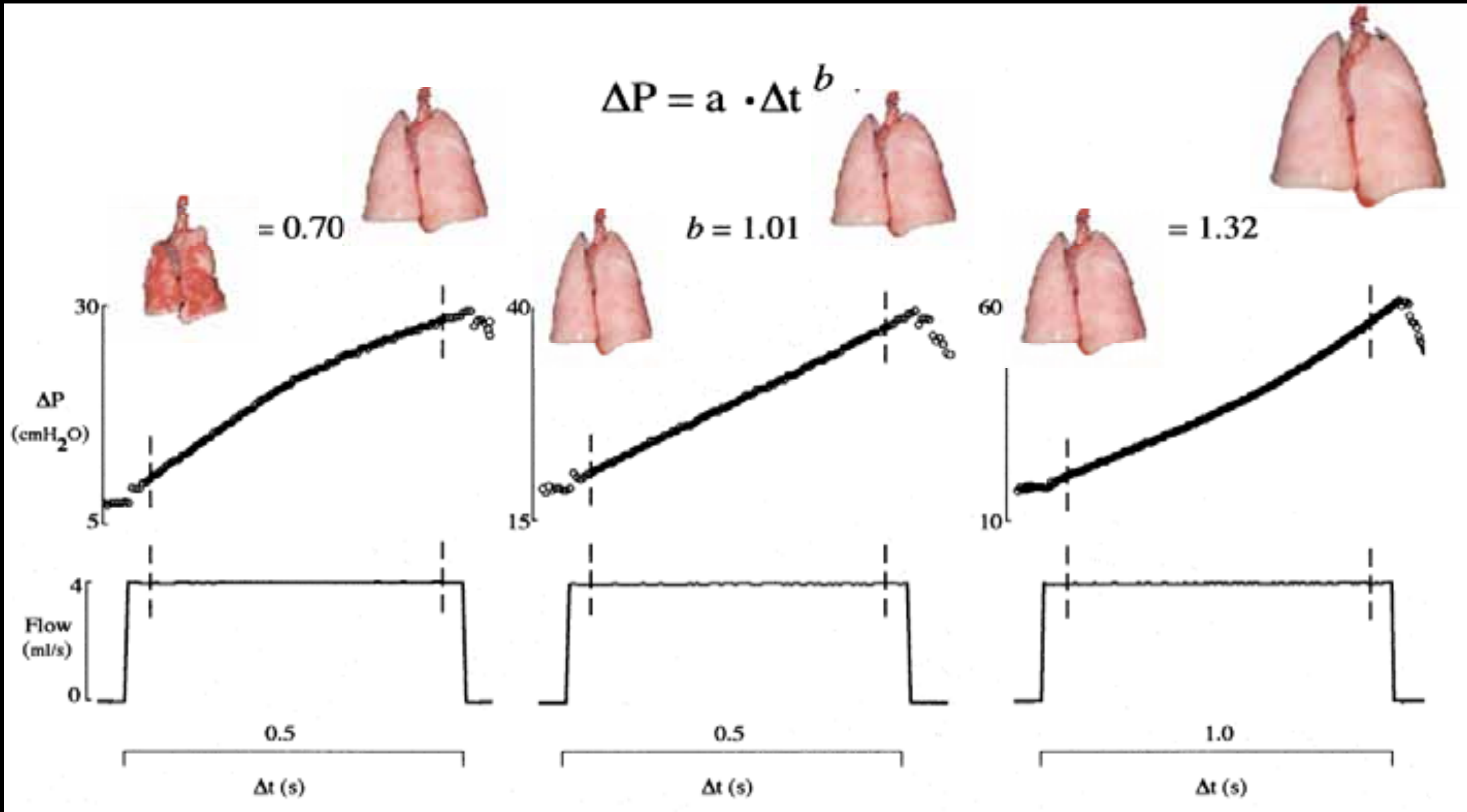
Elastance to titrate PEEP in ALI/ARDS

Carvalho AR, Pelosi P et al. Intensive Care Med. 2008 Dec;34(12):2291-9



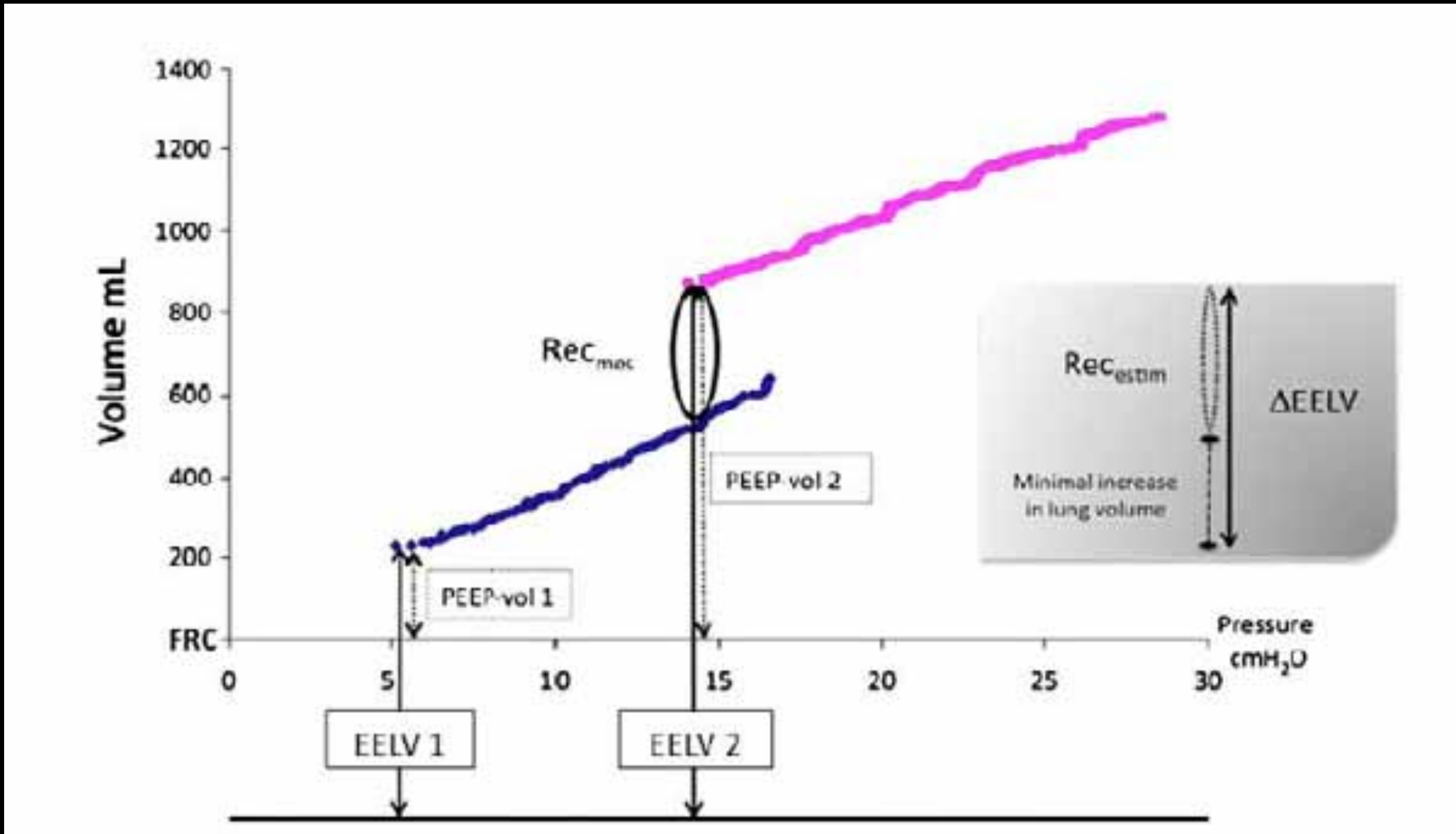
The stress index: is it useful to set TV ?

Fanelli V et al Crit Care Med. 2009 Mar;37(3):1046-53.
Grasso S et al Crit Care Med. 2004 Apr;32(4):1018-27
Ranieri VM et al. Am J Respir Crit Care Med. 1994 Jan;149(1):19-27



PEEP-induced changes in lung volume in ARDS. Two methods to estimate alveolar recruitment

Dellamonica J et al Intensive Care Med (2011) 37:1595–1604



Probes

Curvilinear probe

Probe 5-10 MHz Lung periphery

Probe 4-5 MHz Deep Lung

Image quality 1 to 17 cm

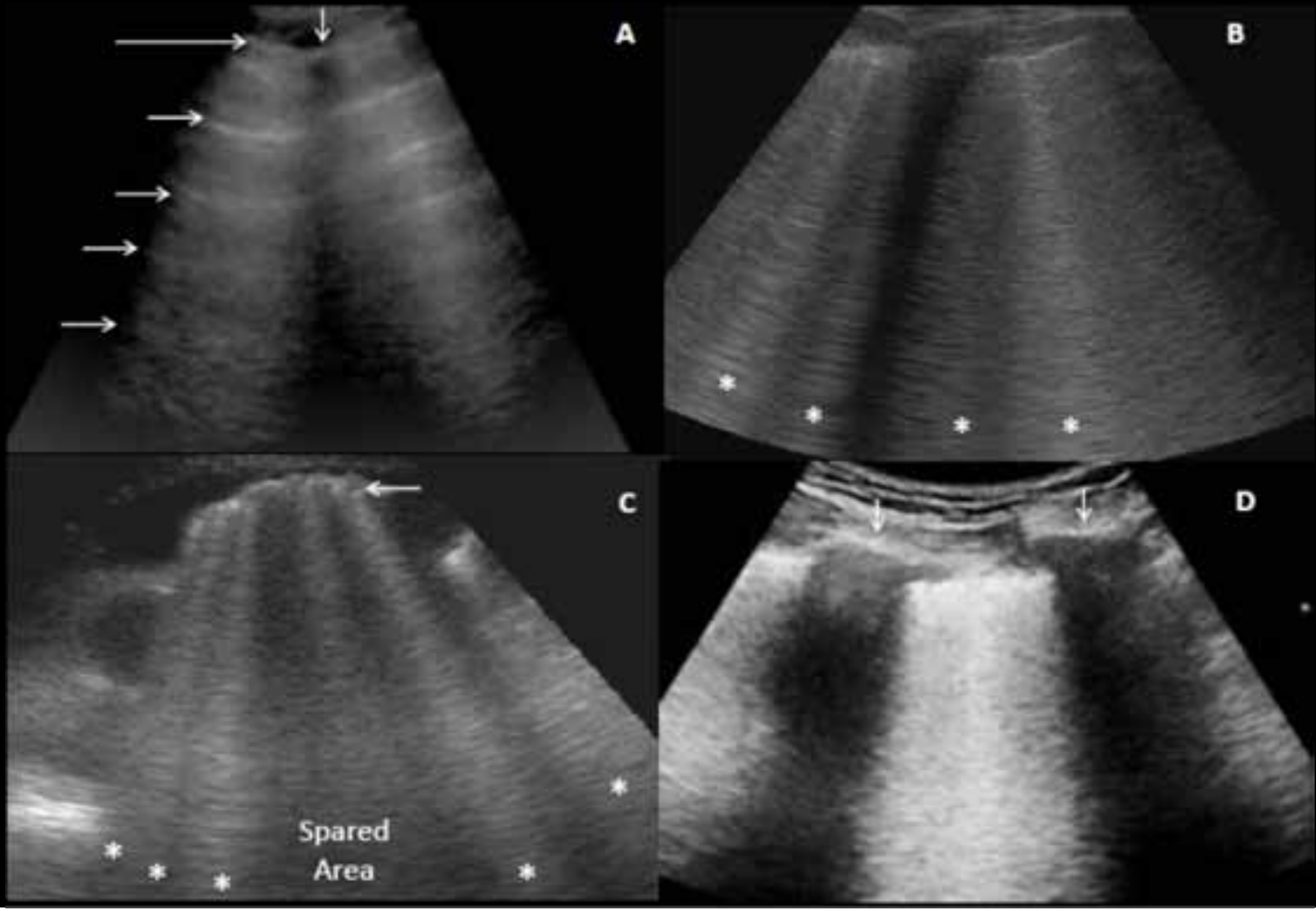
Phased array probe 3 MHz
Hemodynamic monitoring

Linear probe 7.5 MHz
vascular application

Convex probe 3.5 MHz
Lung and hemodynamic applications

Lung imaging for titration of mechanical ventilation
The role of lung ultrasound

Luecke T, Corradi F, Pelosi P Curr Opinion in Anaesthesiology, 2011 (Ahead of Print)



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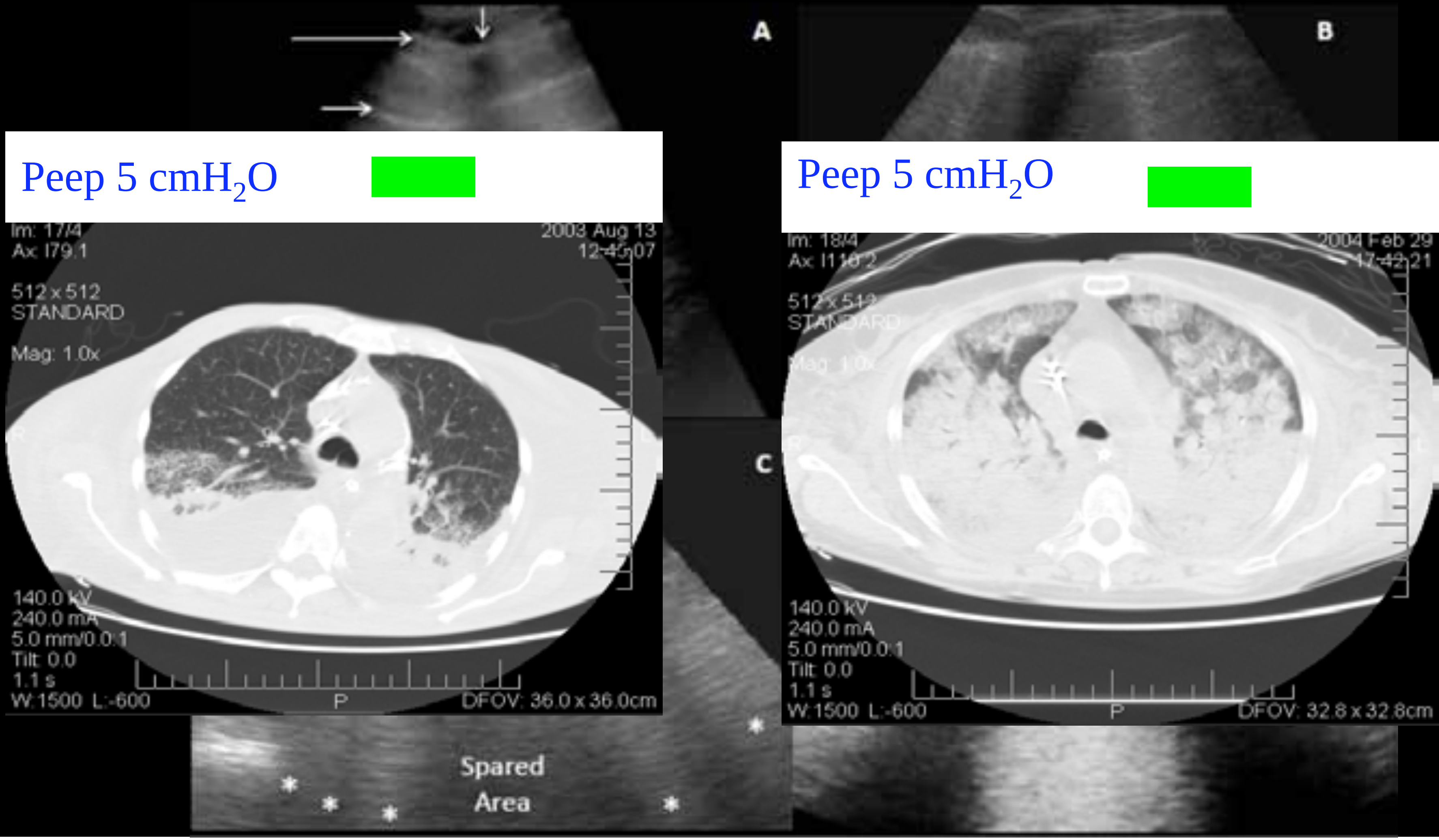
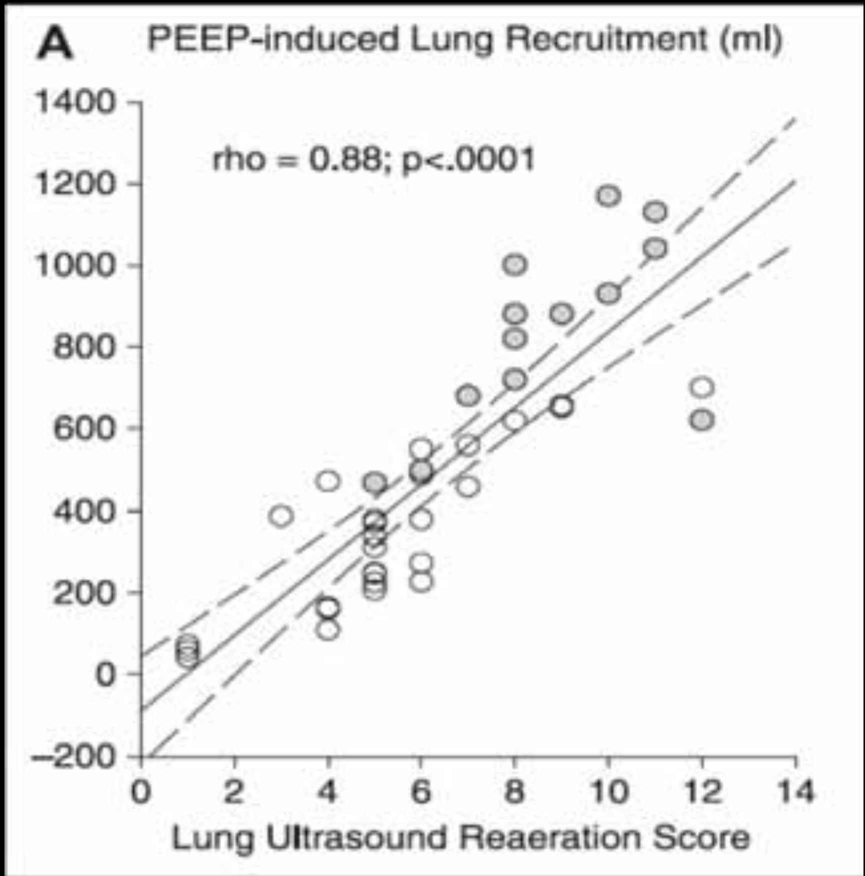
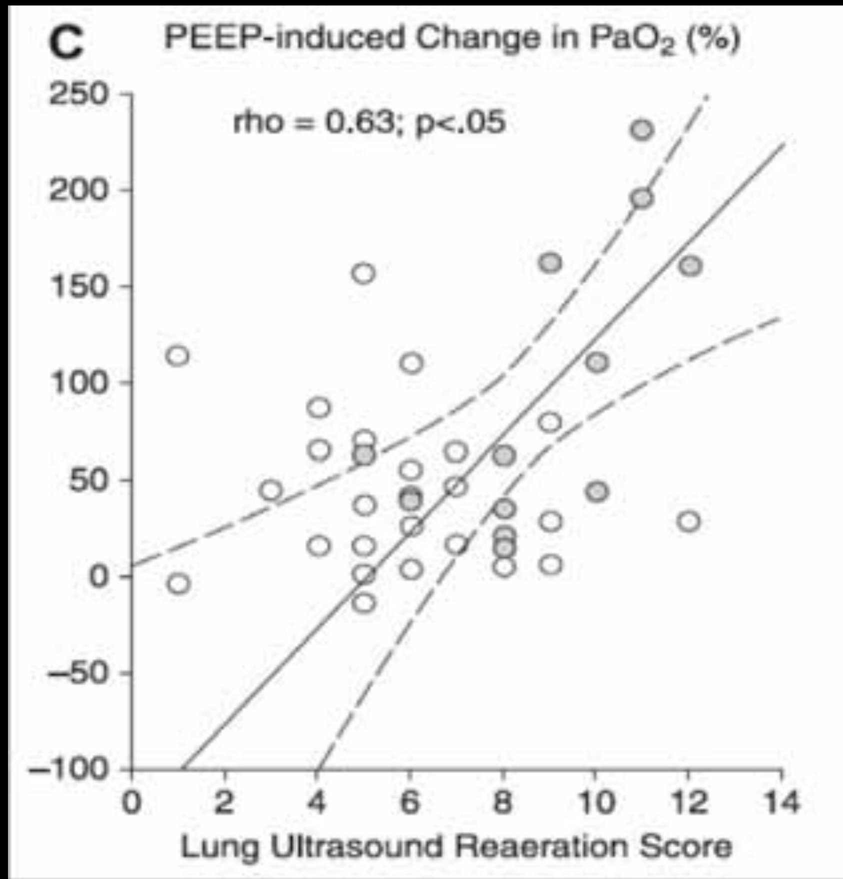


Bedside Ultrasound Assessment of PEEP–induced Lung Recruitment

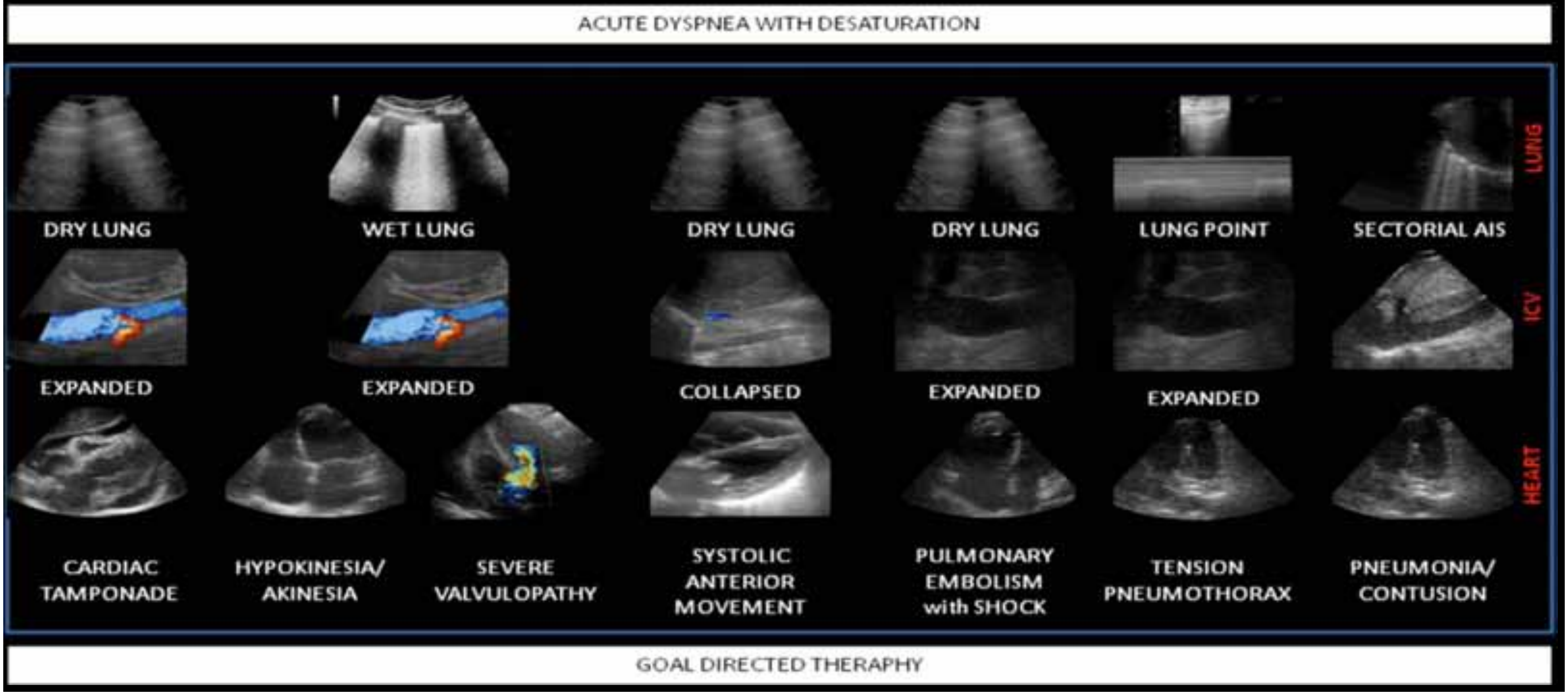
Bouhemad B et al. Am J Respir Crit Care Med 183: 341–347, 2011





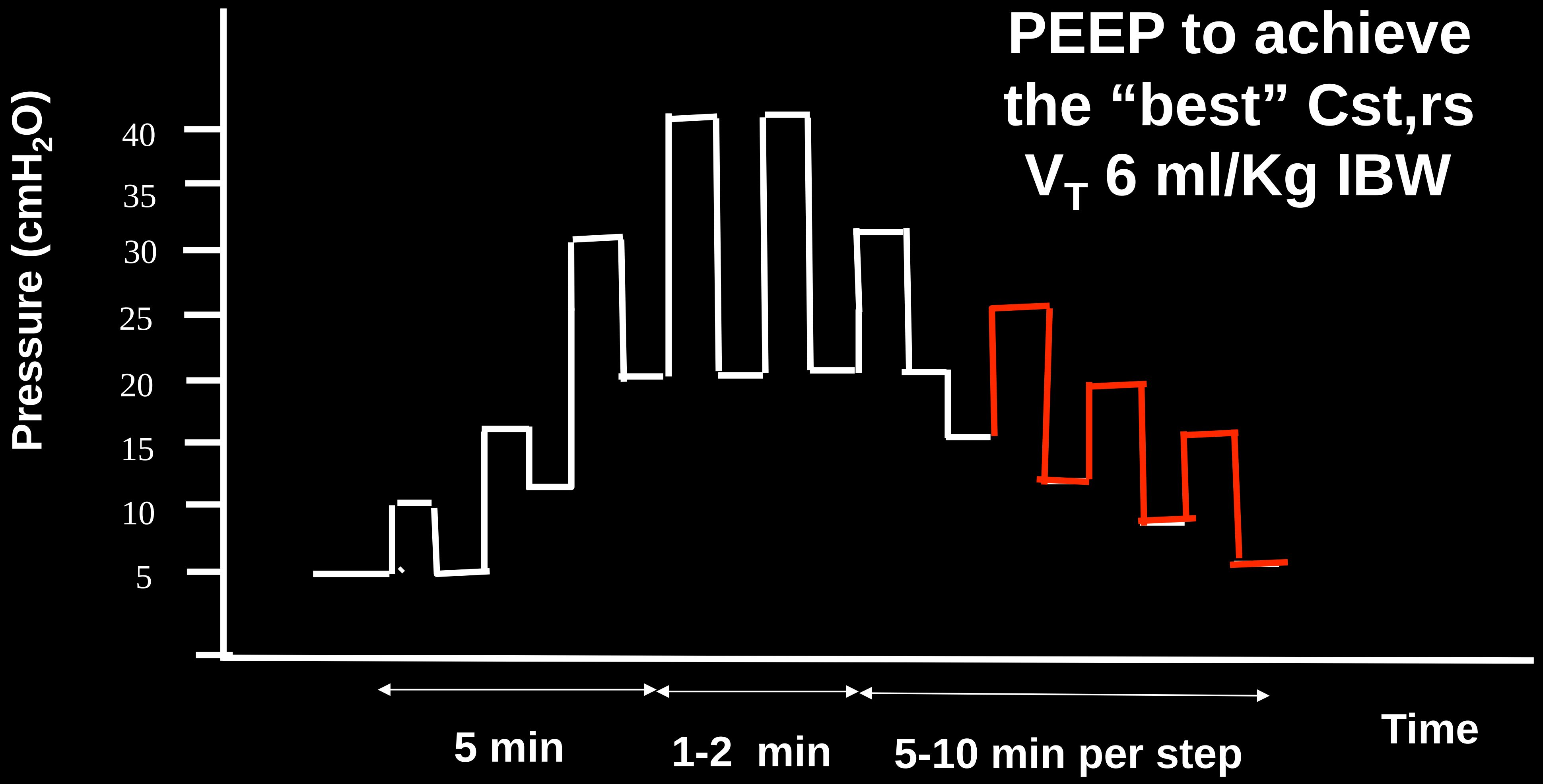
LUNG ULTRASOUND PROTOCOL

Pelosi P, Corradi F
Anesthesiology 2012 (Ahead of Print)



How to perform a PEEP trial in most severe ARDS patients ?

Pelosi P, Abreu GM, Rocco PR Crit Care 2010; 14(2):210.



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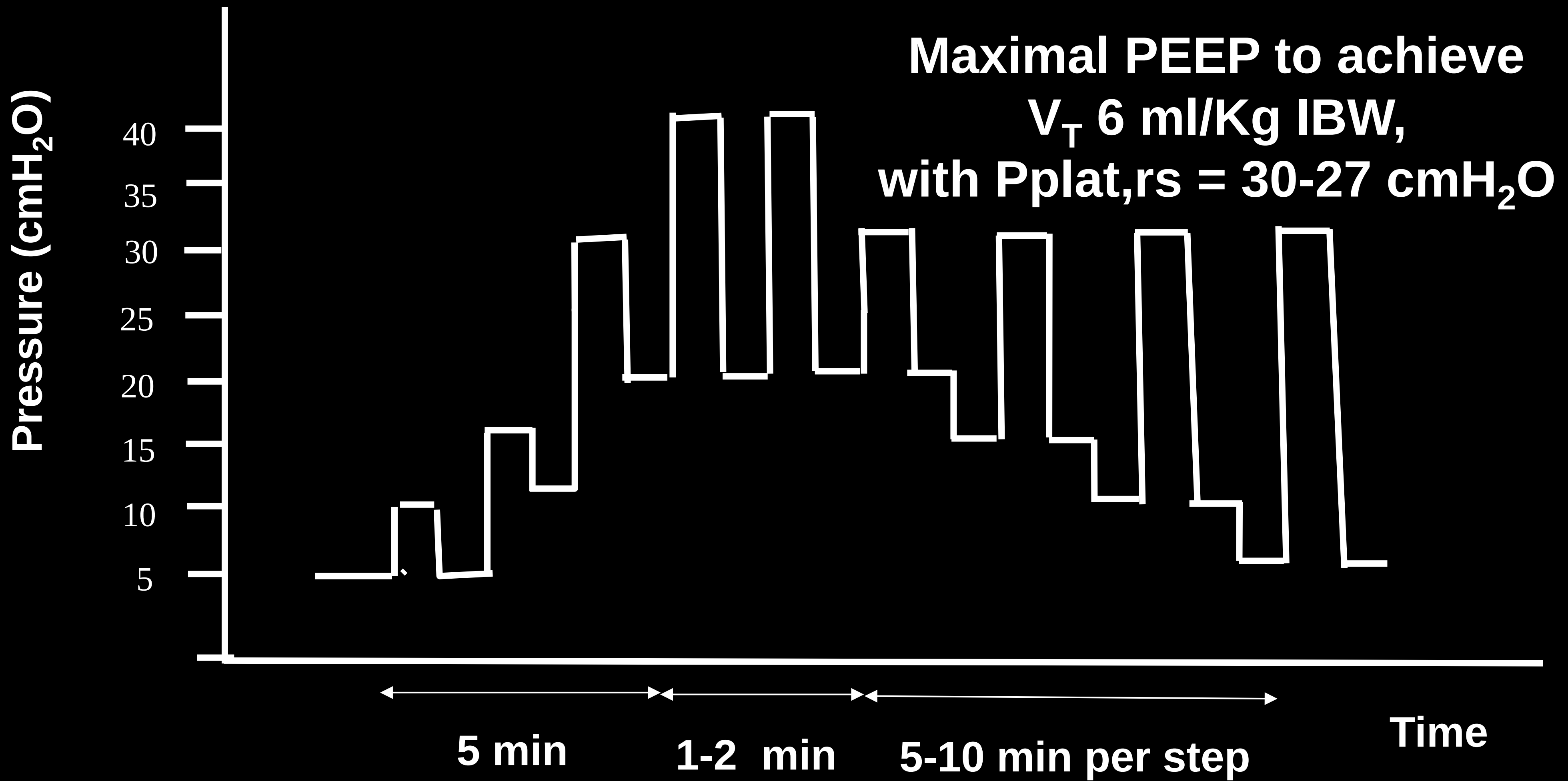

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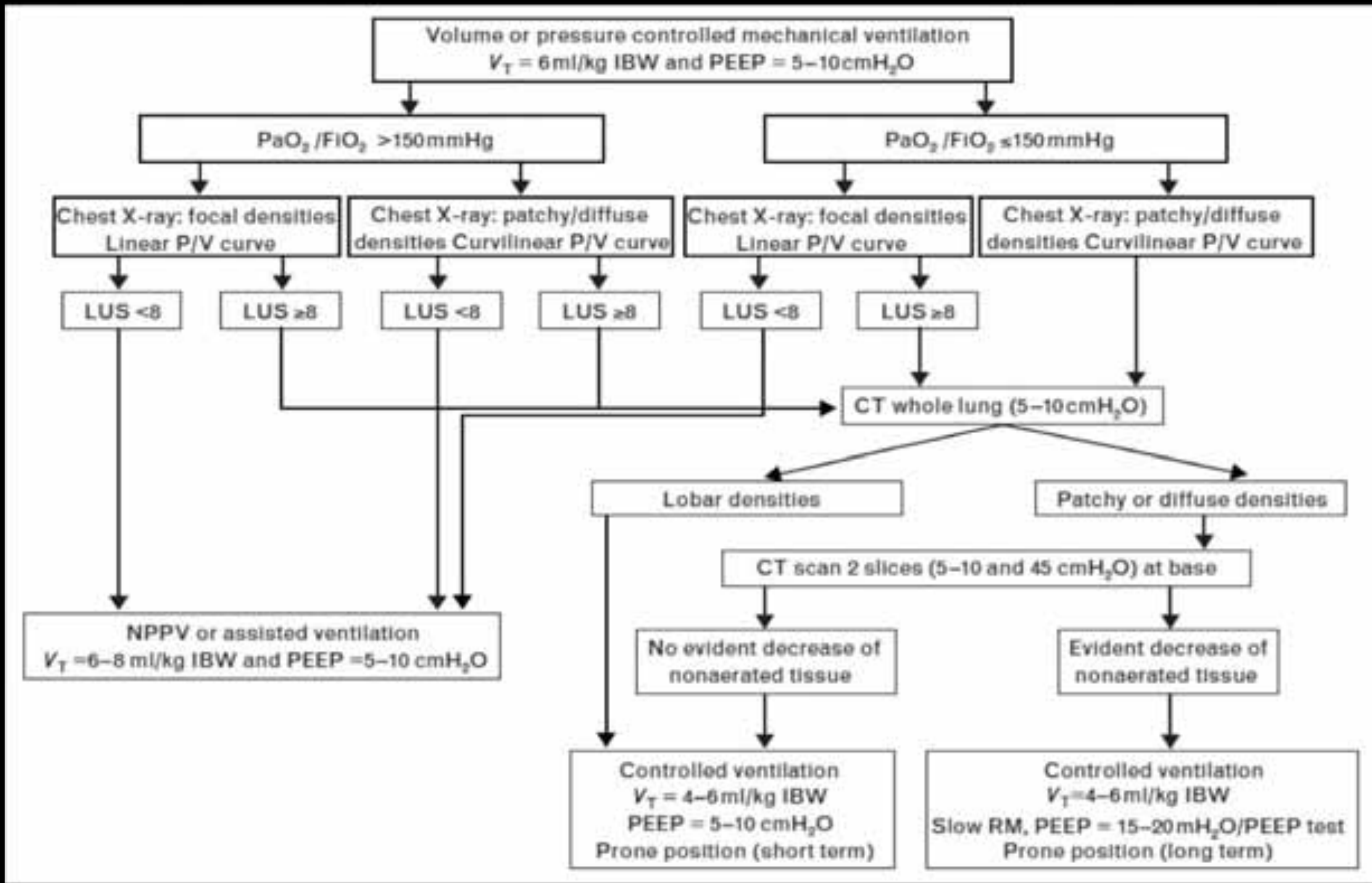
Use of computed tomography scanning to guide lung recruitment and adjust PEEP in ALI/ARDS

Pelosi P. et al. Curr Opin Crit Care. 2011 Jun;17(3):268-74



Thanks

Royal Library, British Museum, London, UK