FACULTAD DE MEDICINA

PONTIFICIA UNIVERSIDAD
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Escuela de Medicina

SDRA y maniobras de reclutamiento

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Objetivos

1. Conocer algunas generalidades del SDRA
2. Describir las alteraciones mecánicas de los pulmones afectados por SDRA
3. Entender los efectos fisiológicos de las maniobras de reclutamiento

1. Generalidades en SDRA

SDRA definición

Acute Respiratory Distress Syndrome
The Berlin Definition

The panel agreed that ARDS is a type of **acute diffuse**, **inflammatory** lung injury, leading to increased pulmonary **vascular permeability**, increased lung weight, **and loss of aerated lung tissue**.

The clinical hallmarks are **hypoxemia** and bilateral radiographic opacities, associated with **increased venous admixture** increased physiological **dead space**, and **decreased lung compliance**.

The morphological hallmark of the acute phase is **diffuse alveolar damage** (ie, edema, inflammation, hyaline membrane, or hemorrhage).

The Berlin definition, JAMA 2012

SDRA definición

Table 3. The Berlin Definition of Acute Respiratory Distress Syndrome

	Acute Respiratory Distress Syndrome
Timing	Within 1 week of a known clinical insult or new or worsening respiratory symptoms
Chest imaging[a]	Bilateral opacities—not fully explained by effusions, lobar/lung collapse, or nodules
Origin of edema	Respiratory failure not fully explained by cardiac failure or fluid overload Need objective assessment (eg, echocardiography) to exclude hydrostatic edema if no risk factor present
Oxygenation[b]	
Mild	200 mm Hg $<$ Pa_{O_2}/F_{IO_2} $\leq$ 300 mm Hg with PEEP or CPAP $\geq$5 cm H_2O[c]
Moderate	100 mm Hg $<$ Pa_{O_2}/F_{IO_2} $\leq$ 200 mm Hg with PEEP $\geq$5 cm H_2O
Severe	Pa_{O_2}/F_{IO_2} $\leq$ 100 mm Hg with PEEP $\geq$5 cm H_2O

The Berlin definition, JAMA 2012

SDRA causas

TABLE 2. CLINICAL DISORDERS ASSOCIATED WITH THE DEVELOPMENT OF THE ACUTE RESPIRATORY DISTRESS SYNDROME.

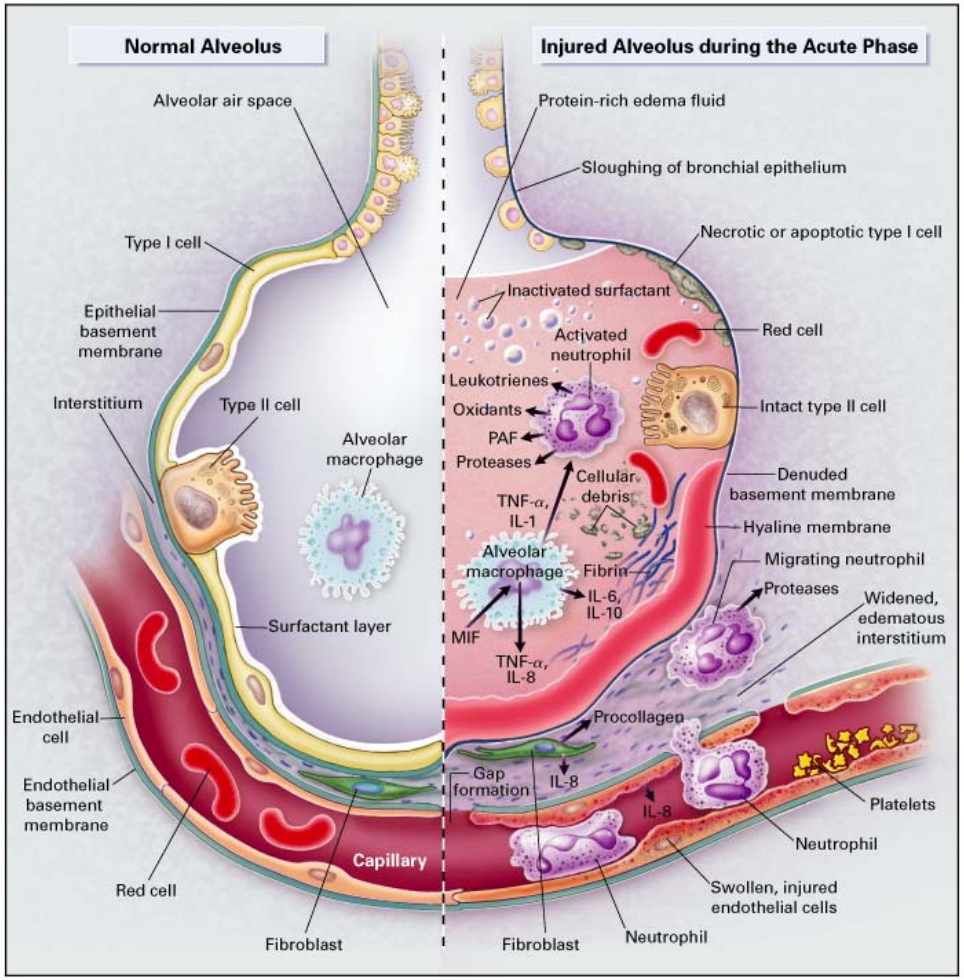
DIRECT LUNG INJURY	INDIRECT LUNG INJURY
Common causes	**Common causes**
Pneumonia	Sepsis
Aspiration of gastric contents	Severe trauma with shock and multiple transfusions
Less common causes	**Less common causes**
Pulmonary contusion	Cardiopulmonary bypass
Fat emboli	Drug overdose
Near-drowning	Acute pancreatitis
Inhalational injury	Transfusions of blood products
Reperfusion pulmonary edema after lung transplantation or pulmonary embolectomy	

Prevalencia 2016: 10% pacientes UCI

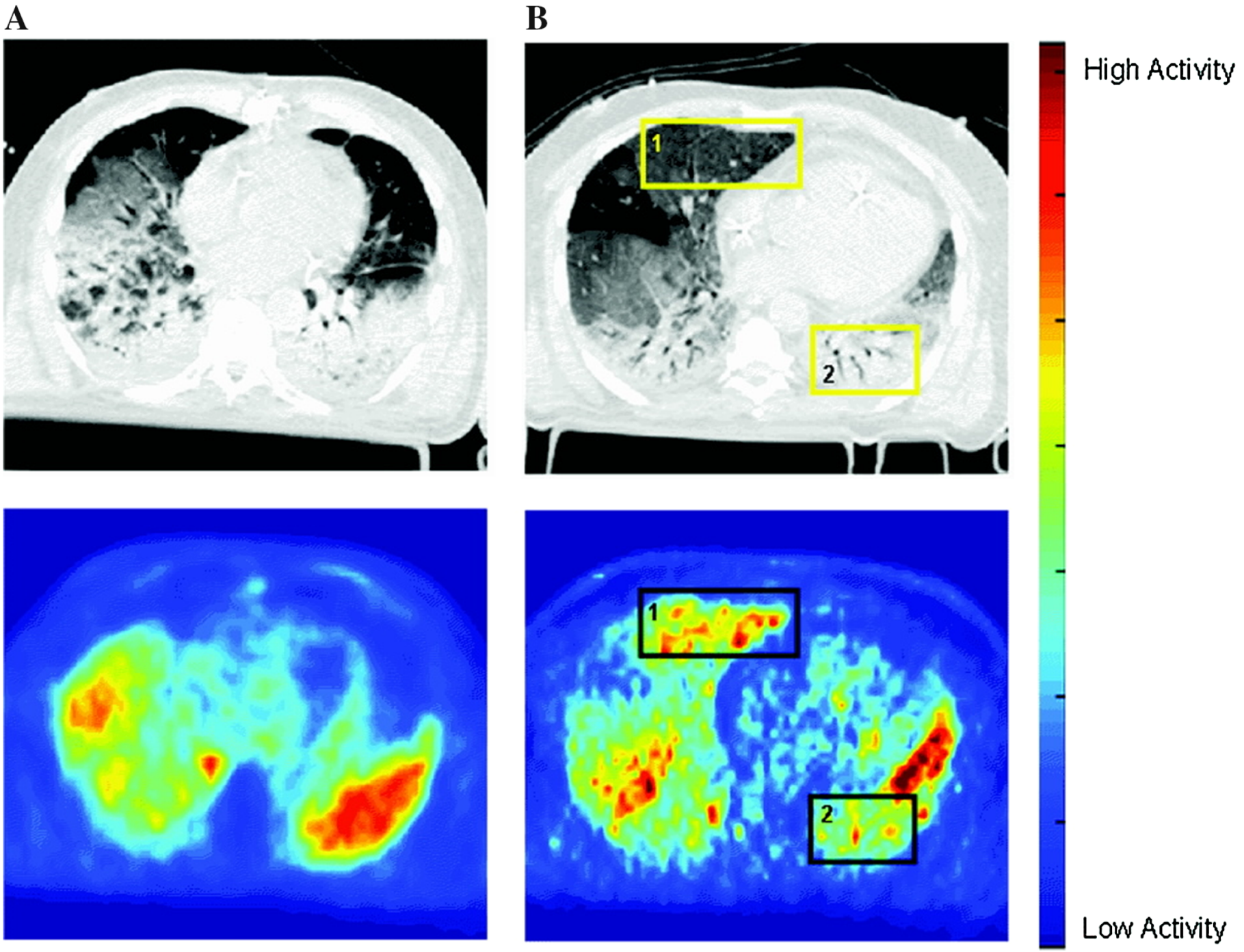
Ware L, NEJM 2000

Bellani G, JAMA 2016

SDRA fisiopatología



Ware L, NEJM 2000


A
B
1
2
1
2
High Activity
Low Activity

Inflamación SDRA - VILI

- Activación de la respuesta inflamatoria innata

PAMPs

DAMPs

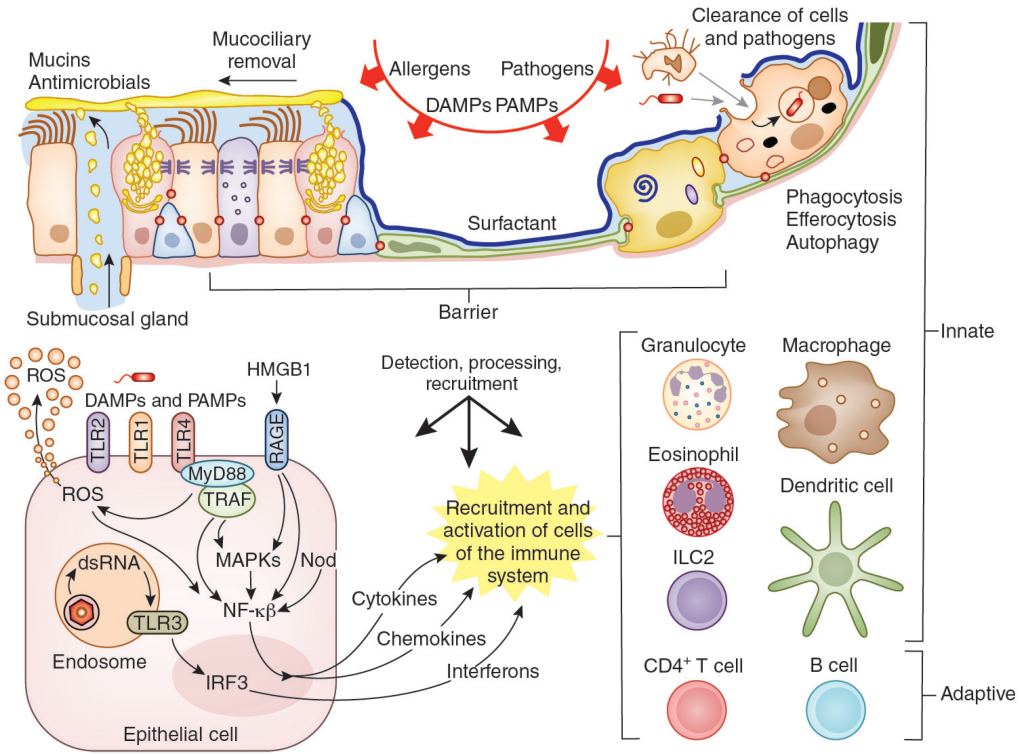
PRRs

↓

Epitelio y macrófagos

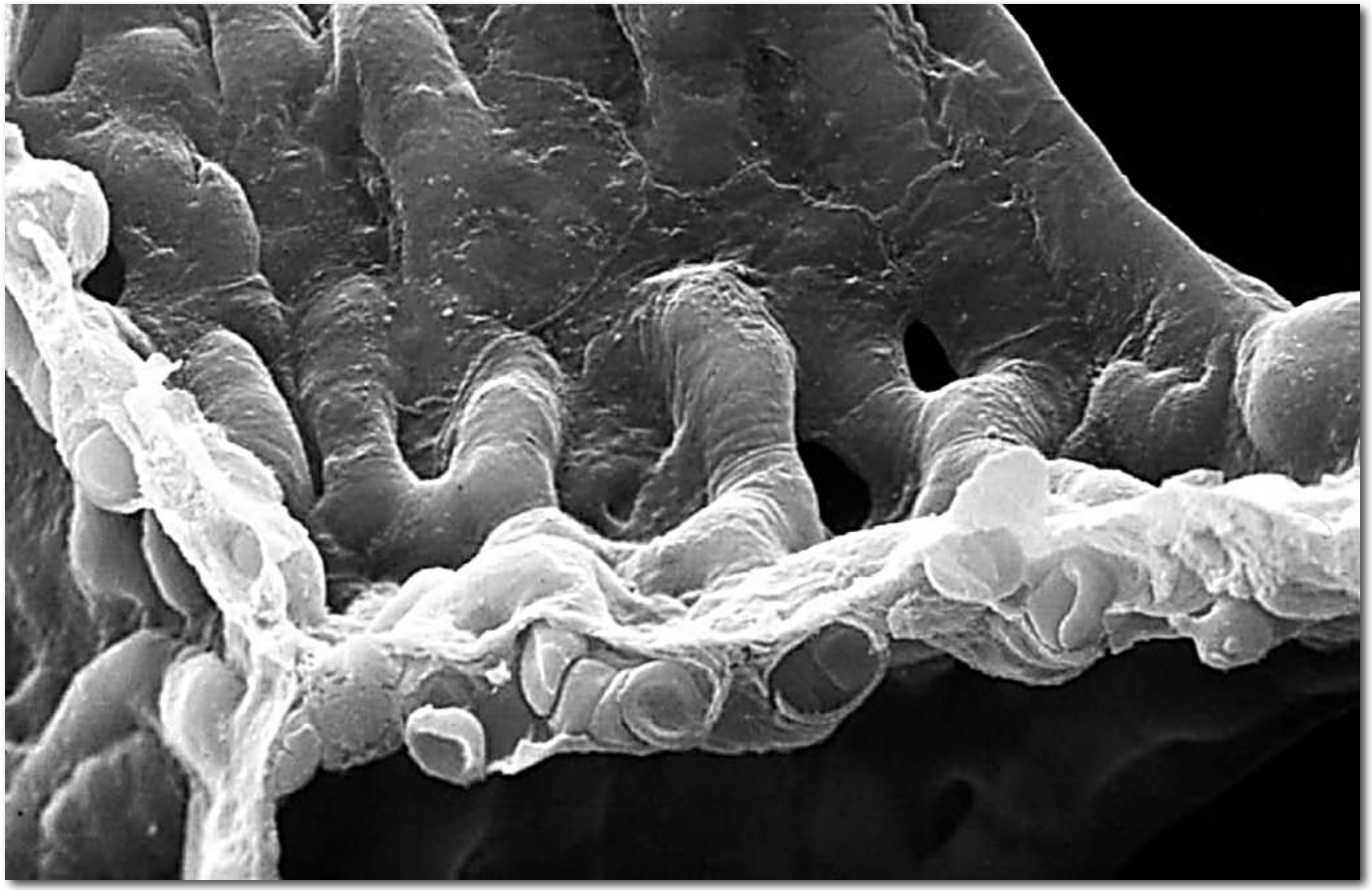
↓

Neutrófilos



Whitsett J, Nature Immunology 2015

SDRA fisiopatología



EUROPEAN
LUNG FOUNDATION

http://www.european-lung-foundation.org/

SDRA outcomes

Table 5. Outcome of Invasively Ventilated Patients by Acute Respiratory Distress Syndrome Severity at Diagnosis

Parameter	All (n = 2377)	Mild (n = 714)	Moderate (n = 1106)	Severe (n = 557)	*P* Value[a]
Duration of invasive ventilation, median (IQR), d					
All patients	8 (4-15)	7 (3-14)	8 (4-16)	9 (4-16)	.04
Surviving patients	8 (4-15)	6 (3-13)	8 (4-15)	11 (6-18)	<.001
ICU length of stay, median (IQR), d					
All patients	10 (5-20)	10 (5-19)	11 (6-20)	11 (5-19)	.39
Surviving patients	11 (7-21)	10 (6-19)	12 (7-21)	14 (7-23)	.03
ICU mortality, No. (%) [95% CI]	838 (35.3) [33.3-37.2]	29.7%	35%	23 [38	42.9% 001
Day 28 mortality, No. (%) [95% CI]	828 (34.8) [32.9-36.8]	[26.2-33.0]	[32.4-38.1]	22 [36.8-45.1]	.001
Hospital length of stay, median (IQR), d					
All patients	17 (8-33)	18 (10-33)	17 (8-33)	16 (6-31)	.22
Surviving patients	23 (14-40)	23 (14-40)	22 (13-40)	26 (14-43)	.41
Hospital mortality, No. (%) [(95% CI]	952 (40.0) [38.1-42.1]	249 (34.9) [31.4-38.5]	446 (40.3) [37.4-43.3]	257 (46.1) [41.9-50.4]	<.001

Bellani G. and cols , JAMA 2016

SDRA outcomes

Table 2. Recovery of Pulmonary Function among Patients with the Acute Respiratory Distress Syndrome during the First 12 Months after Discharge from the ICU.

Variable	3 Mo (N=71)*	6 Mo (N=77)†	12 Mo (N=80)‡
	median (interquartile range)		
Forced vital capacity (% of predicted)	72 (57–86)	80 (68–94)	85 (71–98)
Forced expiratory volume in one second (% of predicted)	75 (58–92)	85 (69–98)	86 (74–100)
Total lung capacity (% of predicted)§	92 (77–97)	92 (83–101)	95 (81–103)
Residual volume (% of predicted)§	107 (87–121)	97 (82–117)	105 (90–116)
Carbon monoxide diffusion capacity (% of predicted)§¶	63 (54–77)	70 (58–82)‖	72 (61–86)

Herridge M, NEJM 2003

SDRA outcomes

Table 3. Ability to Exercise and Return to Work and Health-Related Quality of Life among Patients with the Acute Respiratory Distress Syndrome during the First 12 Months after Discharge from the ICU.

Outcome	3 Months	6 Months	12 Months
Distance walked in 6 min			
No. evaluated	80*	78†	81‡
Median — m	281	396	422
Interquartile range — m	55–454	244–500	277–510
Percentage of predicted value§	49	64	66
Returned to work — no./total no. (%)¶	13/83 (16)	26/82 (32)	40/82 (49)‖

Herridge M, NEJM 2003

SDRA outcomes

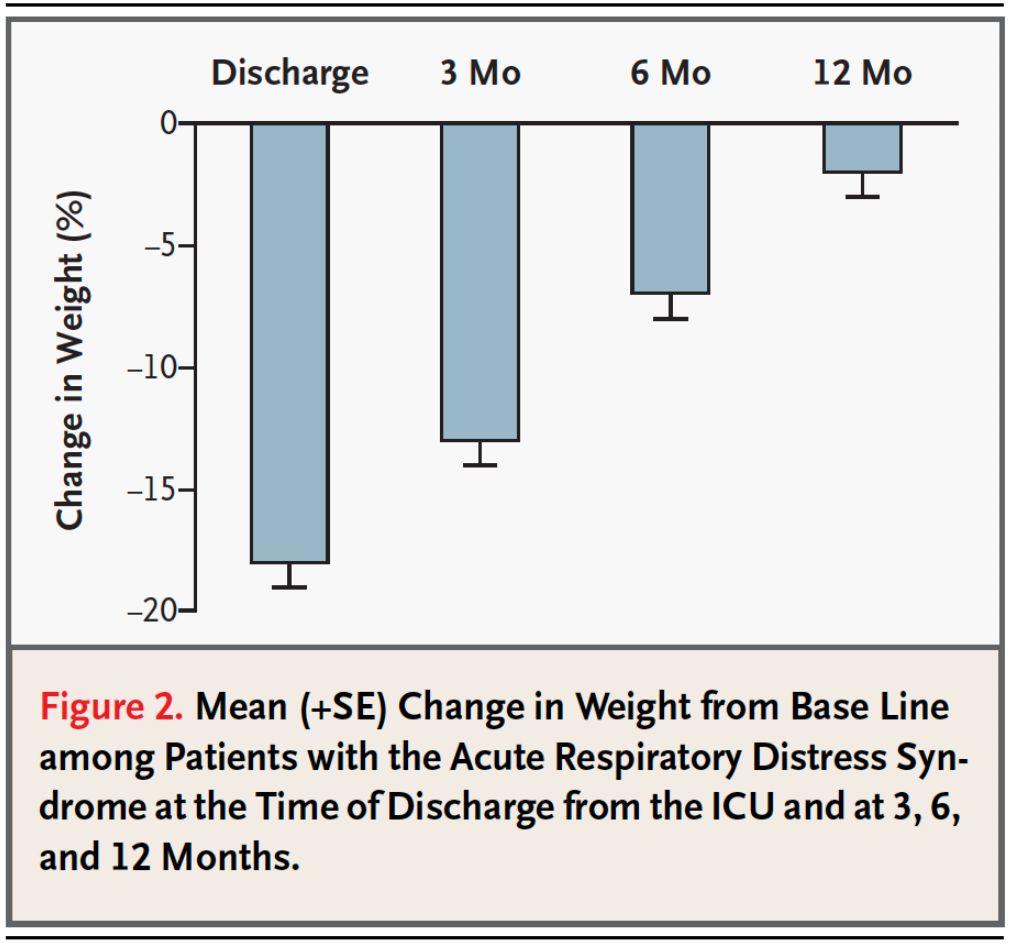


Figure 2. Mean (+SE) Change in Weight from Base Line among Patients with the Acute Respiratory Distress Syndrome at the Time of Discharge from the ICU and at 3, 6, and 12 Months.

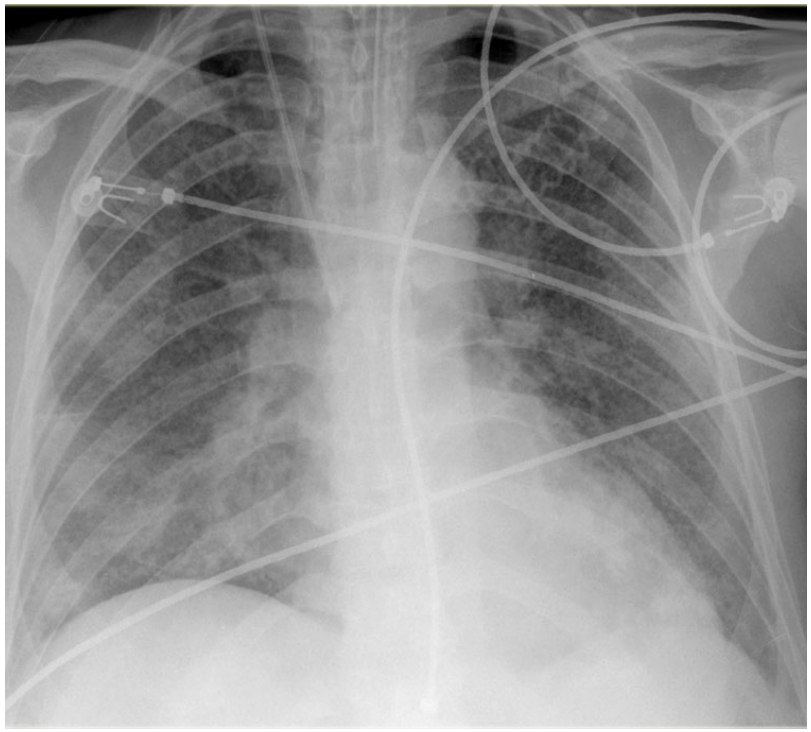
Herridge M, NEJM 2003

Recapitulando

- SDRA
  - Prevalencia 10%
  - Mortalidad 35-40%
  - Morbilidad a mediano plazo

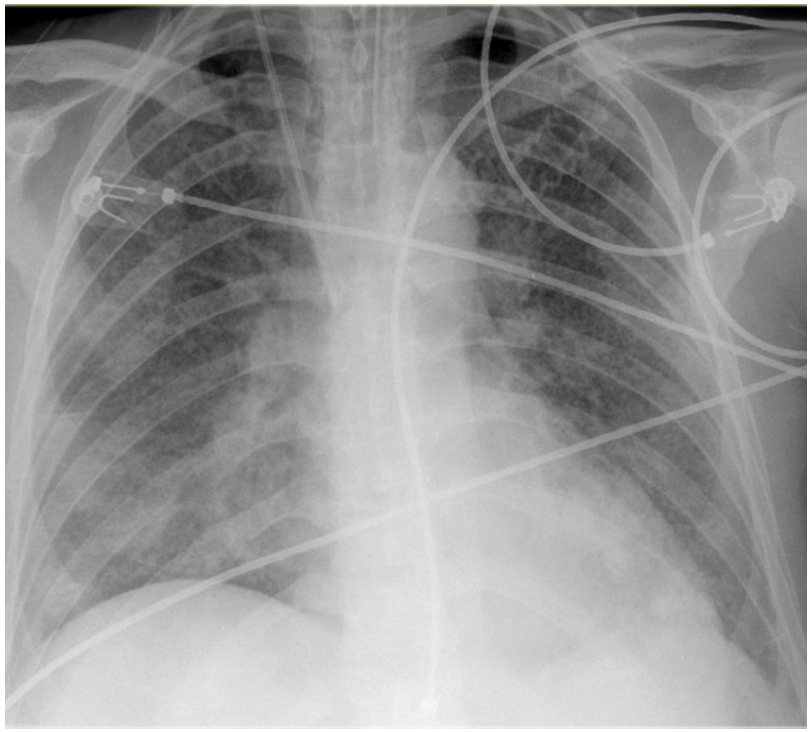
2. Alteraciones Mecánicas en SDRA

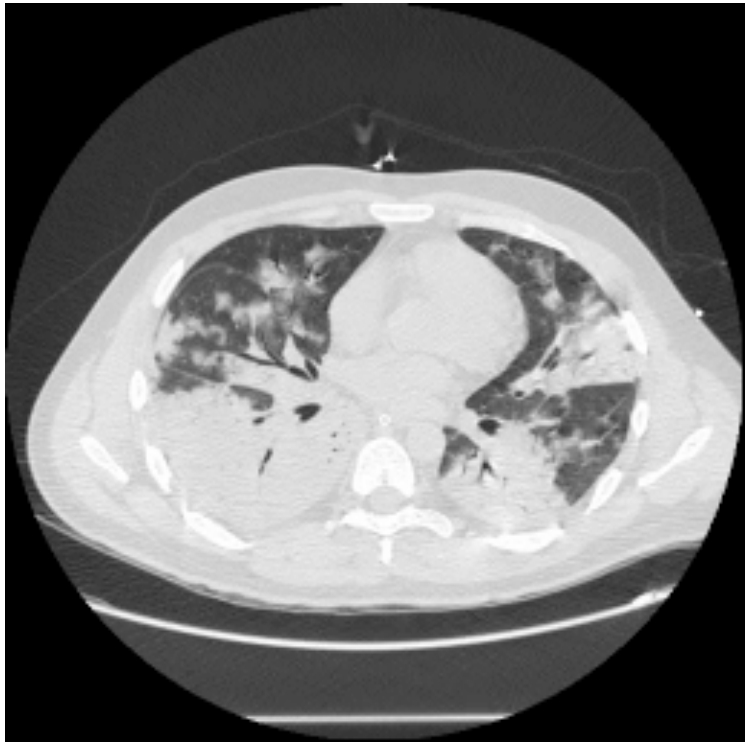
Desede los años 70 a los 90…



….Los pulmones distresados eran considerados homogéneamente rígidos y pesados.

Desede los años 70 a los 90…



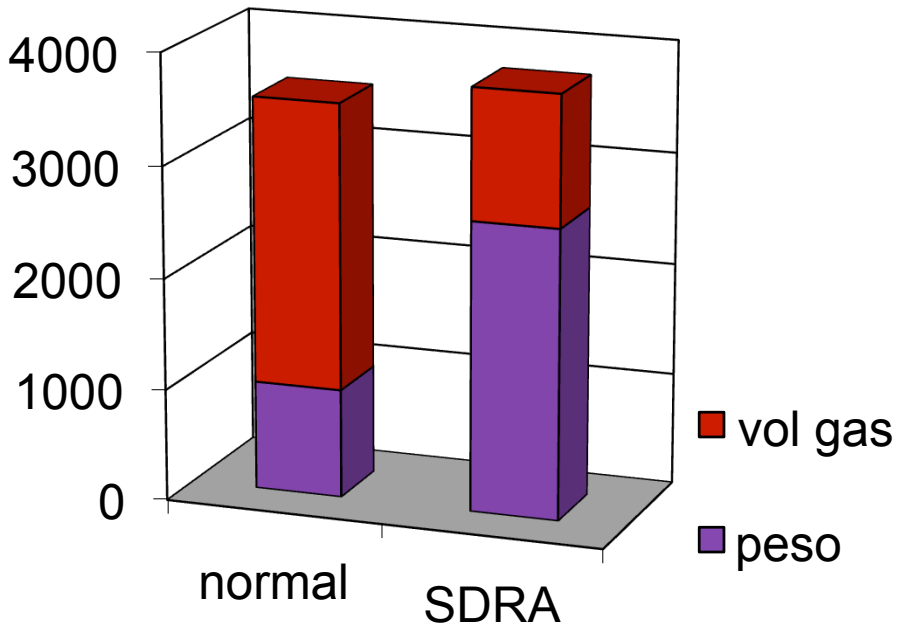


Baby lung

Normaly aerated tissue
367±262 ml (ARDS Difuso)

Equivalente a 13% de voluntarios sanos

Equivalente a niño de 5 a 6 años



Puybasset L, ICM 2000
Gattinoni, Intensive Crit Care Med 1987

Acute Respiratory Distress Syndrome
The Berlin Definition

Table 5. Predictive Validity of ARDS Definitions in the Physiologic Database

	Modified AECC Definition[a]		Berlin Definition ARDS[a]		
	ALI Non-ARDS	ARDS	Mild	Moderate	Severe
No. (%) [95% CI] of patients	66 (25) [19-30]	203 (75) [70-80]	66 (25) [20-30]	161 (59) [54-66]	42 (16) [11-21]
Mortality, No. (%) [95% CI][b]	13 (20) [11-31]	84 (43) [36-50]	13 (20) [11-31]	62 (41) [33-49]	22 (52) [36-68]
Ventilator-free days Median (IQR)	8.5 (0-23.5)	0 (0-16.0)	8.5 (0-23.5)	0 (0-16.5)	0 (0-6.5)
Missing, No.	10	26	10	25	1
Duration of mechanical ventilation in survivors, median (IQR), d	6.0 (3.3-20.8)	13.0 (5.0-25.5)	6.0 (3.3-20.8)	12.0 (5.0-19.3)	19.0 (9.0-48.0)
Lung weight, mg[c] Mean (SD)	1371 (360.4)	1602 (508.1)	371 (360.4)	1556 (469.7)	1828 (630.2)
Missing, No.	16	48	16	32	16
Shunt, mean (SD), %[c,d]	21 (21)	32 (13)	21 (12)	29 (11)	40 (16)

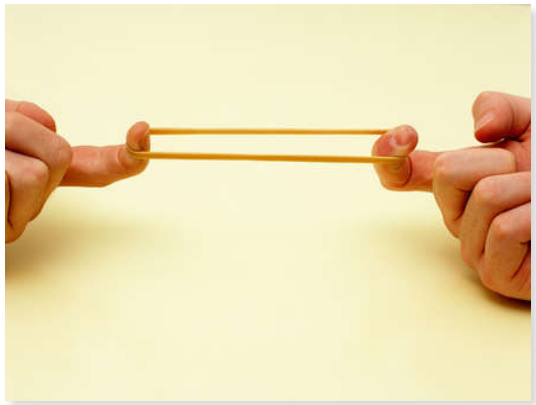
mortalidad ***27%*** ***32%*** ***45%***

peso pulmonar (g) ***1370*** ***1560*** ***1830***

efinition Task Force. JAMA 2012;307(23): 2526-2533

Baby lung y Strain

$$strain = \Delta L / L_0$$



$$strain = Vt / EELV$$
$$strain = Vt / FRC$$

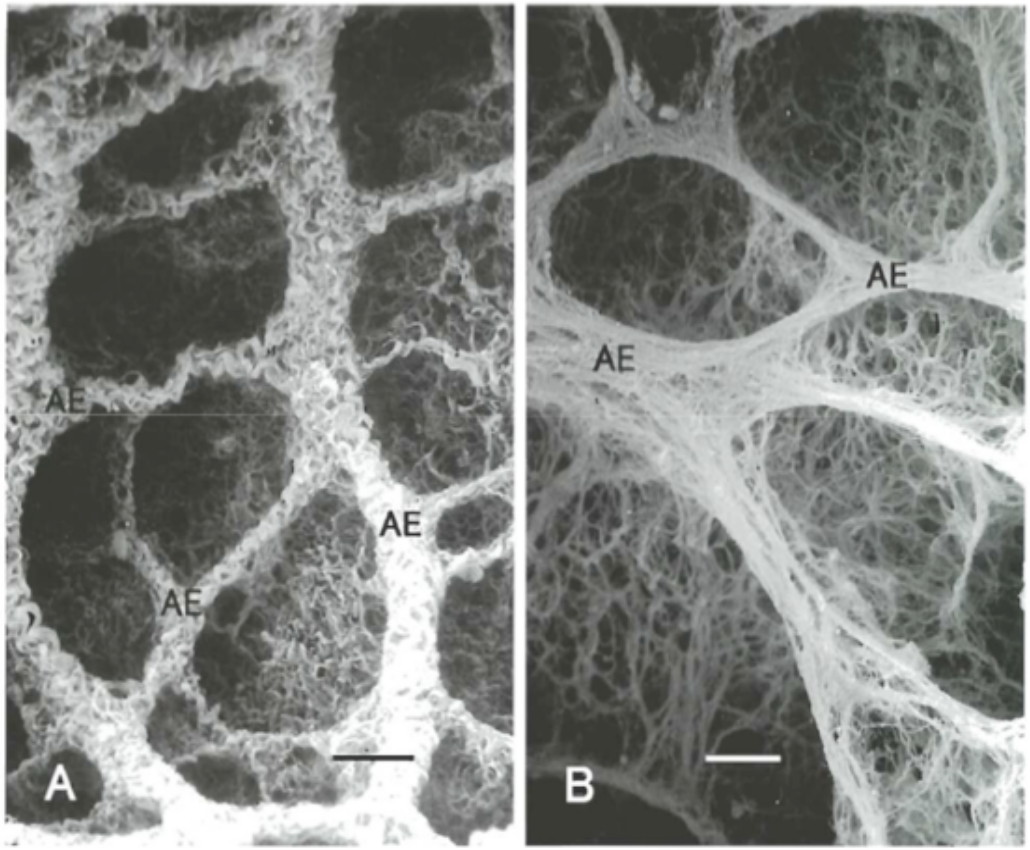
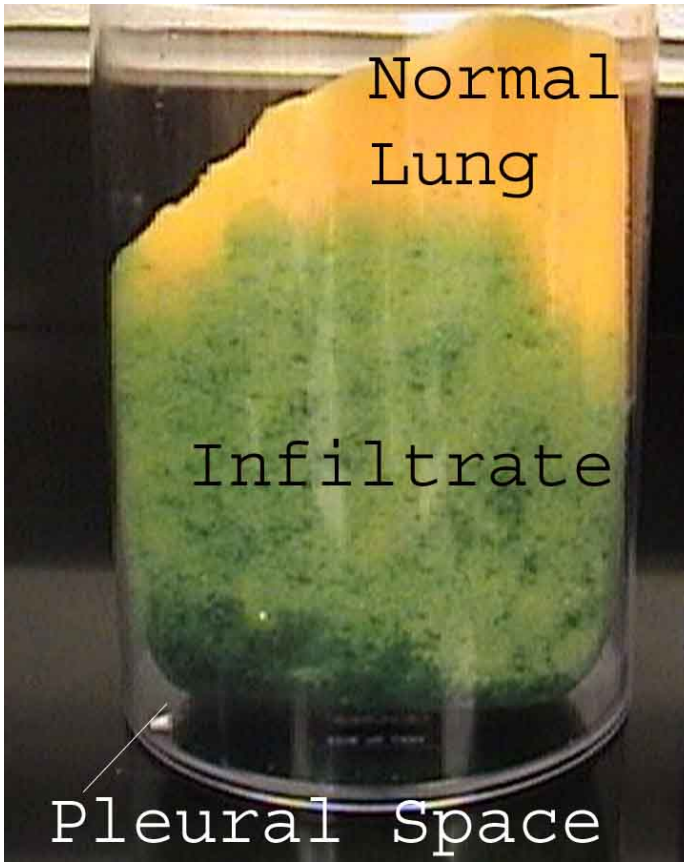
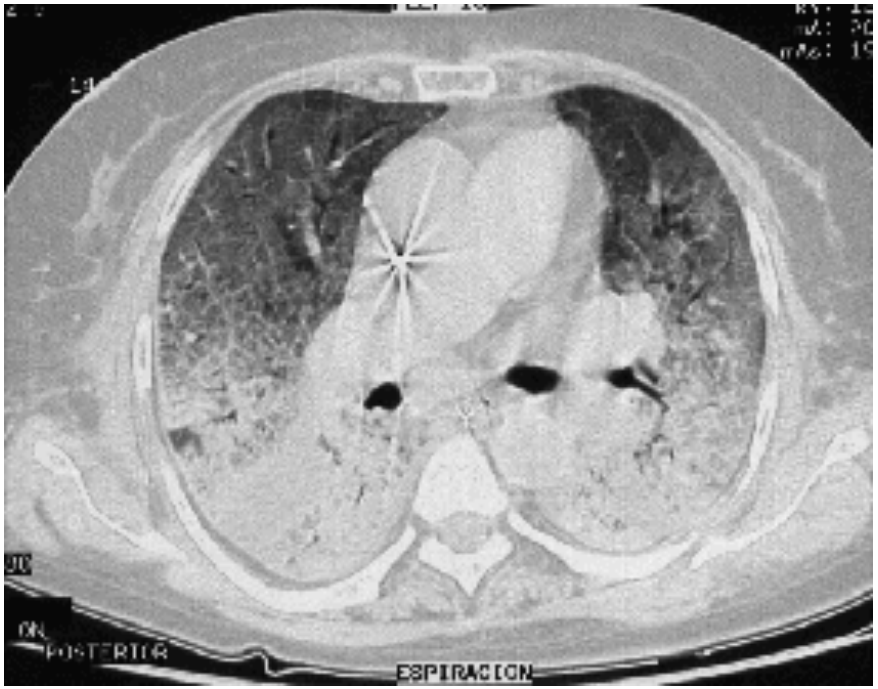


Fig. 4. Scanning electron micrographs of collagen fiber networks in rat lung. Collagen fibers at the alveolar entrances (AE) in the collapsed lung (**A**) take zigzag or helical courses, while those in the inflated lung (**B**) are straight. Scale bar = 100 μm

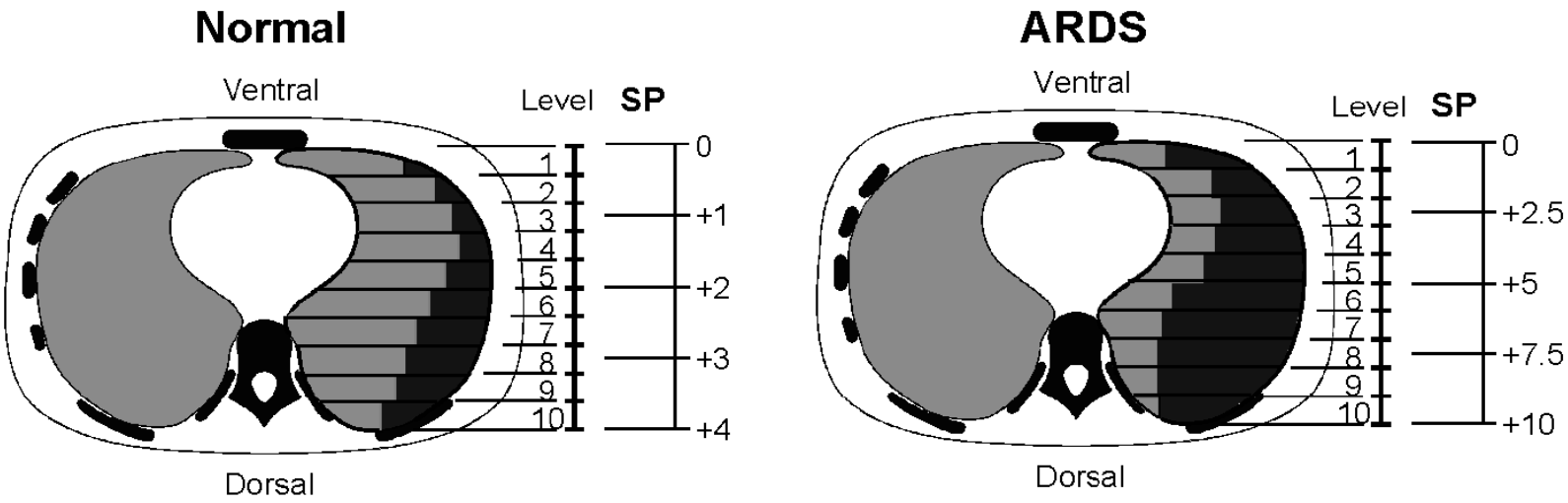
Toshima M, et al. Arch Histol Cytol 2004

Pulmón de esponja



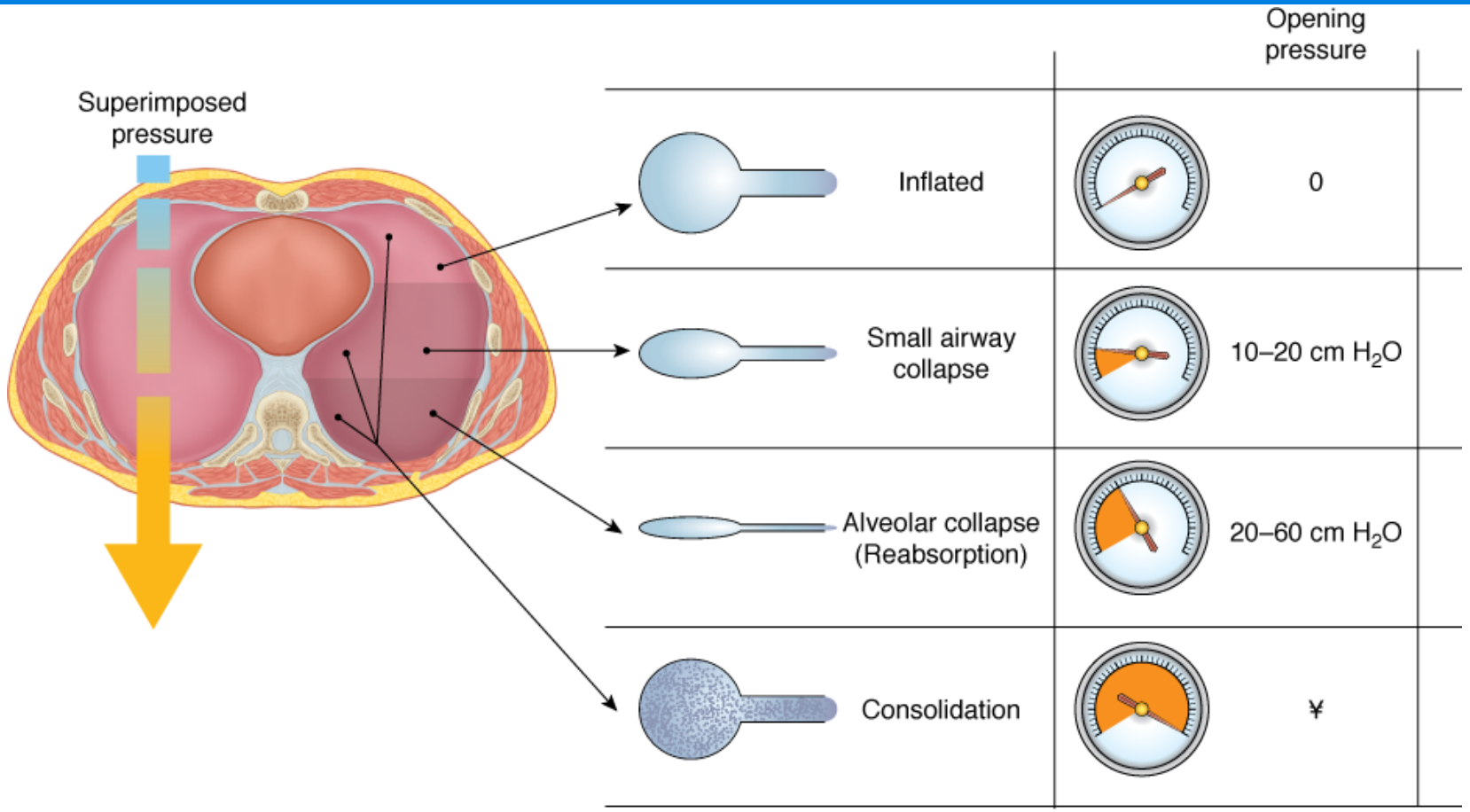


Gradiente superimpuesta



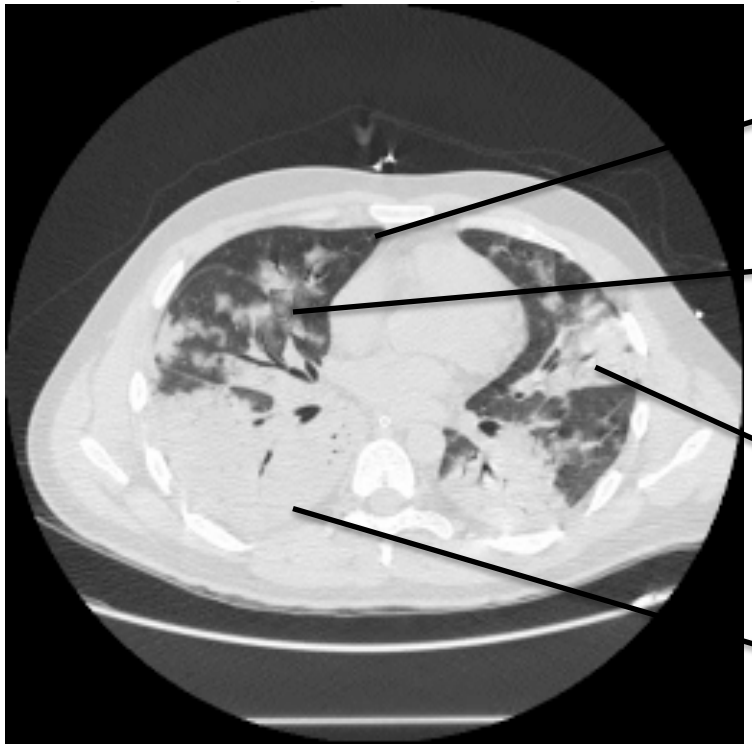
Gattinoni L , Intensive Care Med 2005; 31.

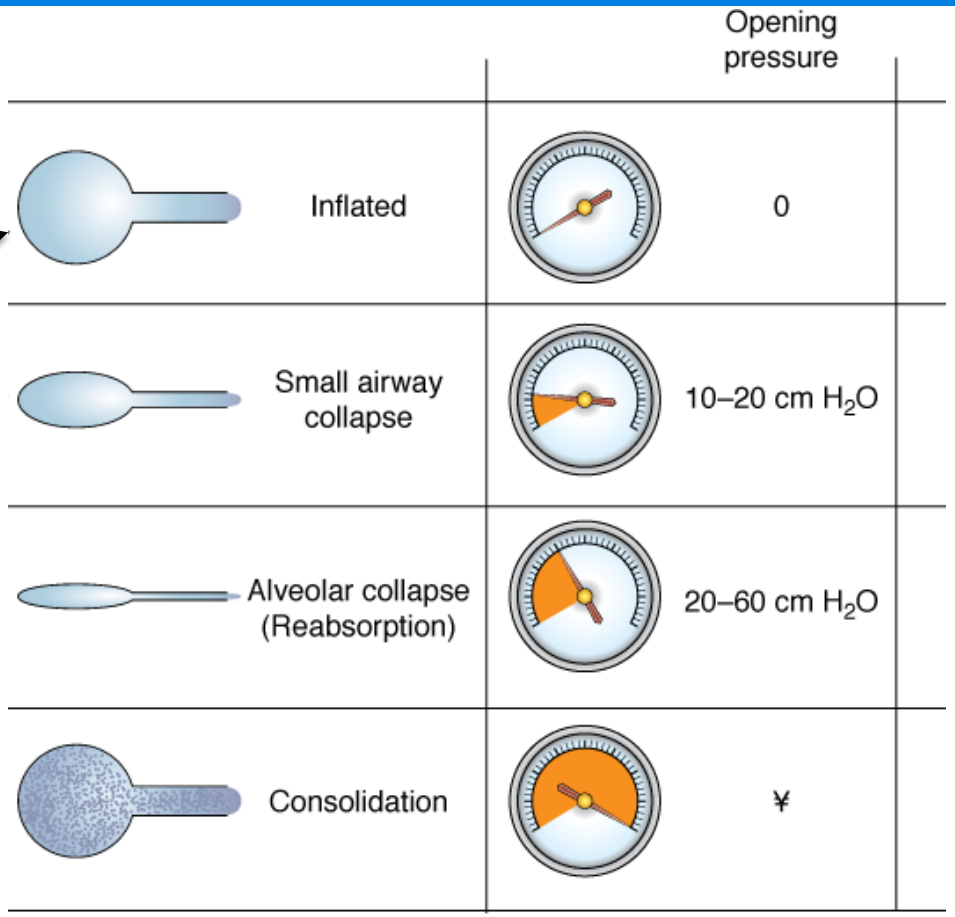
Pulmón inhomogéneo



Source: Tobin MJ: *Principles and Practice of Mechanical Ventilation, 3rd Edition:* www.accessanesthesiology.com

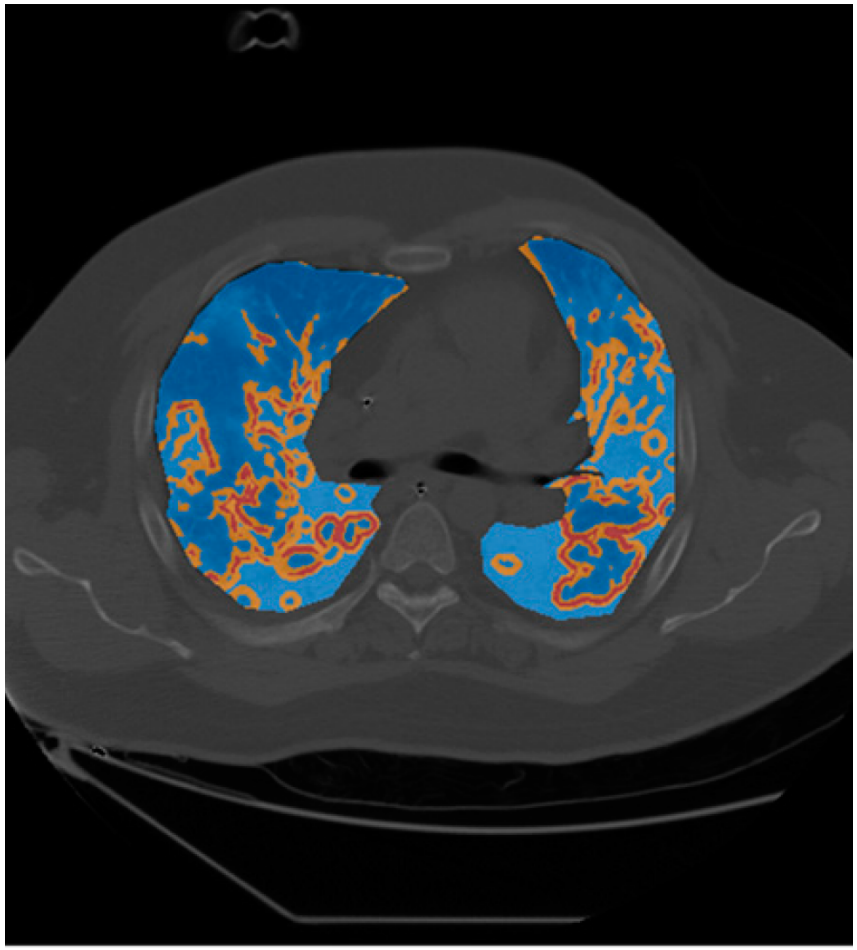
Pulmón inhomogéneo





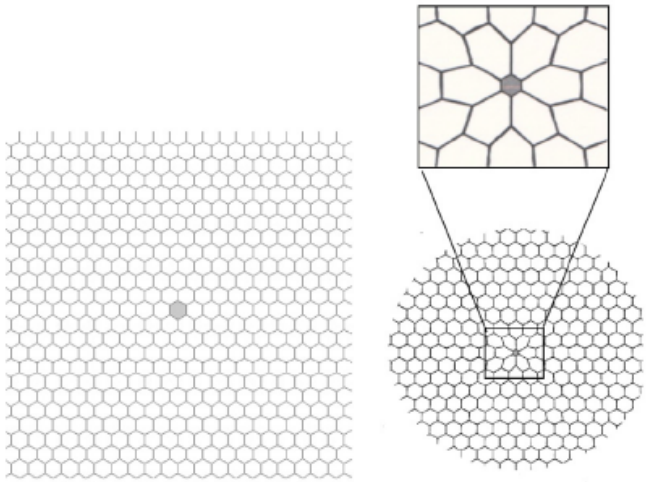
Pulmón inhomogéneo

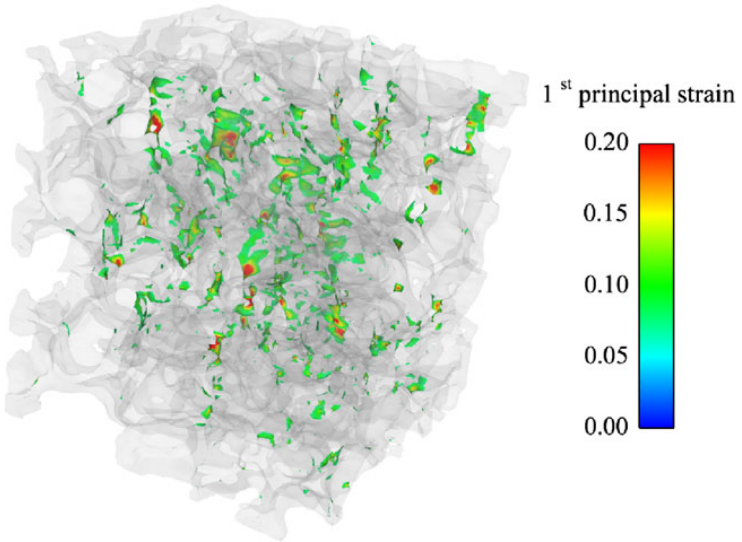
- “Inhomogeneities are associated with overall disease severity and mortality.”



Cressoni M, Am J Respir Crit Care Med 2014

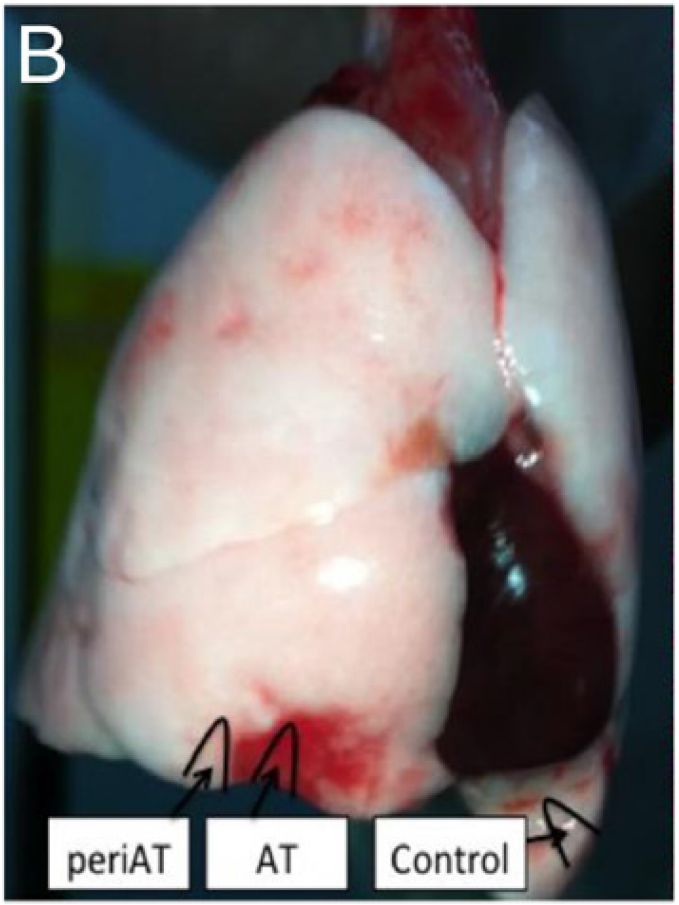
Pulmón inhomogéneo





Makiyama A.M. Respiratory Physiology & Neurobiology 2014
Raush S, Annals of Biomedical Engineering 2011
Mead J, J Appl Physiol 1970

Pulmón inhomogéneo



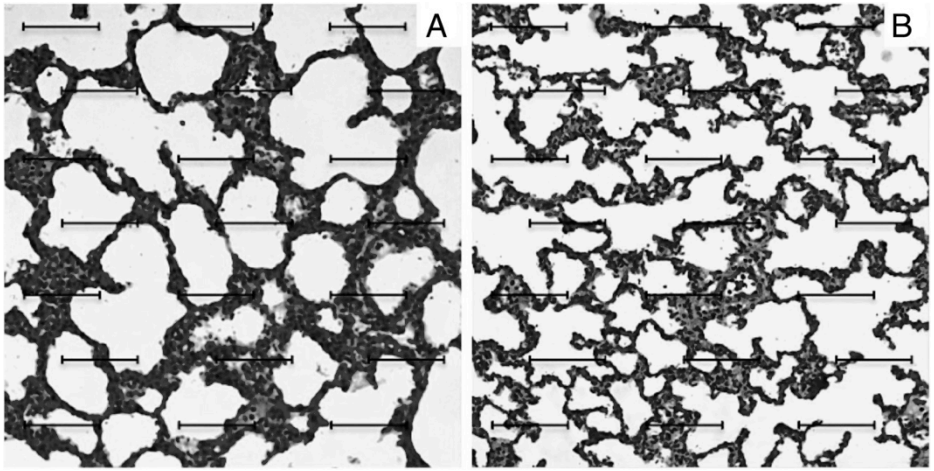
Retamal J, Critical Care 2014

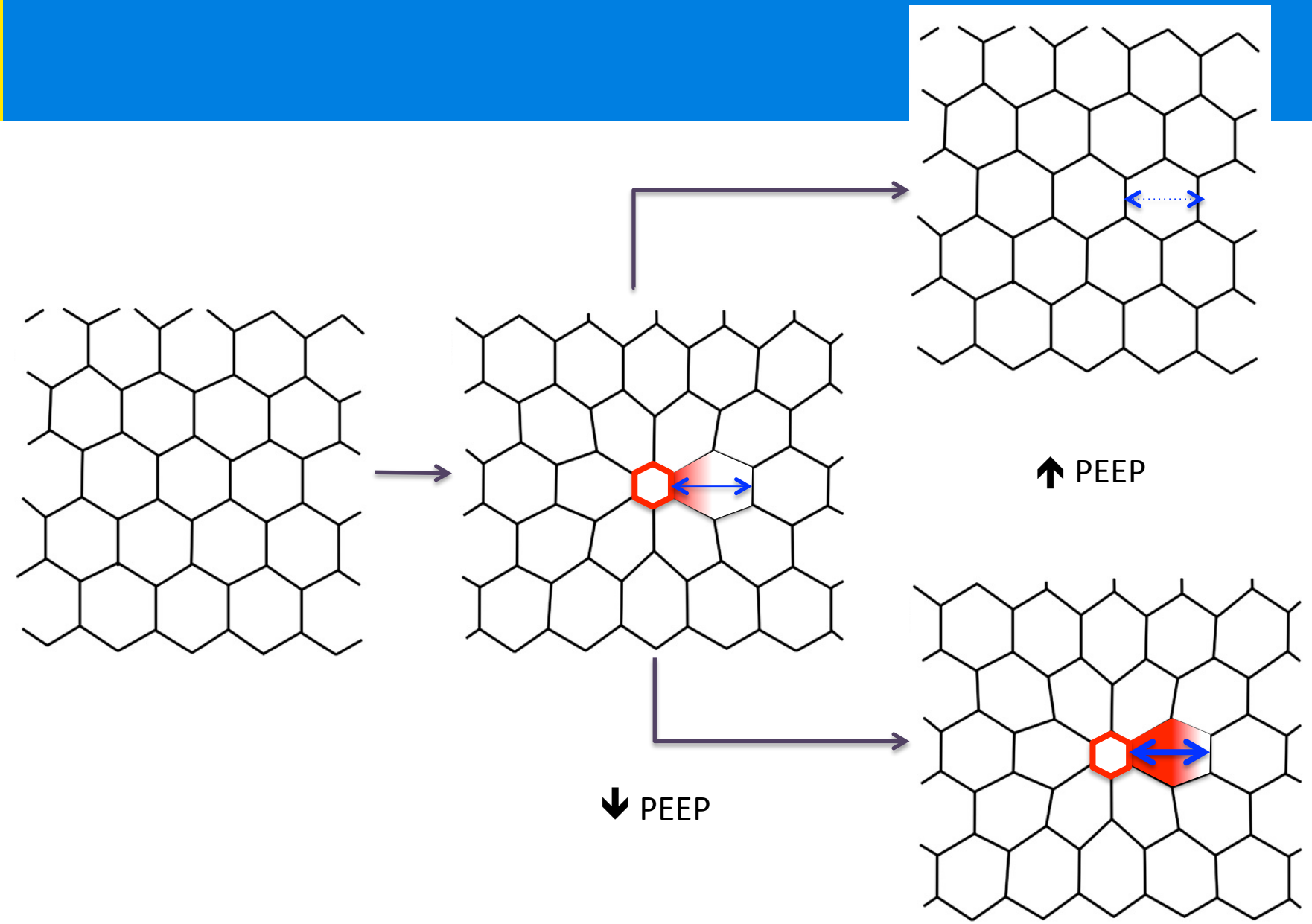
- Area Periatelectasia:

  Más inflamación

  Más destrucción alveolar

  Más hiperinsuflación




PEEP
PEEP

Resumen 2

- Por estas razones la estrategias de alta recliutabilidad tienen un espacio….al menos teórico hasta ahora

- El parénquimás es mas pequeño, inestable y heterogeneo en la medidad que el SDRA es más severo

En SDRA severo

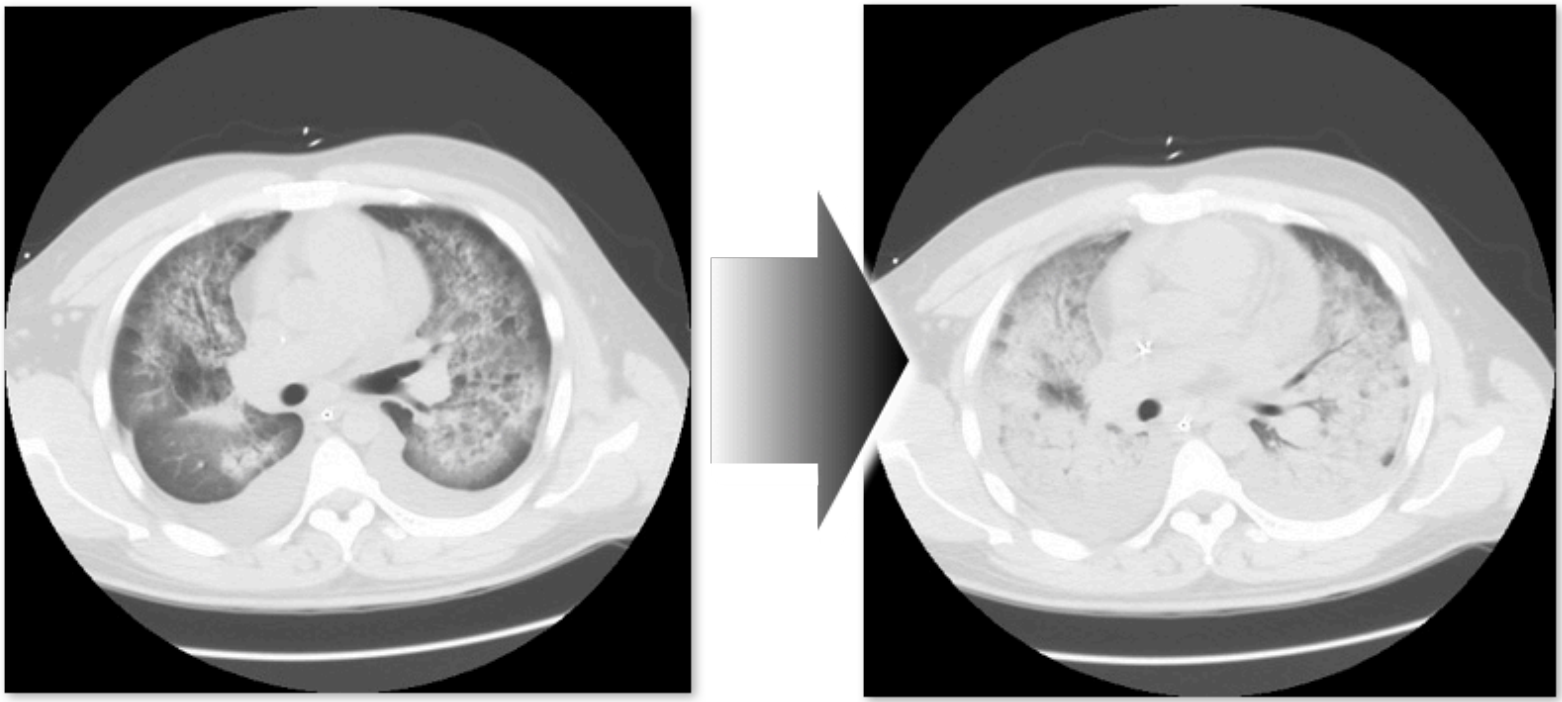
- Antes de pensar en MR:
  - VT 6 ml/kg
  - Prono
  - BNM
  - Restricción de fluídos?

IMPORTANTE¡¡¡

MUY IMPORTANTE¡¡¡

3. Efectos Fisiológicos de las Maniobras de Reclutamiento

ARDS: problem is collapse…



alveolar instability → collapse → shunt → ↓ PaO_2

alveolar instability → collapse

- ***recruitment and derecruitment*** *of unstable alveoli HARMS THE LUNG*

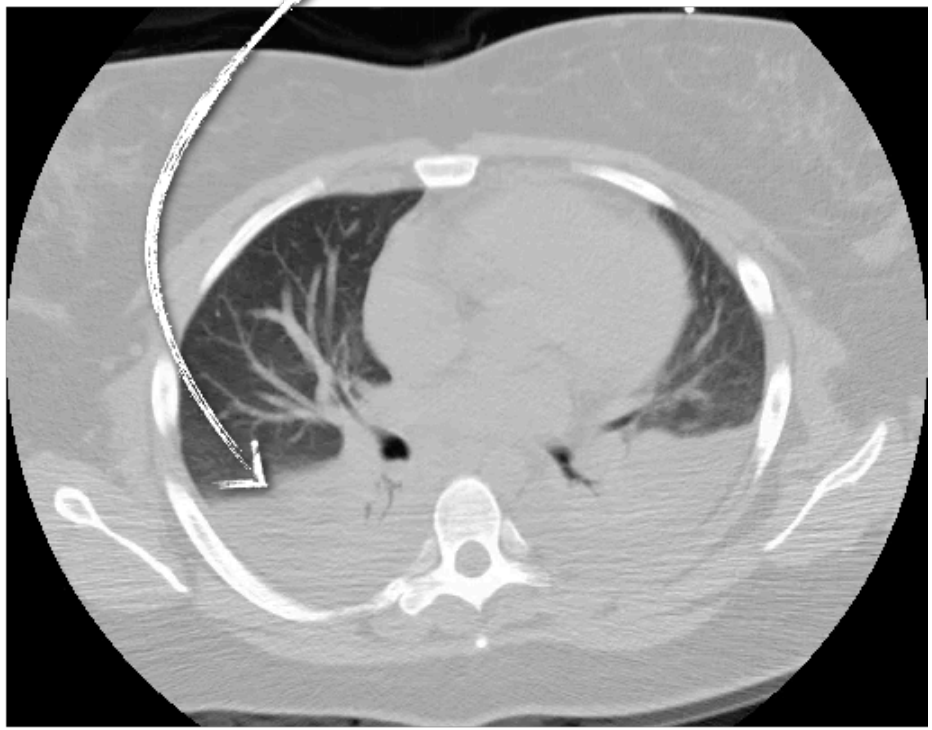
lung collapse

↓

↑ shunt → ***↓ PaO_2***

↑ R/D → ***↑ lung damage***

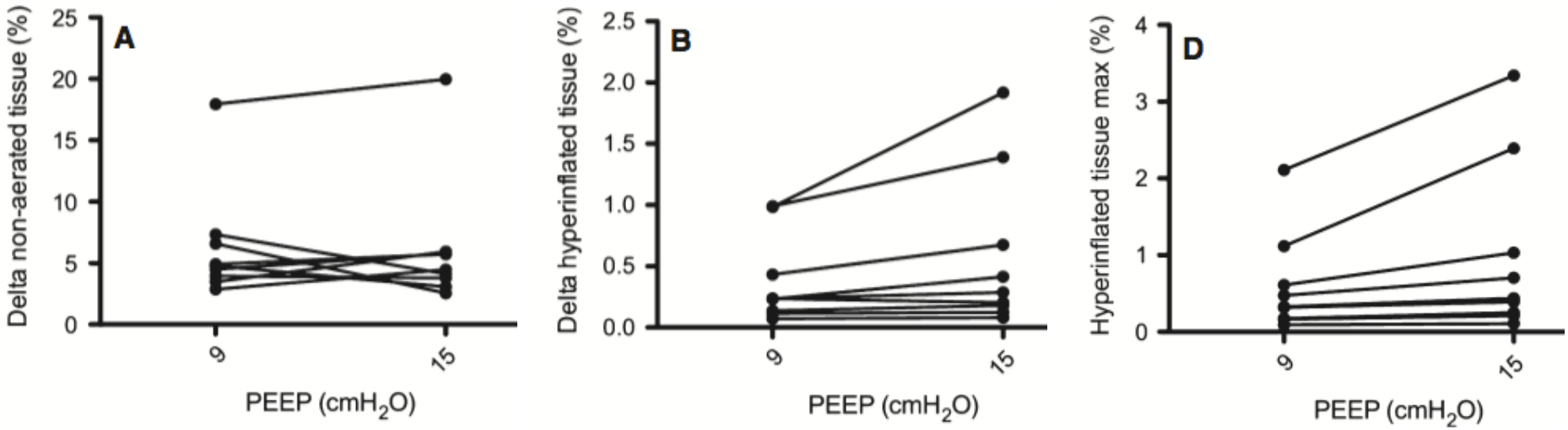
"atelectrauma"



Muscedere JG, et al. AJRCCM 1994; 149: 1327-34.
Halter JM, et al. AJRCCM 2003; 167: 1620-6.
Valenza F, et al. Crit Care Med 2003; 31: 1993-8.
Amato et al. NEJM 1998; 338: 347-354.
Ranieri VM et al. JAMA 1999; 282: 54-61.

High PEEP levels are associated with overdistension and tidal recruitment/derecruitment in ARDS patients

J. Retamal[1,2], G. Bugedo[1], A. Larsson[2] and A. Bruhn[1]



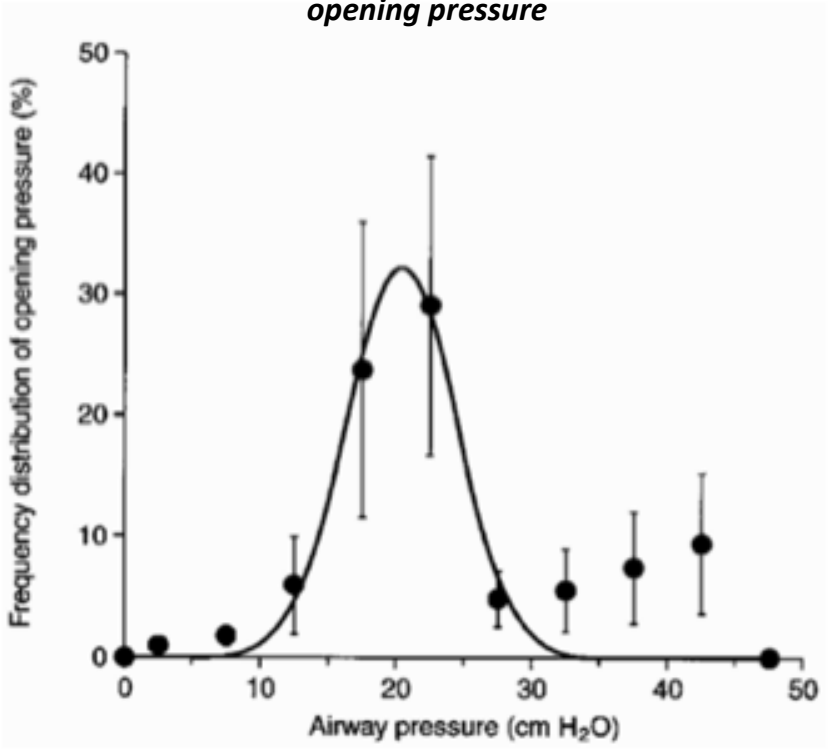
Retamal J, et al. Acta Anaesthesiologica Scandinavica 2015

Recruitment and Derecruitment during Acute Respiratory Failure

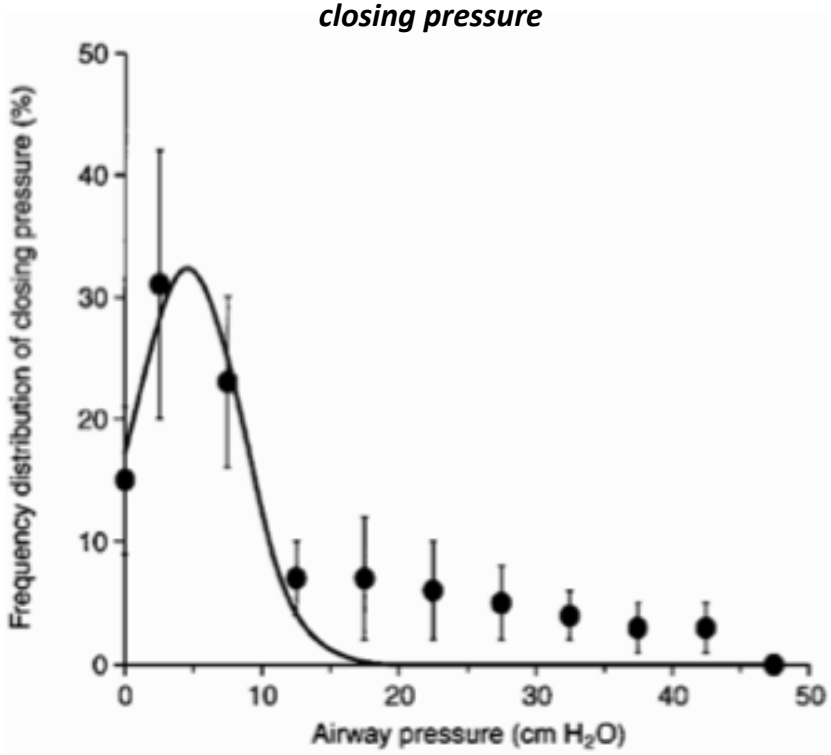
A Clinical Study

STEFANIA CROTTI, DANIELE MASCHERONI, PIETRO CAIRONI, PAOLO PELOSI, GIULIO RONZONI, MICHELE MONDINO, JOHN J. MARINI, and LUCIANO GATTINONI

opening pressure



closing pressure



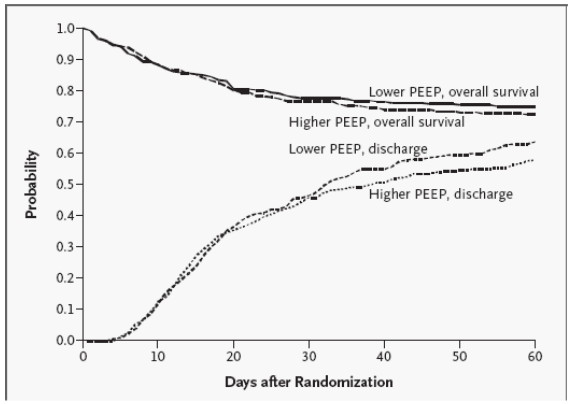
Crotti S, et al. Am J Respir Crit Care Med 2001; 164: 131.

estrategias alto PEEP (dp ARDSnet)

Alveoli study

Higher versus Lower Positive End-Expiratory Pressures in Patients with the Acute Respiratory Distress Syndrome

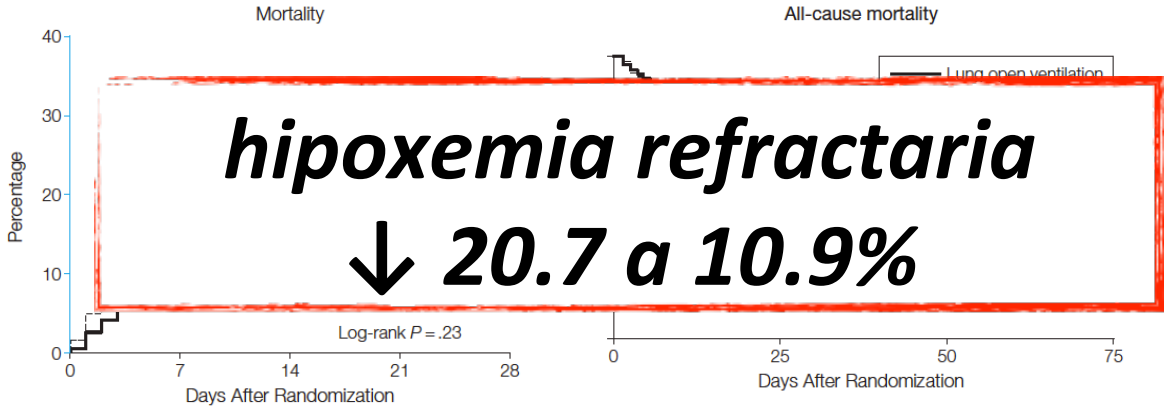
The National Heart, Lung, and Blood Institute ARDS Clinical Trials Network*



The ARDSnet.
N Engl J Med 2004;351:327-36.

Express study

Positive End-Expiratory Pressure Setting in Adults With Acute Lung Injury and Acute Respiratory Distress Syndrome
A Randomized Controlled Trial



hipoxemia refractaria

↓ 20.7 a 10.9%

Mercat A, et al. JAMA 2008

LOV study

Ventilation Strategy Using Low Tidal Volumes, Recruitment Maneuvers, and High Positive End-Expiratory Pressure for Acute Lung Injury and Acute Respiratory Distress Syndrome
A Randomized Controlled Trial

Meade MO, et al. JAMA 20

todos Vt 6 ml/kg IBW

Red de Salud UC · CHRISTUS

max recruitment trials (after ARDSnet)

Open Lung Approach for the Acute Respiratory Distress Syndrome: A Pilot, Randomized Controlled Trial

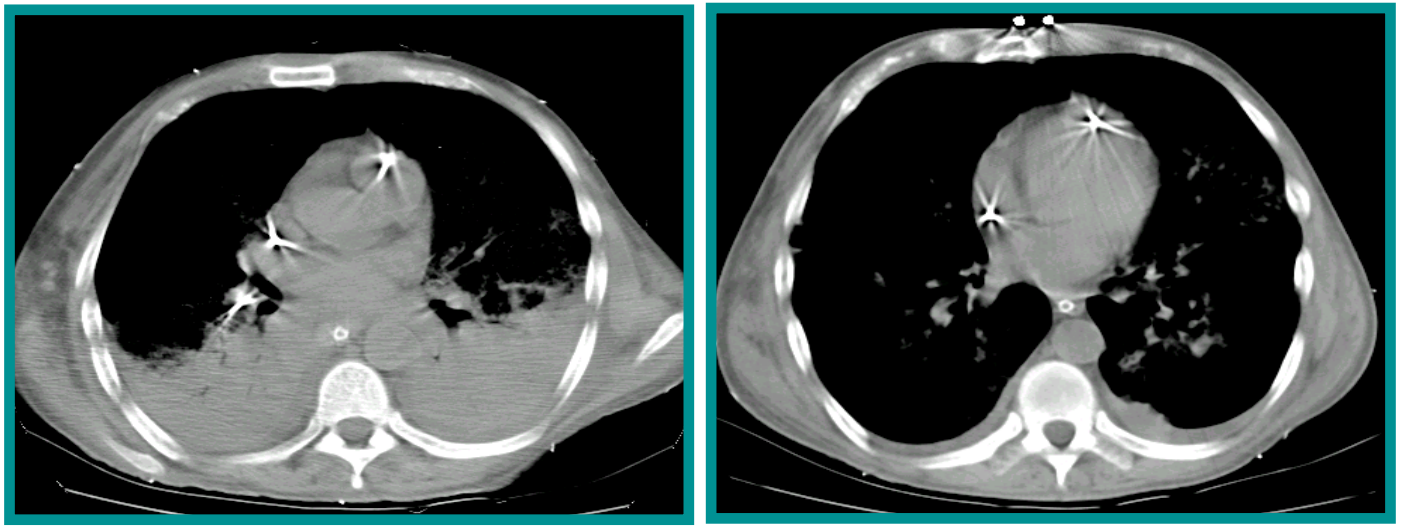
Kacmarek RM, et al. Crit Care Med. 2016; 44(1):32-42.

just finished…

ARDS reclutamiento definición

“ …re-expansion of previously collapsed lung units by means of a brief controlled and individualized increase in transpulmonary pressure …..that results in an instantaneous change of lung´s functional condition”

Lung Recruitment (2 min at Pinsp/PEEP 50/30 cmH_2O)

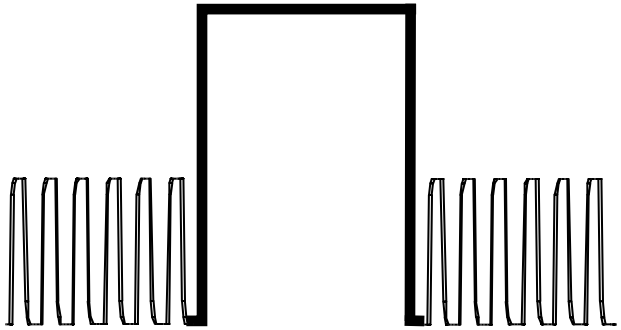


medicina.uc.cl

Clinical Recruitment Maneuvers

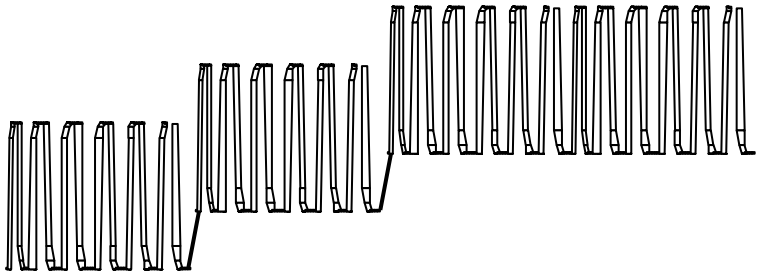
CPAP maneuver

40/40 sustained inflation



Cycling maneuver

PCV fixed deltaP + PEEP increments



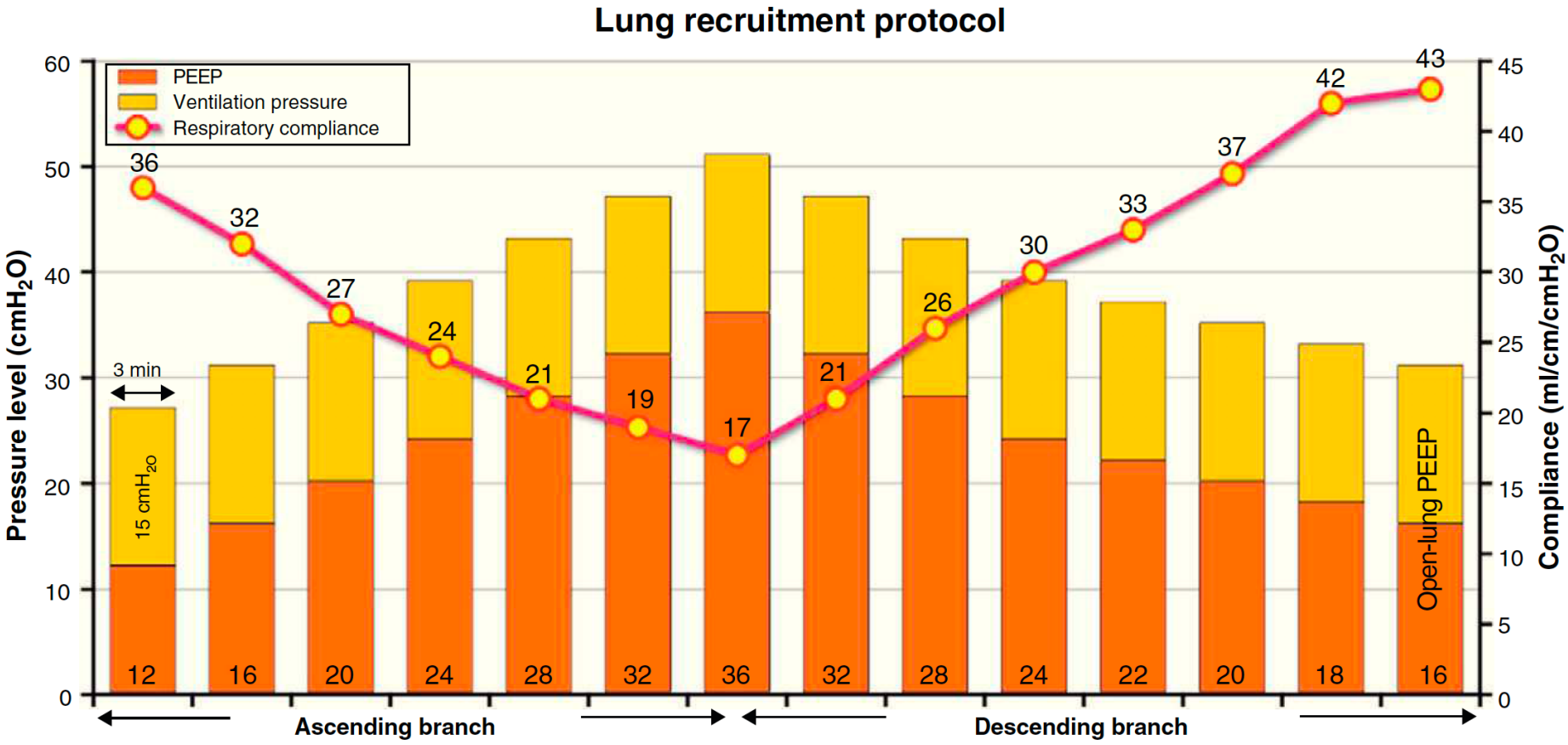
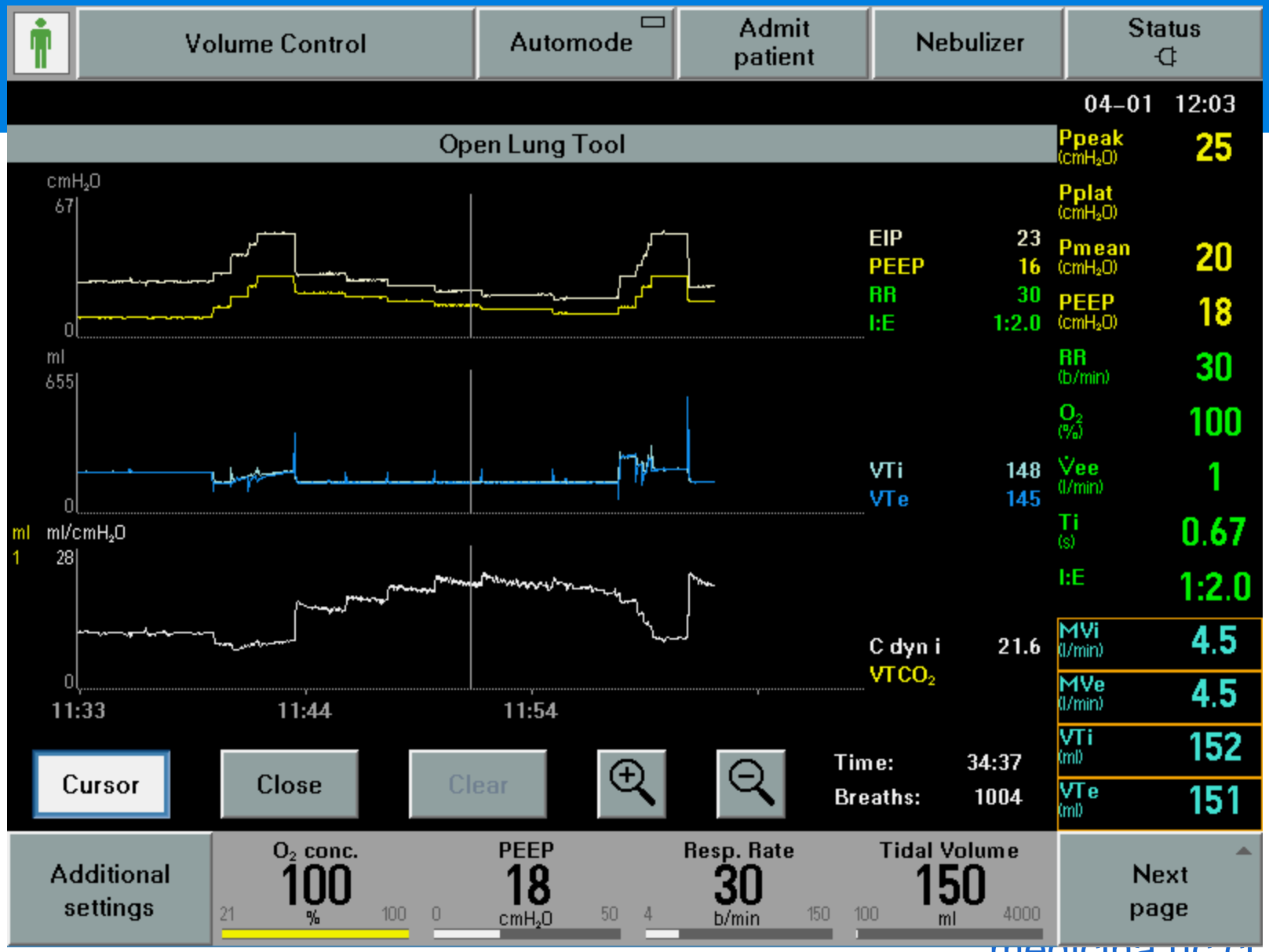


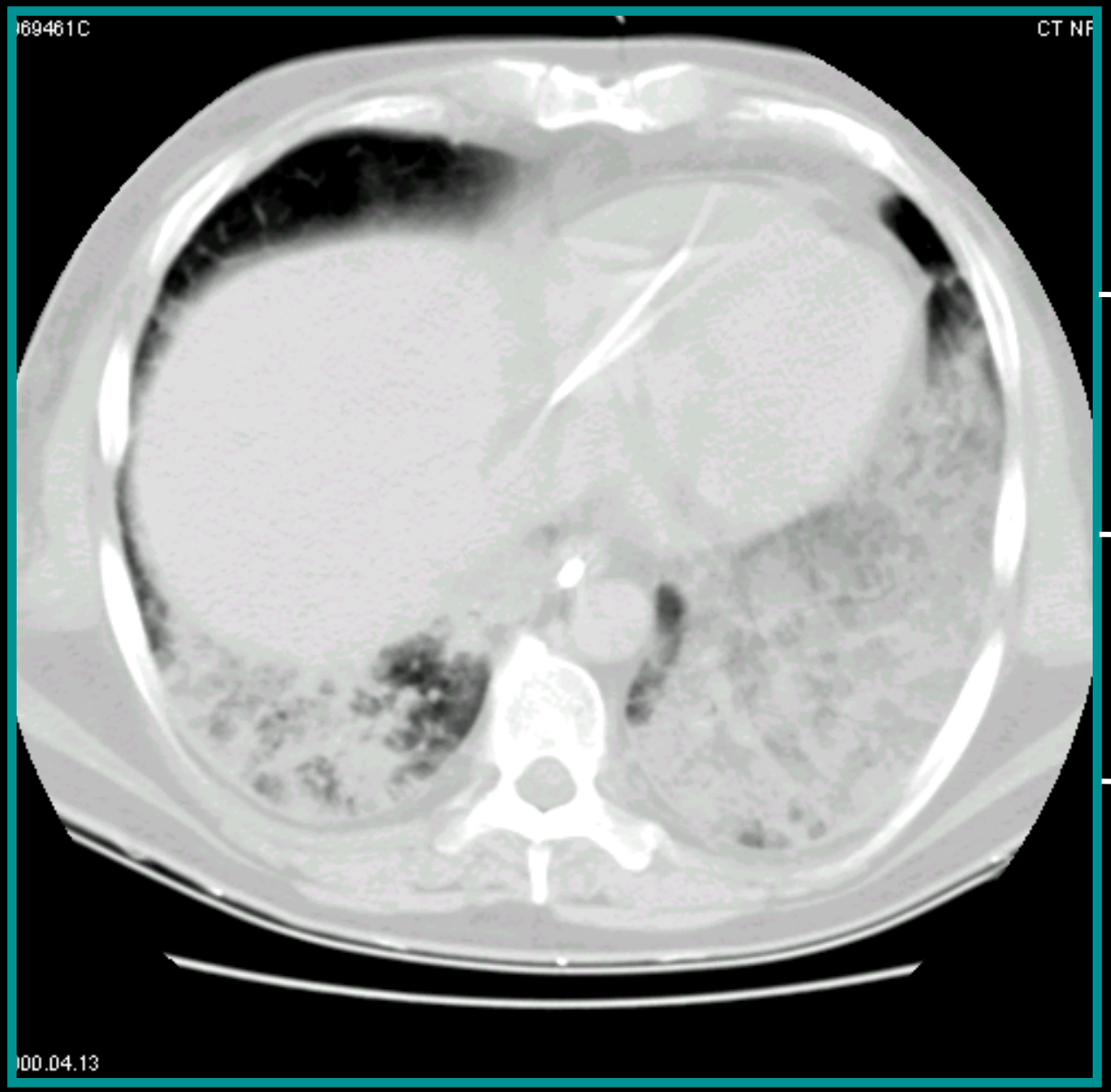
Figure 1 Example of the protocol used for lung recruitment maneuvering (LRM).

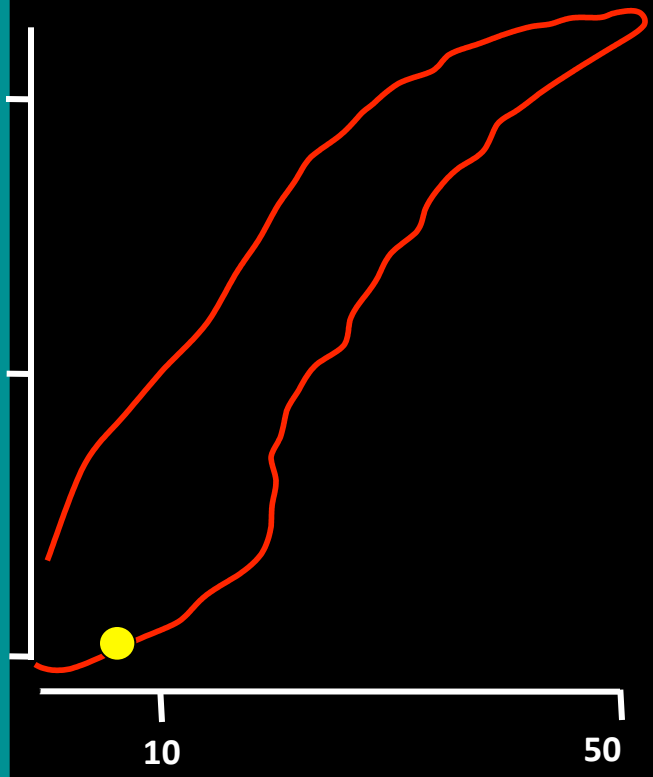


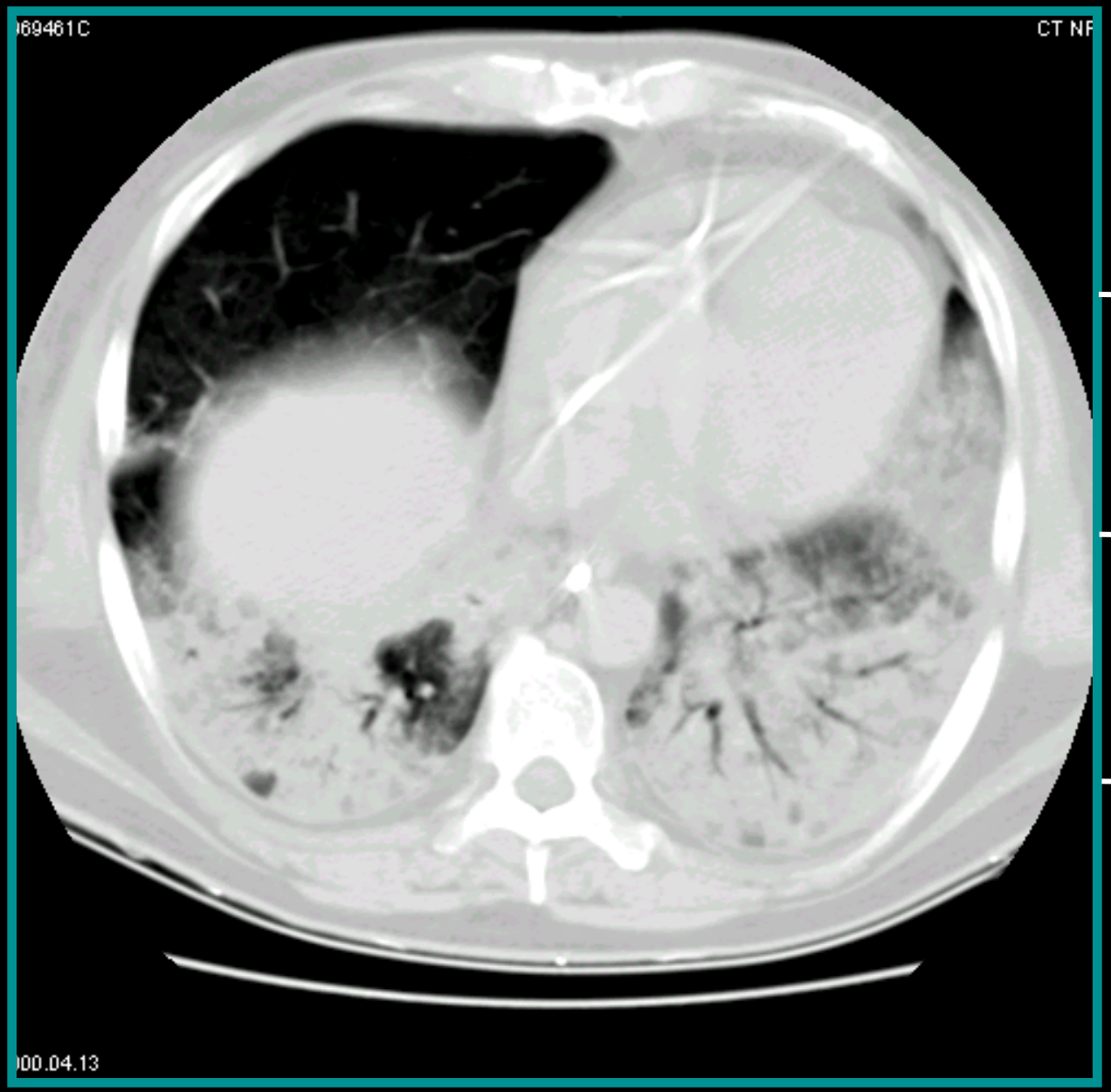
Lung Recruitment in ARDS

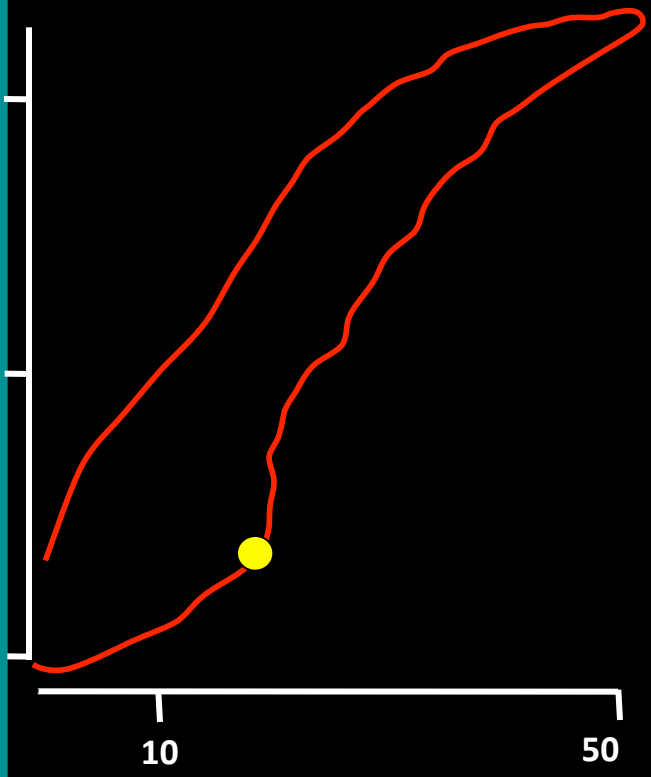
Recruitment Maneuver

Author	year	N	Mode	Pins max (cmH_2O)	Time (sec)
Amato et al	1998	53	CPAP	40	40
Pelosi et al	1999	10	Sigh	45	2
Lapinski et al	1999	14	CPAP	45	20
Richard et al	2001	15	CPAP	45	15
Lim et al	2001	20	Sigh	35	90
Crotti et al	2001	5	PCV	45	40
Richards et al	2001	19	CPAP	50	90
Villagrá et al	2002	17	PCV	50	120
Grasso et al	2002	22	CPAP	40	40
Patroniti et al	2002	13	Sigh	38	5
Bein et al	2002	11	PCV	60	30
Bugedo et al	2003	10	PCV	50	45
Tugrul et al	2003	24	CPAP	45	30
Brower ARDSnet	2003	43	CPAP	40	30
Johannigman et al	2003	12	PCV	40	30
Oczensky et al	2004	30	CPAP	50	30
PovoaP et al	2004	8	PCV	60	120
Borges et al	2006	25	PCV	60	120
Toth et al	2007	20	PCV	40	40
Arnal et al	2011	50	CPAP	40	40
Hodgson et al	2011	20	PCV	55	120
De Matos et al	2012	51	PCV	60	120









Courtesy of Dr Amato & Dr Borges
São Paulo, Brazil

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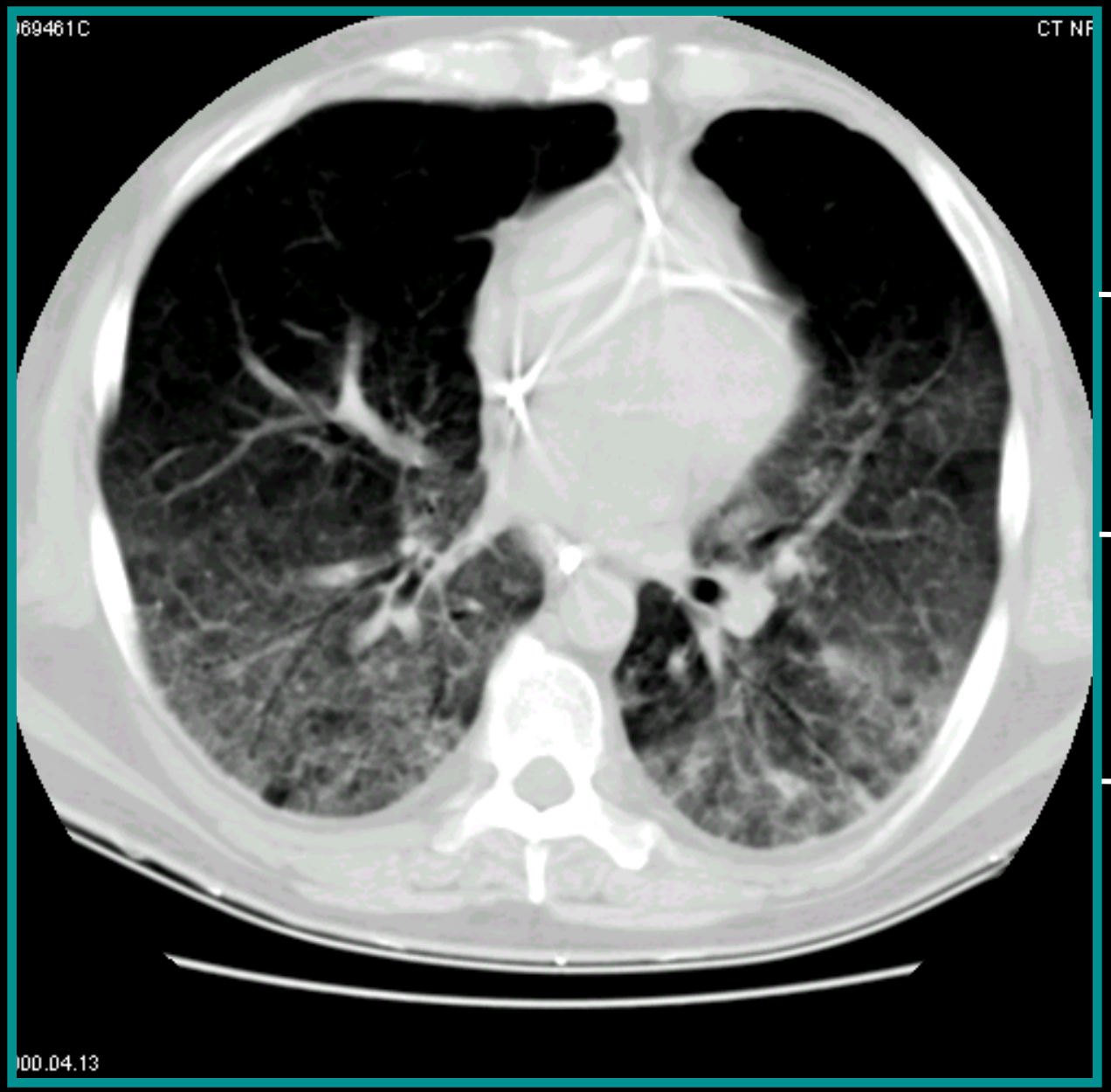
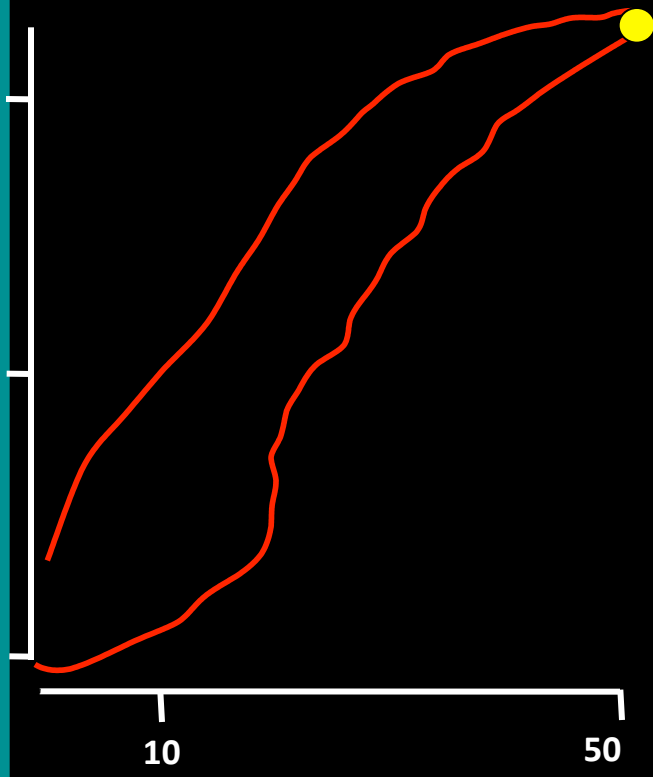
Courtesy of Dr Amato & Dr Borges

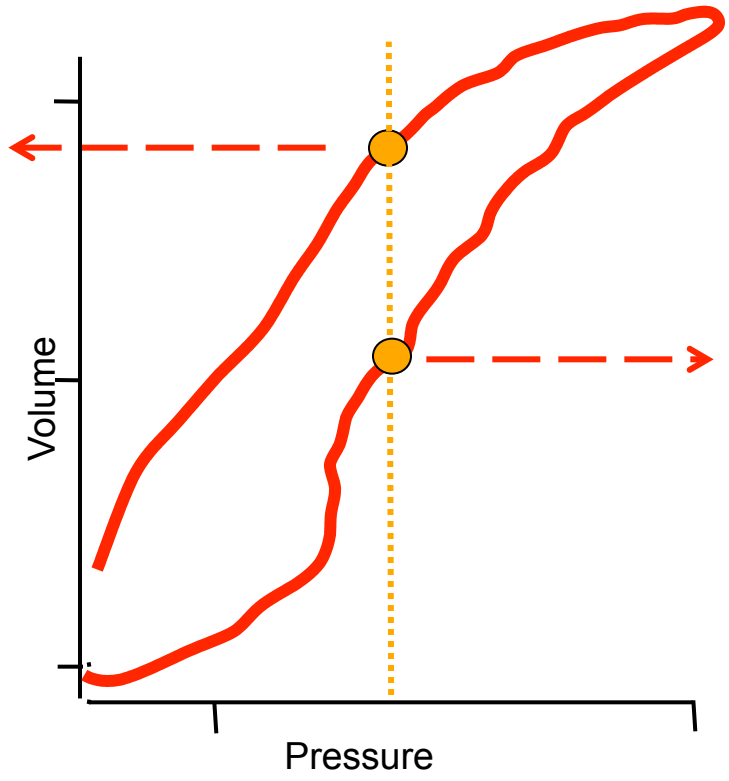
São Paulo, Brazil

Courtesy of Dr Amato & Dr Borges
São Paulo, Brazil





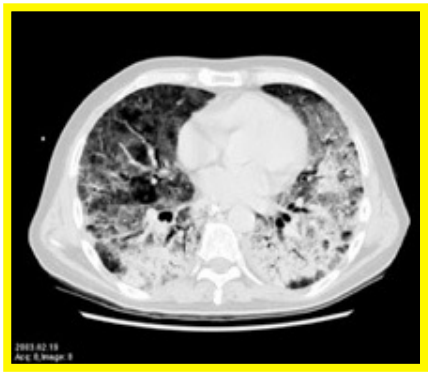
Reclutamiento e histéresis



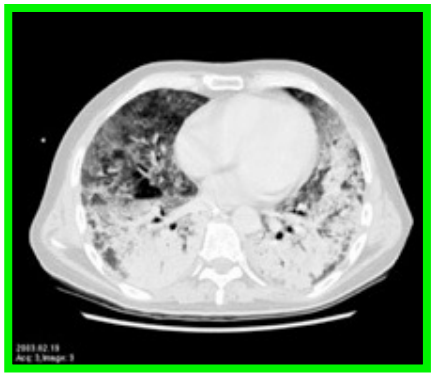
Barbas et al. CCM

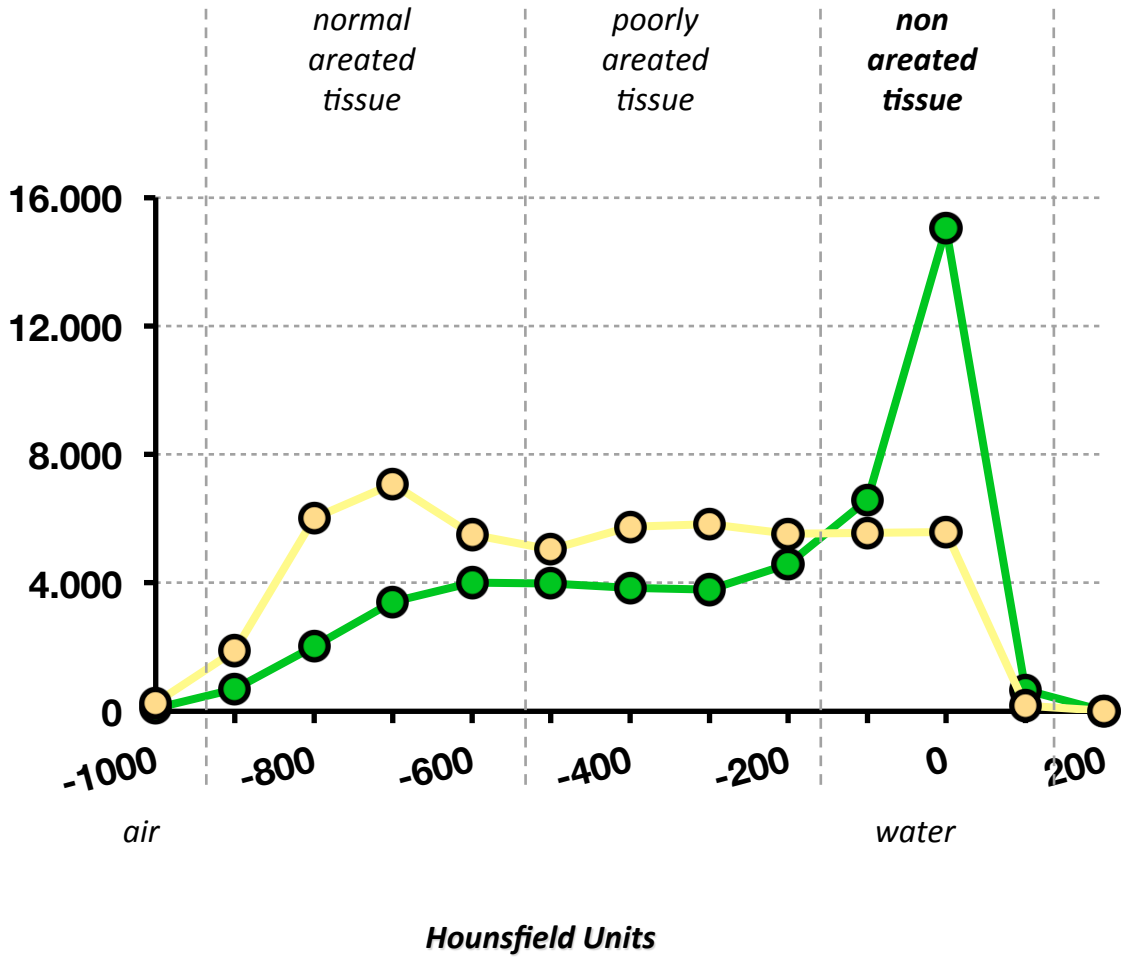
ARDS lung

Pplateau 39



PEEP 5

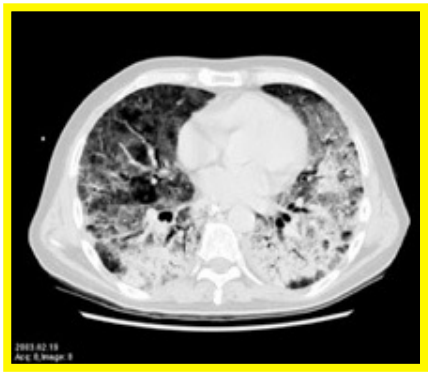




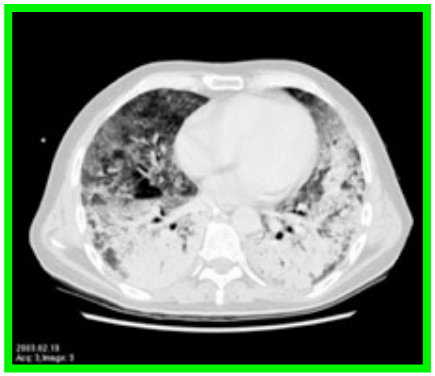
ARDS lung

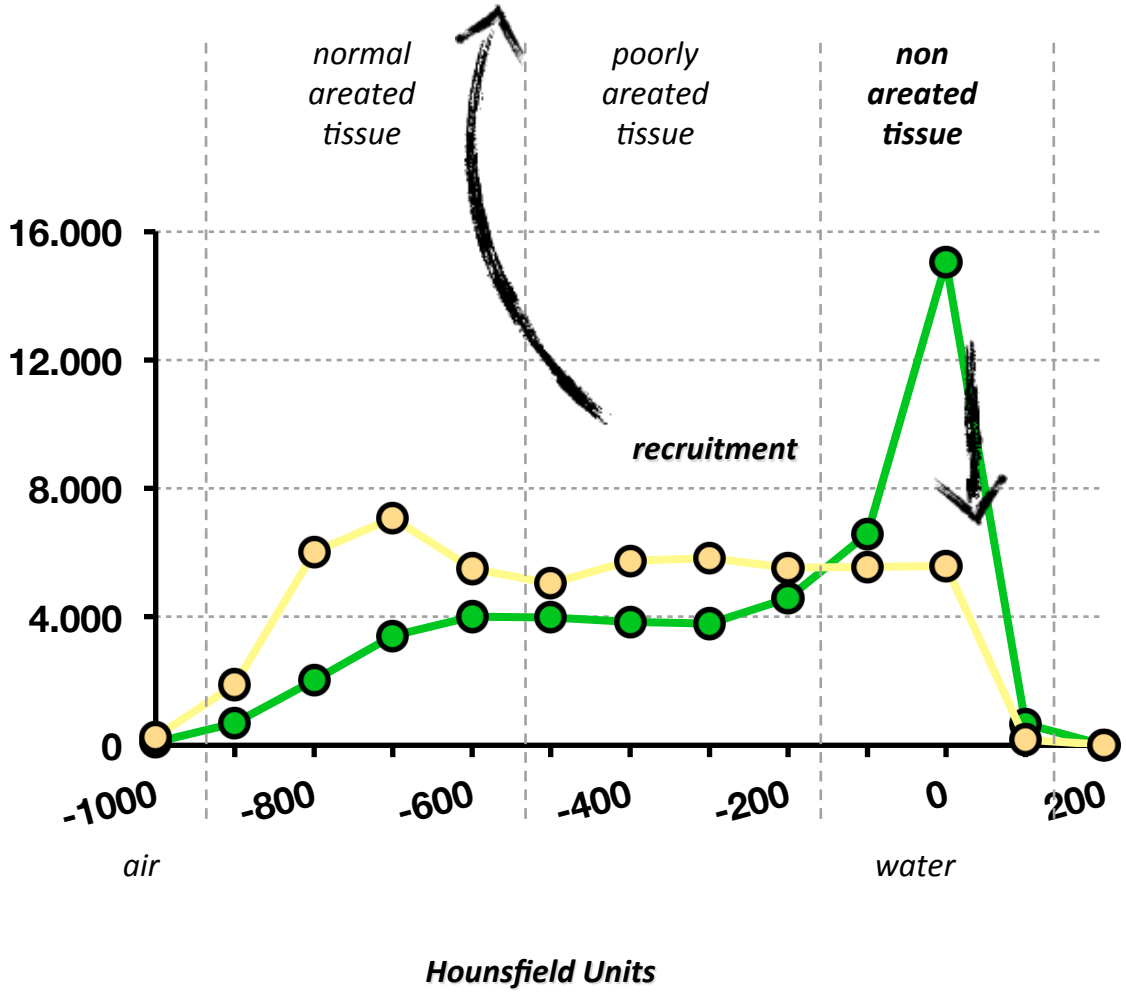
↑ PaO_2 ↓ E_{RS}
↓ Vd/Vt ↑ DO_2

Pplateau 39

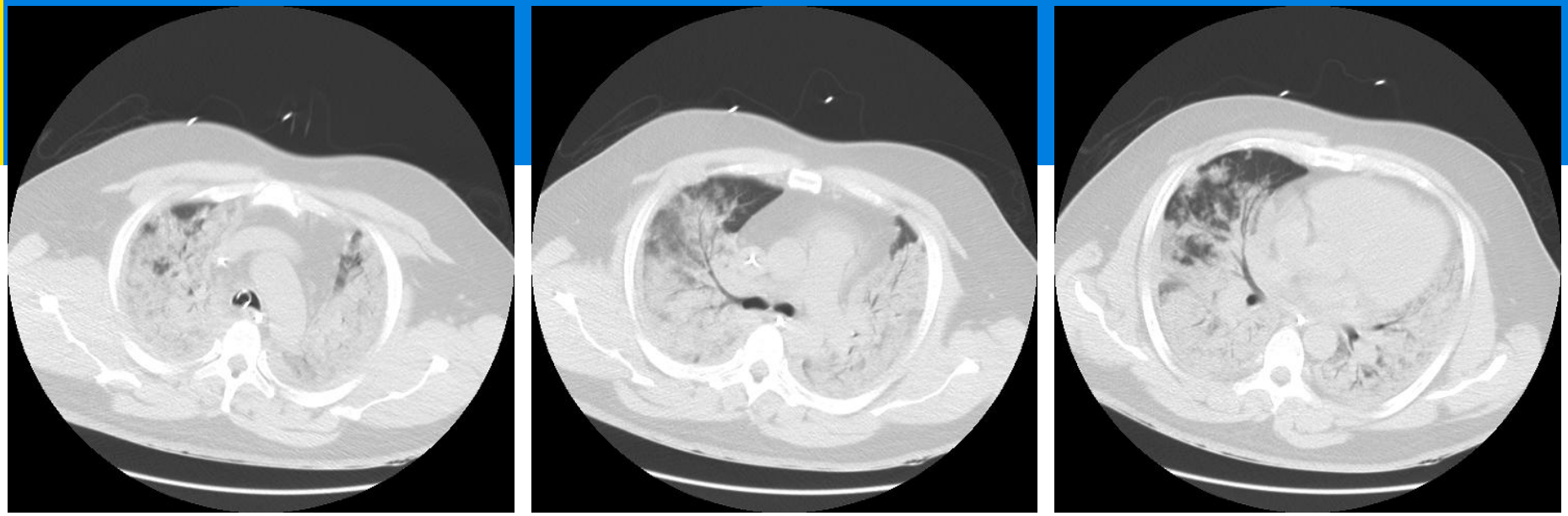


PEEP 5





pausa expiratoria a 5 cmH2O



pausa inspiratoria a 40 cmH2O

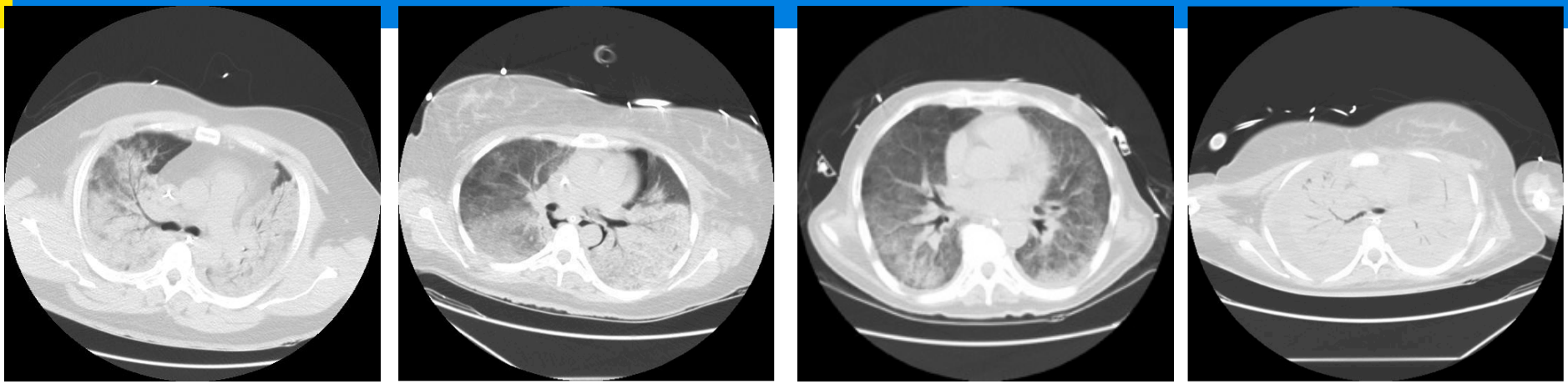
varón, 34 años
NM grave por Influenza A
PaFiO2 87

mujer, 25 años
hemorragia alveolar
PaFiO2 84

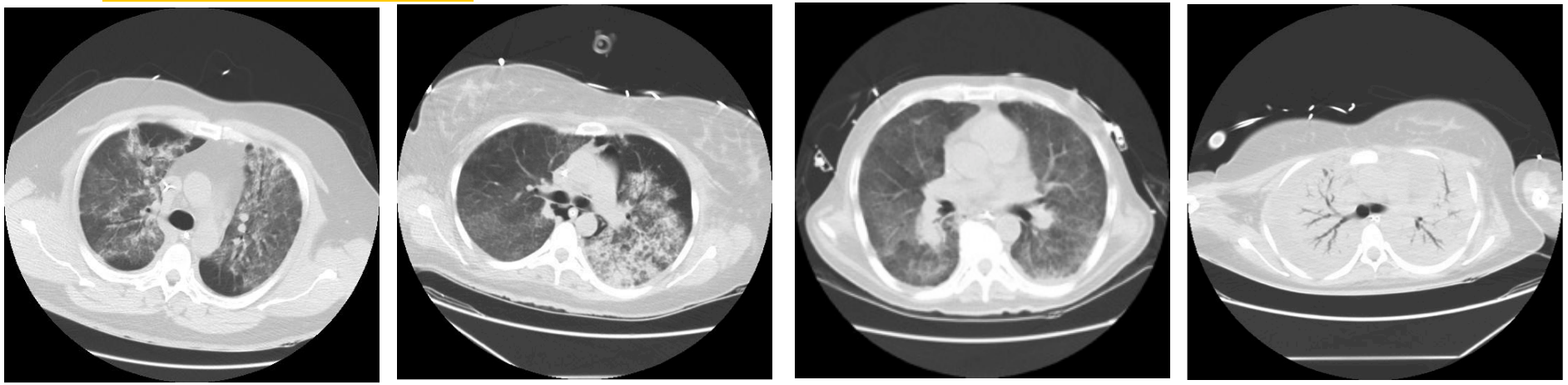
varón, 56 años
NM grave por P jirovecci
PaFiO2 98

mujer, 20 años
NM aspirativa
PaFiO2 40

pausa expiratoria a 5 cmH2O

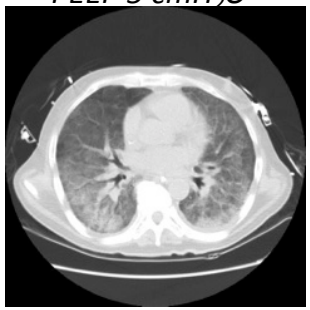


pausa inspiratoria a 40 cmH2O



human ARDS:
recruitment is highly heterogeneous

PEEP 5 cmH$_2$O

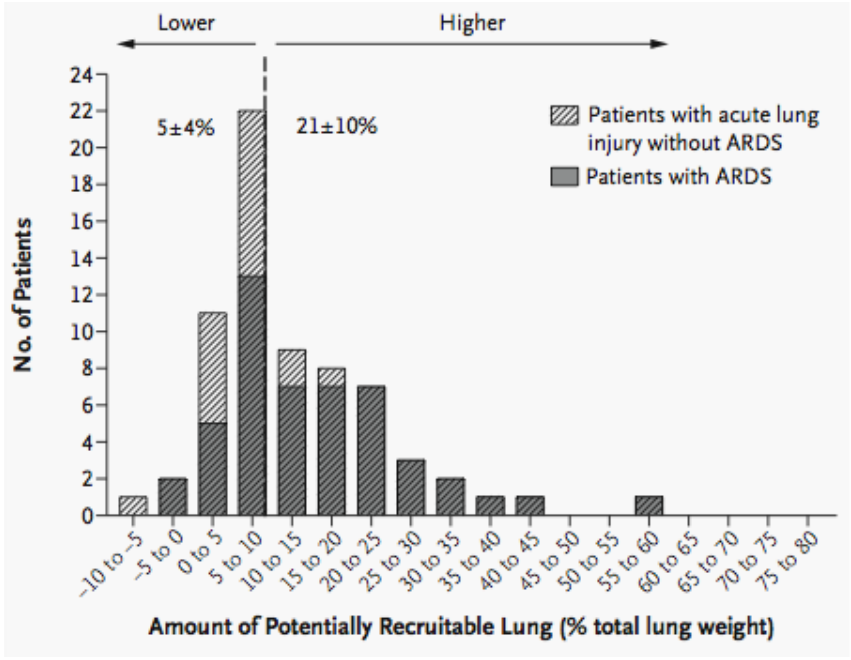


P$_{plateau}$ 40 cmH$_2$O

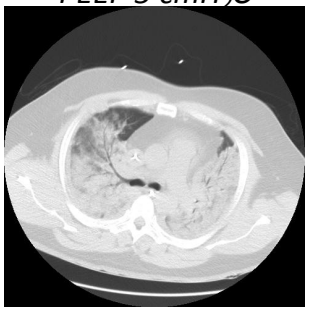
low Vt
moderate PEEP

low recruitability

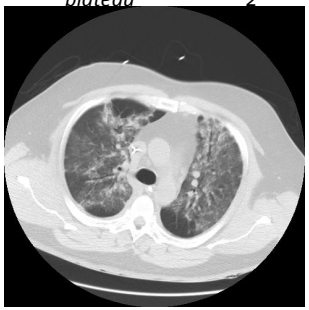
high recruitability



PEEP 5 cmH$_2$O



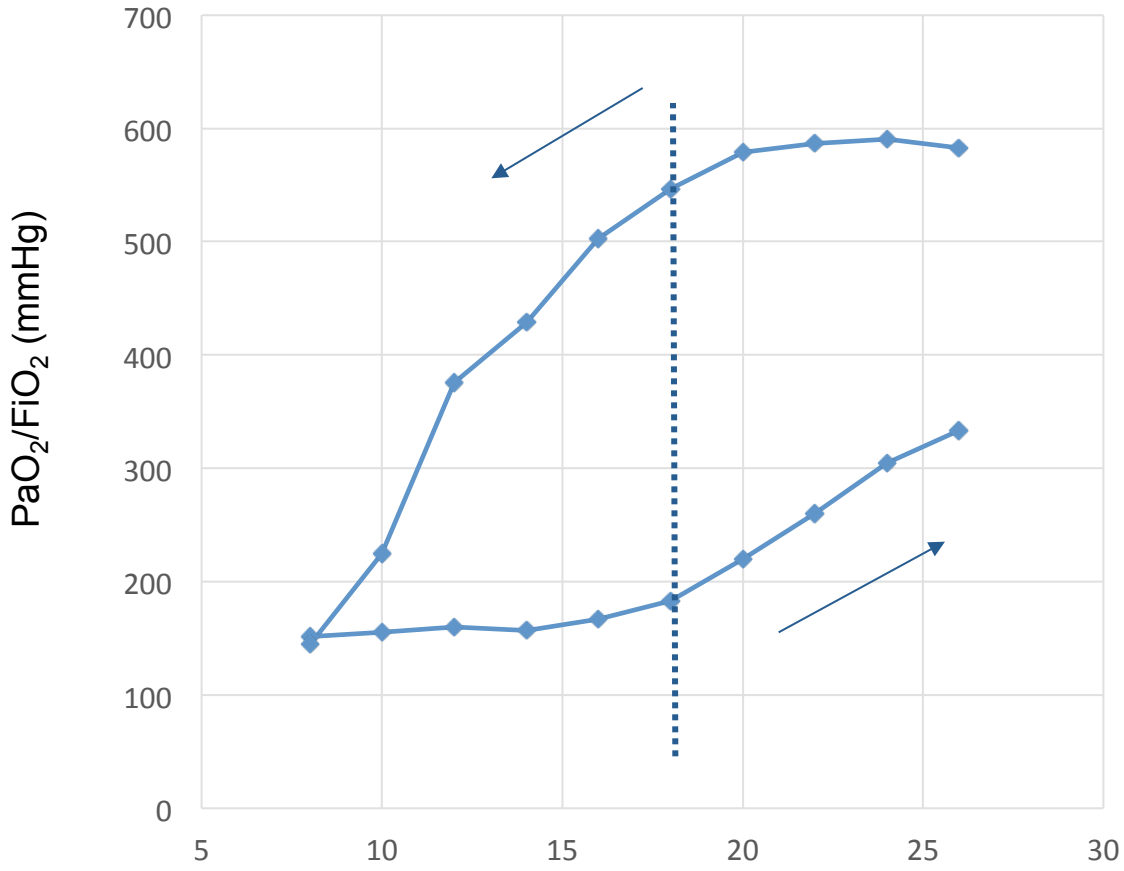
P$_{plateau}$ 40 cmH$_2$O



low Vt
high PEEP

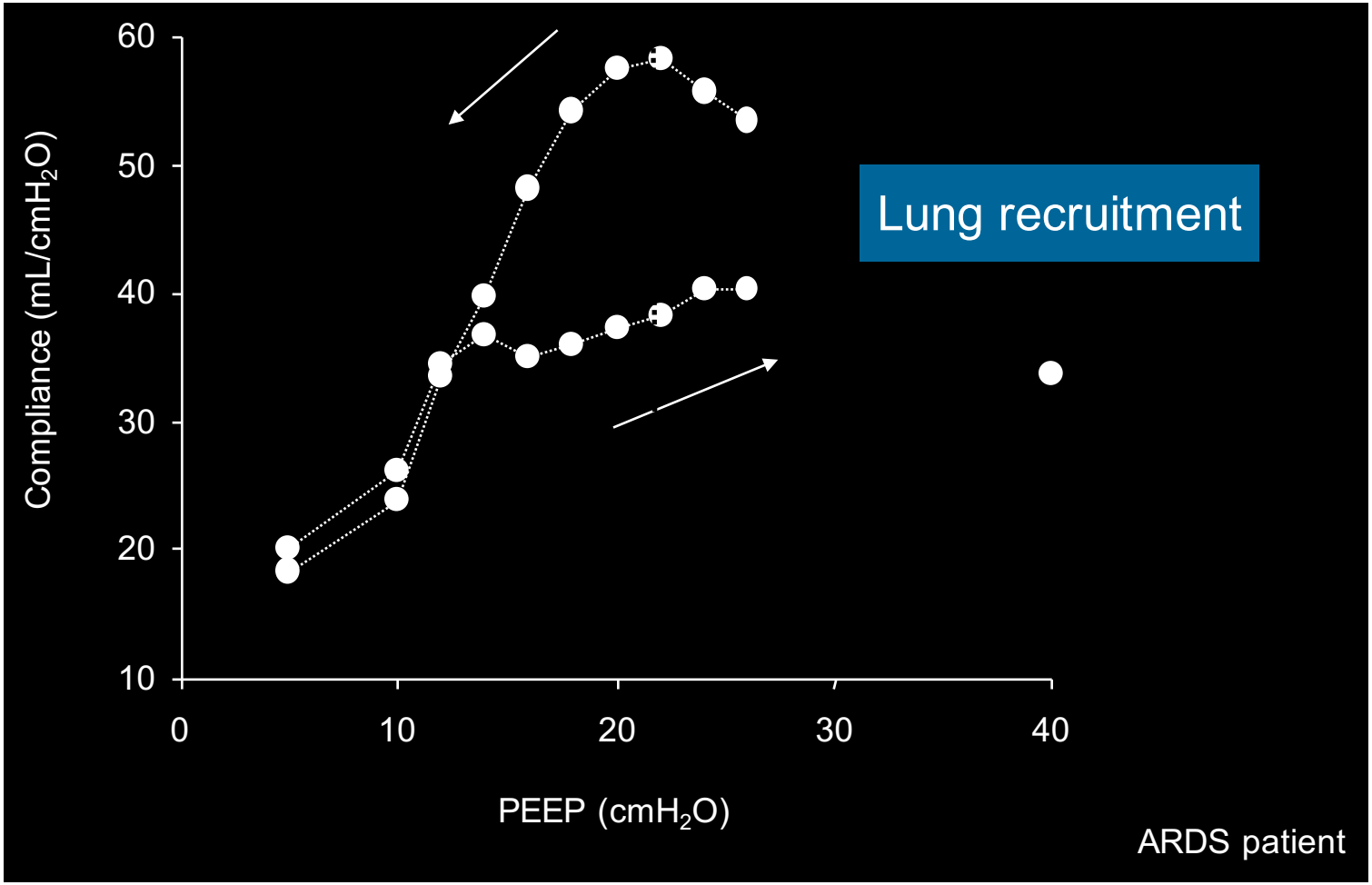
Gattinoni L, et al. NEJM 2006

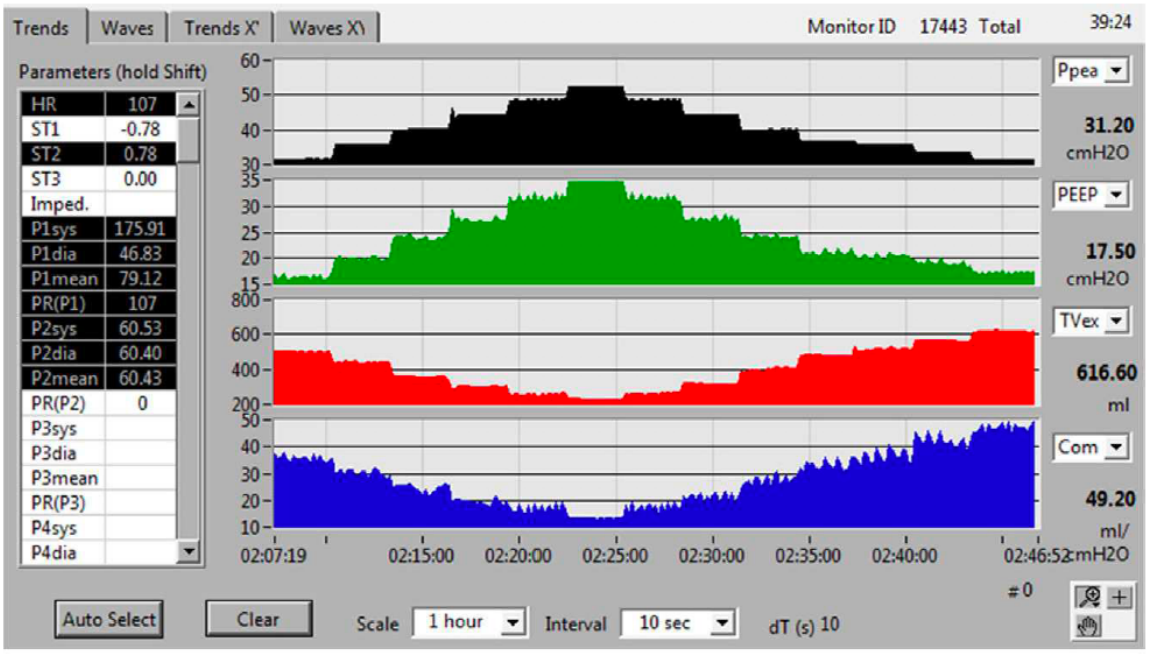
MR y oxigenación



Lung recruitment

MR y mecánica

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Waves
Trends X'
Waves X\
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ST2 0.78
ST3 0.00
Imped.
P1sys 175.91
P1dia 46.83
P1mean 79.12
PR(P1) 107
P2sys 60.53
P2dia 60.40
P2mean 60.43
PR(P2) 0
P3sys
P3dia
P3mean
PR(P3)
P4sys
P4dia
Ppea
31.20
cmH2O
PEEP
17.50
cmH2O
TVex
616.60
ml
Com
49.20
ml/
cmH2O
02:07:19
02:15:00
02:20:00
02:25:00
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Clear
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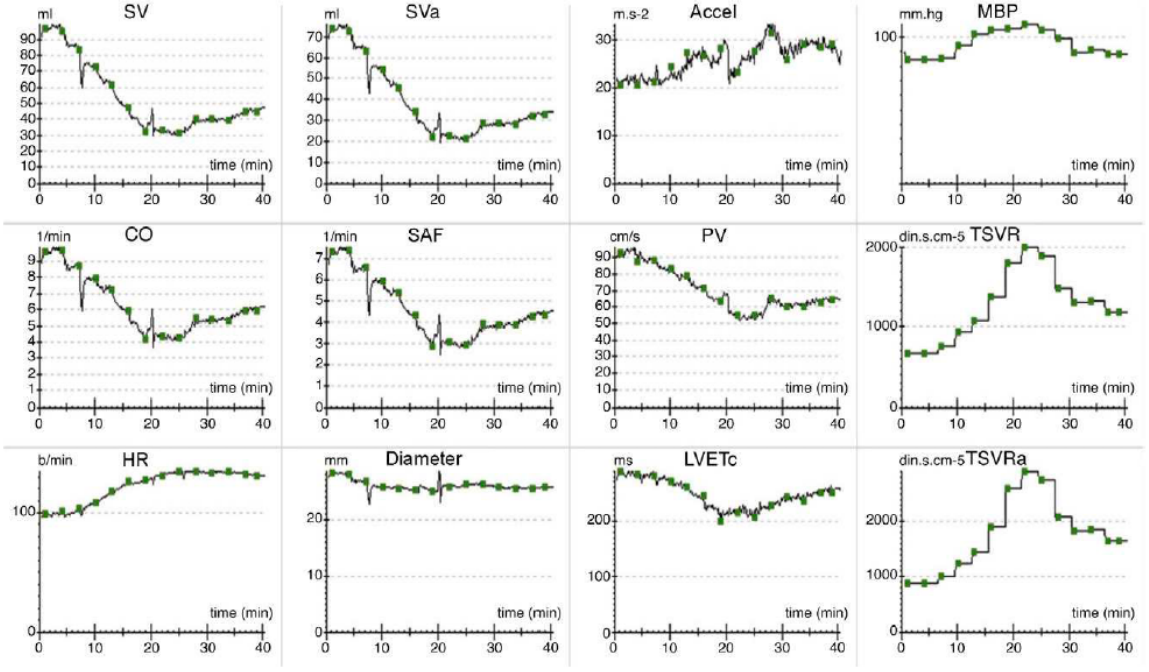
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LVETc
TSVRa
time (min)

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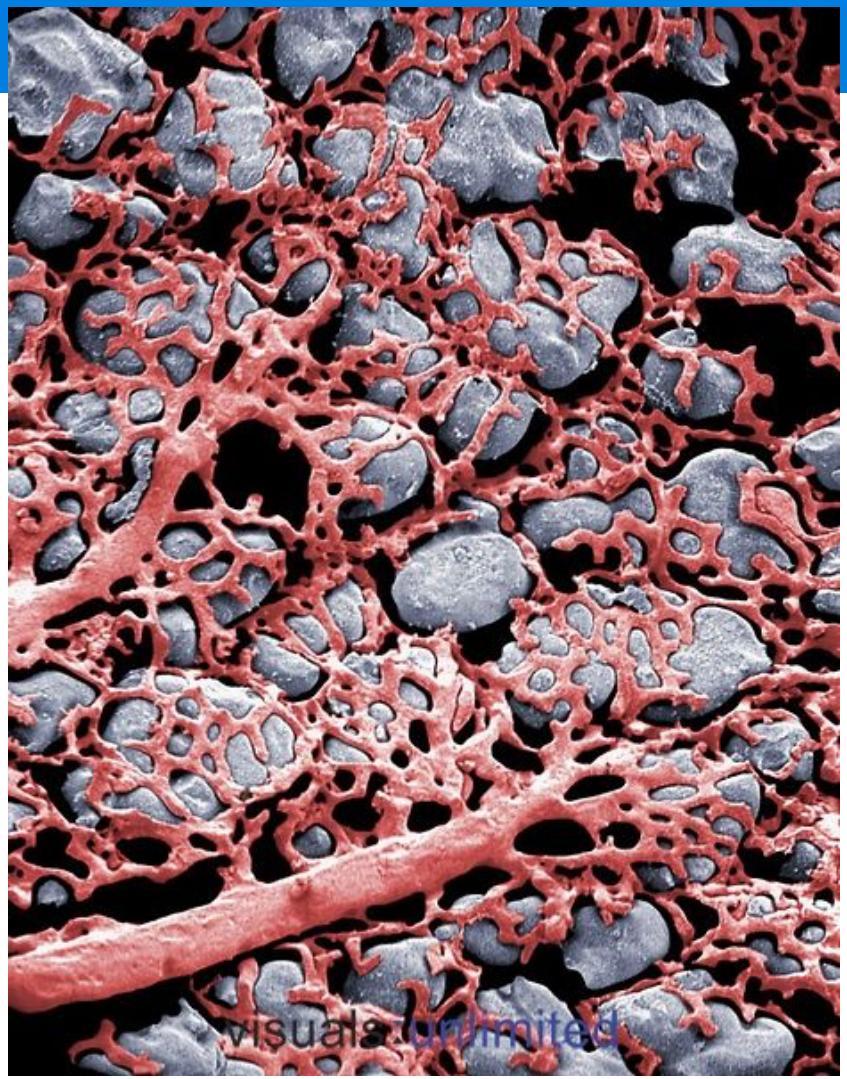

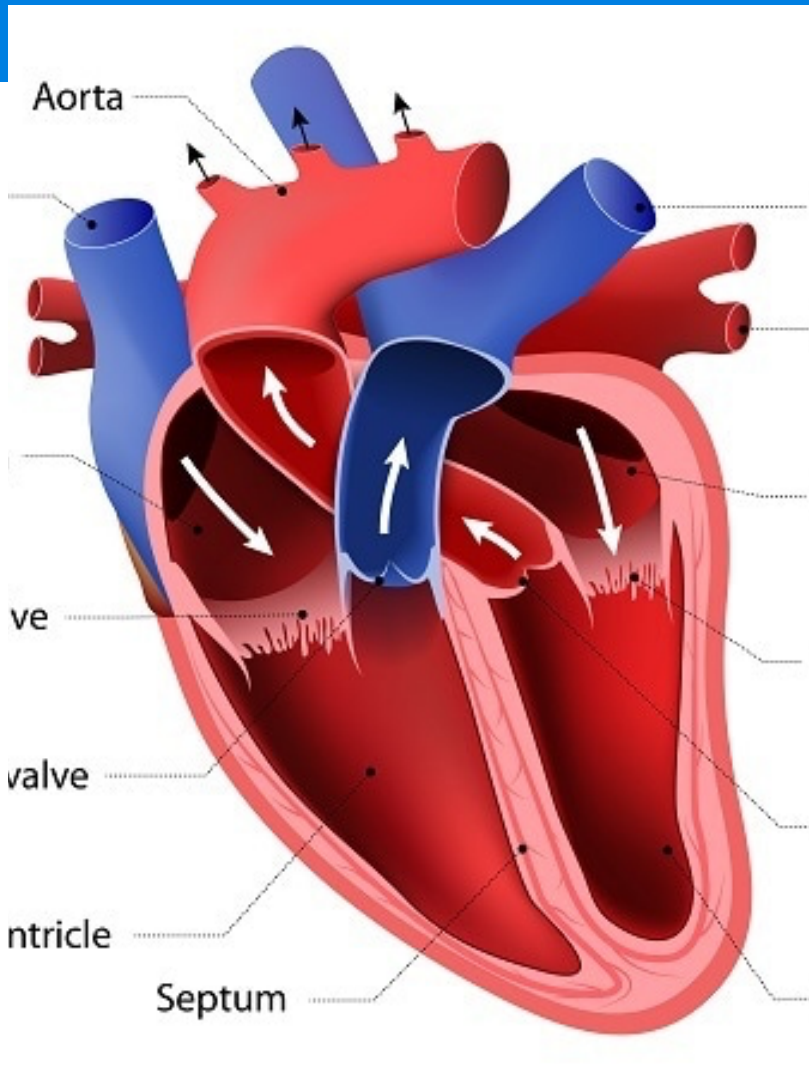

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Conclusiones

- MR aumentan la cantidad de tejido pulmonar aireado
- MR mejoran oxigenación y mecánica respiratoria
- Precaucion con hipoventilación y bajo gasto cardiaco
- Las estrategias de alto reclutamiento serían utiles en pacientes con SDRA severo
- Hay varias formas de hacer MR, mas que una maniobra se debe enfocar como una estrategia
- Alto PEEP y MR no han demostrado disminución de mortalidad ni outcomes duros.

Gracias por su atención

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Escuela de Medicina