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Servicio de Anestesia, Reanimación y Tratamiento del Dolor
HOSPITAL GENERAL UNIVERSITARIO VALENCIA

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Hospital General
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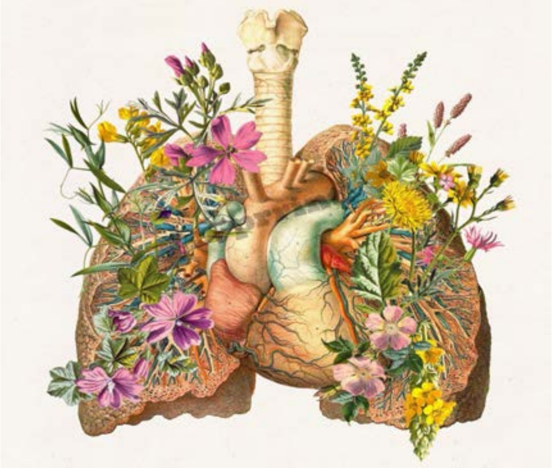


Ventilación mecánica
Efectos fisiológicos y resultados clínicos

Prof. F Javier Belda MD, PhD
Professor of Anesthesiology and Critical Care
University of Valencia (Spain)
fjbelda@uv.es

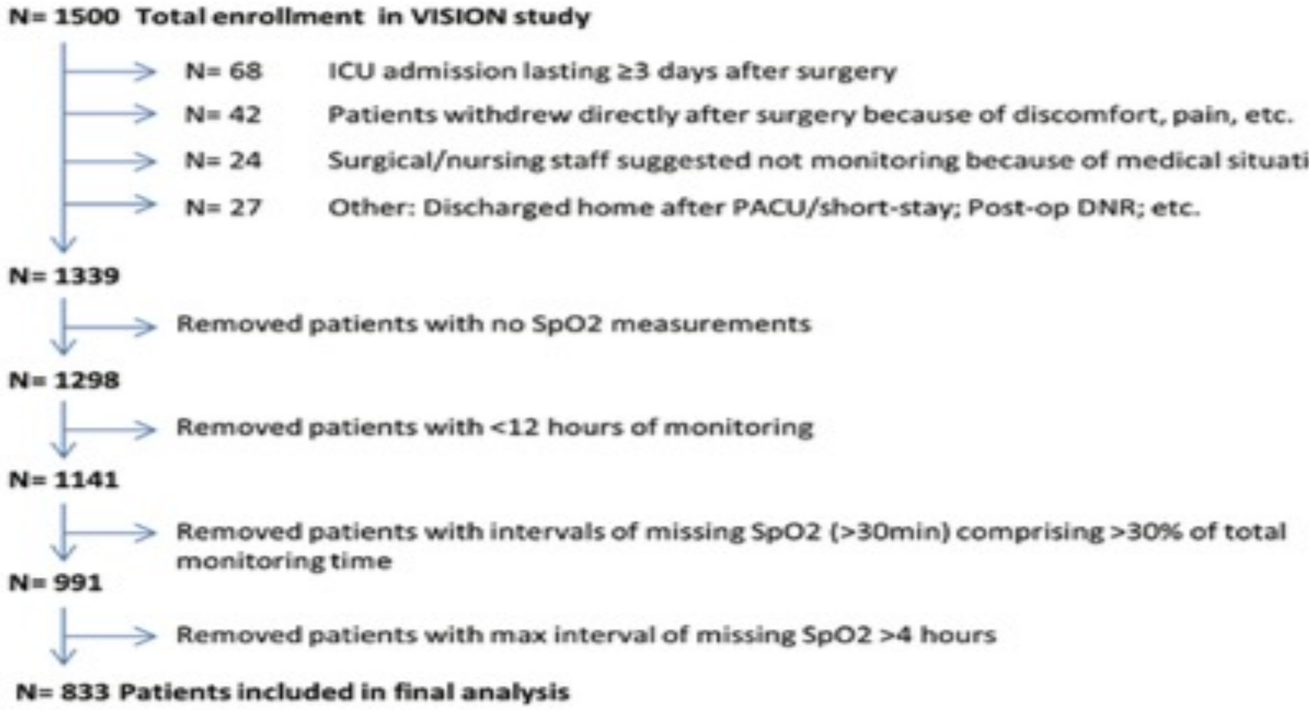
Section Editor: Sorin J. Brull

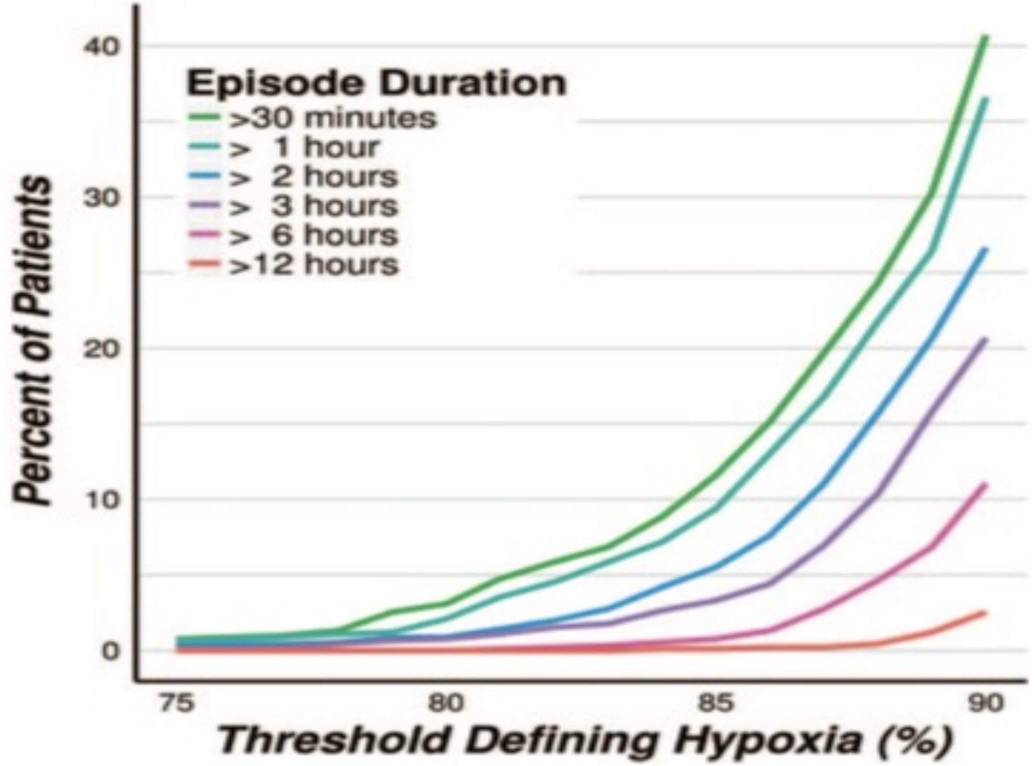
Postoperative Hypoxemia Is Common and Persistent: A Prospective Blinded Observational Study

Zhuo Sun, MD,* Daniel I. Sessler, MD,*† Jarrod E. Dalton, PhD,* PJ Devereaux, MD, PhD,†‡
Aram Shahinyan, MD,* Amanda J. Naylor, BA,* Matthew T. Hutcherson, BS,*
Patrick S. Finnegan, BA, NREMT-B,* Vikas Tandon, MD,‡ Saeed Darvish-Kazem, MD,‡§
Shaan Chugh, MD,‡ Hussain Alzayer, BSc, MD,‡|| and Andrea Kurz, MD*

Postoperative Hypoxemia: 833 patients from Cleveland Clinic

SpO_2 < 90%/48h





Anesth Analg 2015;121:709-15

ORIGINAL ARTICLE

Epidemiology, practice of ventilation and outcome for patients at increased risk of postoperative pulmonary complications

LAS VEGAS - an observational study in 29 countries

Eur J Anaesthesiol 2017; **34**:492–507

The LAS VEGAS investigators*

Table 5 Patient outcomes *N = 9864*

Variable	All patients	Low risk of PPCs	Increased risk of PPCs	Relative Risk (95% CI)	*P*
Postoperative pulmonary complications					
Total PPCs[a]	10.4 (1004/9697)	7.0 (467/6675)	19.2 (505/2632)	3.16 (2.76 to 3.61)	<0.001
Unplanned supplemental O_2[b]	8.5 (826/9697)	5.8 (390/6675)	15.5 (408/2632)	2.96 (2.55 to 3.42)	<0.001
Respiratory failure	1.6 (156/9697)	0.9 (60/6675)	3.4 (90/2632)	3.90 (2.81 to 5.43)	<0.001
Invasive MV	1.1 (107/9697)	0.6 (41/6675)	2.3 (61/2632)	3.84 (2.58 to 5.72)	<0.001
ARDS	0.1 (9/9697)	0.0 (1/6675)	0.3 (8/2632)	20.35 (2.54 to 162.76)	<0.001
Pneumonia	0.4 (40/9697)	0.1 (10/6675)	1.1 (28/2632)	7.17 (3.48 to 14.77)	<0.001
Pneumothorax	0.1 (13/9697)	0.1 (8/6675)	0.2 (4/2632)	1.27 (0.38 to 4.23)	0.697
Postoperative outcome					
Length of hospital stay	1.0 [0.0 to 4.0]	1.0 [0.0 to 3.0]	4.0 [1.0 to 7.0]	-	<0.001
In-hospital mortality	0.6 (56/8973)	0.2 (13/6163)	1.7 (41/2445)	8.07 (4.32 to 15.08)	<0.001
Hospital-free days[c]	26.0 [23.0 to 27.0]	26.0 [24.0 to 27.0]	23.0 [21.0 to 26.0]	-	<0.001

Futier et al. IMPROVE NEJM 2014: 35%
ProveNet. PROVHILO Lancet 2015: 40%
Ferrando et al. iPROVE Lancet respir Med 2018: 40%

First question: How do you ventilate your patients in OR and ICU?

A. PROTECTIVE MECHANICAL VENTILATION
B. NON PROTECTIVE MECHANICAL VENTILATION
C. NONE OF THE ABOVE

What means PMV for you?

A. Stay inside the OR
B. To apply the protocol
C. Prevent Lung Injury

Avoid overdistention: Low VT
Prevent colapse and
closing-reopening: PEEP

Feature Articles

Ventilator-associated lung injury in patients without acute lung injury at the onset of mechanical ventilation*

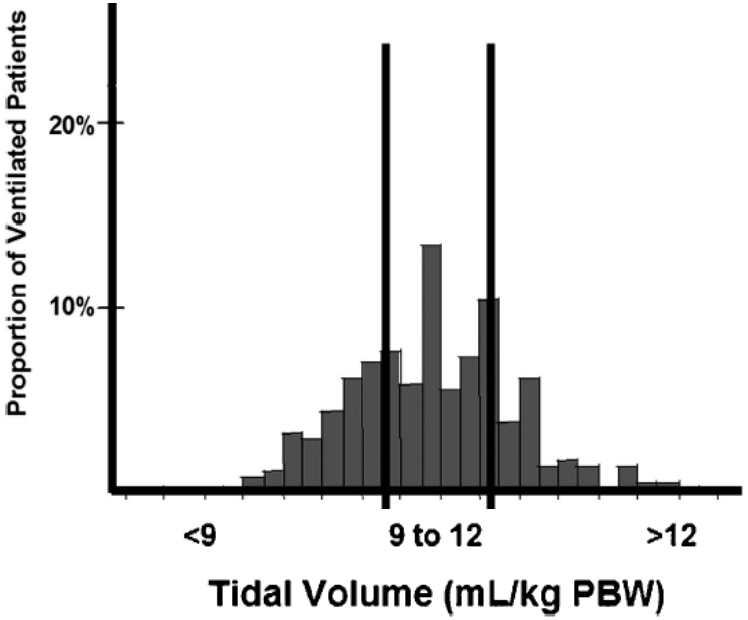
Ognjen Gajic, MD; Saqib I. Dara, MD; Jose L. Mendez, MD; Adebola O. Adesanya, MD; Emir Festic, MD; Sean M. Caples, MD; Rimki Rana, MD; Jennifer L. St. Sauver, PhD; James F. Lymp, PhD; Bekele Afessa, MD; Rolf D. Hubmayr, MD

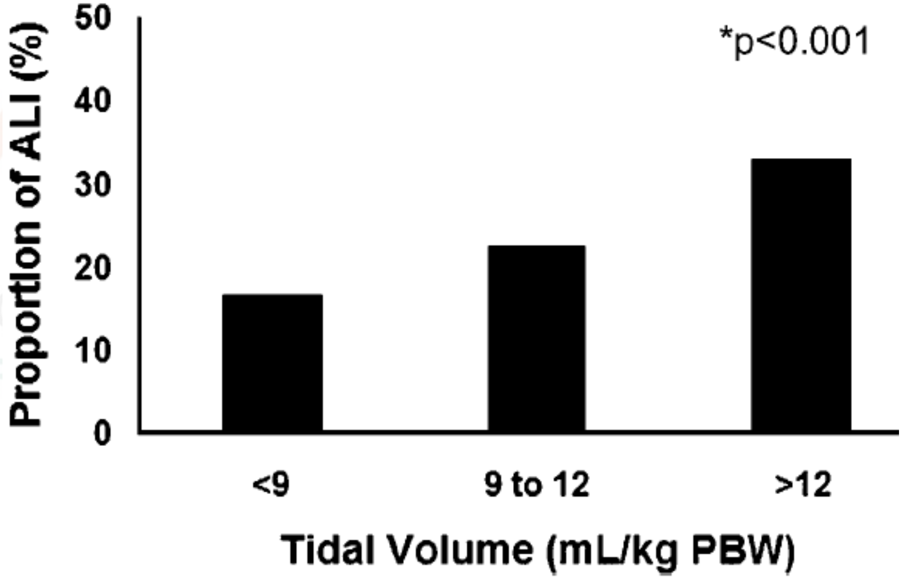
Critical Care Medicine

Crit Care Med 2004;32:1817-1824

332 patients without ALI under VM ≥48h

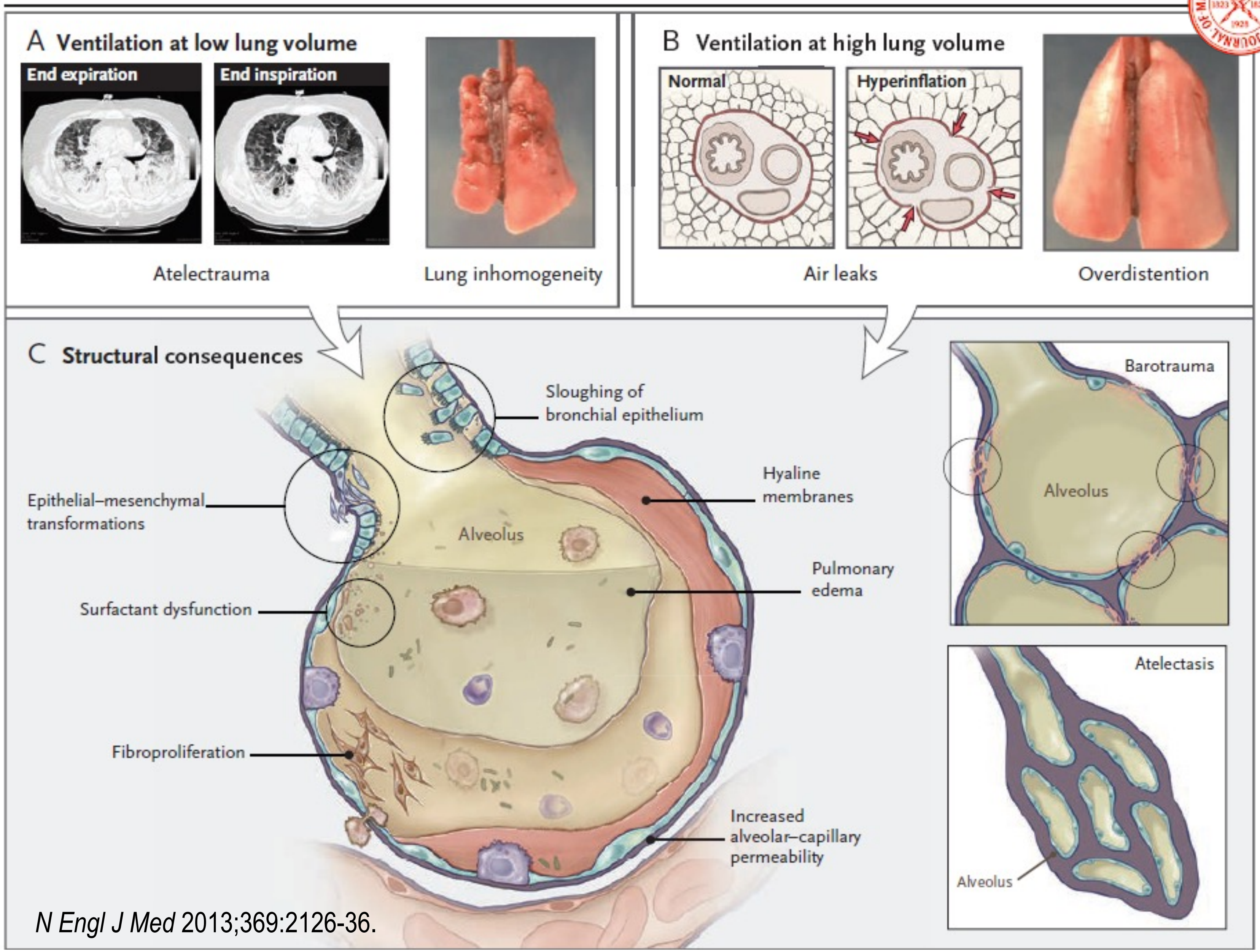
25% developed ARDS after 2,5 days of MV





Factors associated with the development of Acute Lung Injury:
Use of high VT
Acidemia, Transfusion of blood products
Restrictive lung disease.

OR for ALI development:
1.3 for each ml VT above 6 ml/kg PBW.



N Engl J Med 2013;369:2126-36.

The NEW ENGLAND JOURNAL of MEDICINE

Ventilator-Induced Lung Injury

Arthur S. Slutsky, M.D., and V. Marco Ranieri, M.D.

VILI Physiopathology

High VT
- Barotrauma
- Alveolar rupture
- Volutrauma
- Overdistention

Repetitive Opening-closing
- Atelectrauma

Mechanical injury:
activation proinflammatory cytokine cascade
- Biotrauma

The NEW ENGLAND JOURNAL of MEDICINE

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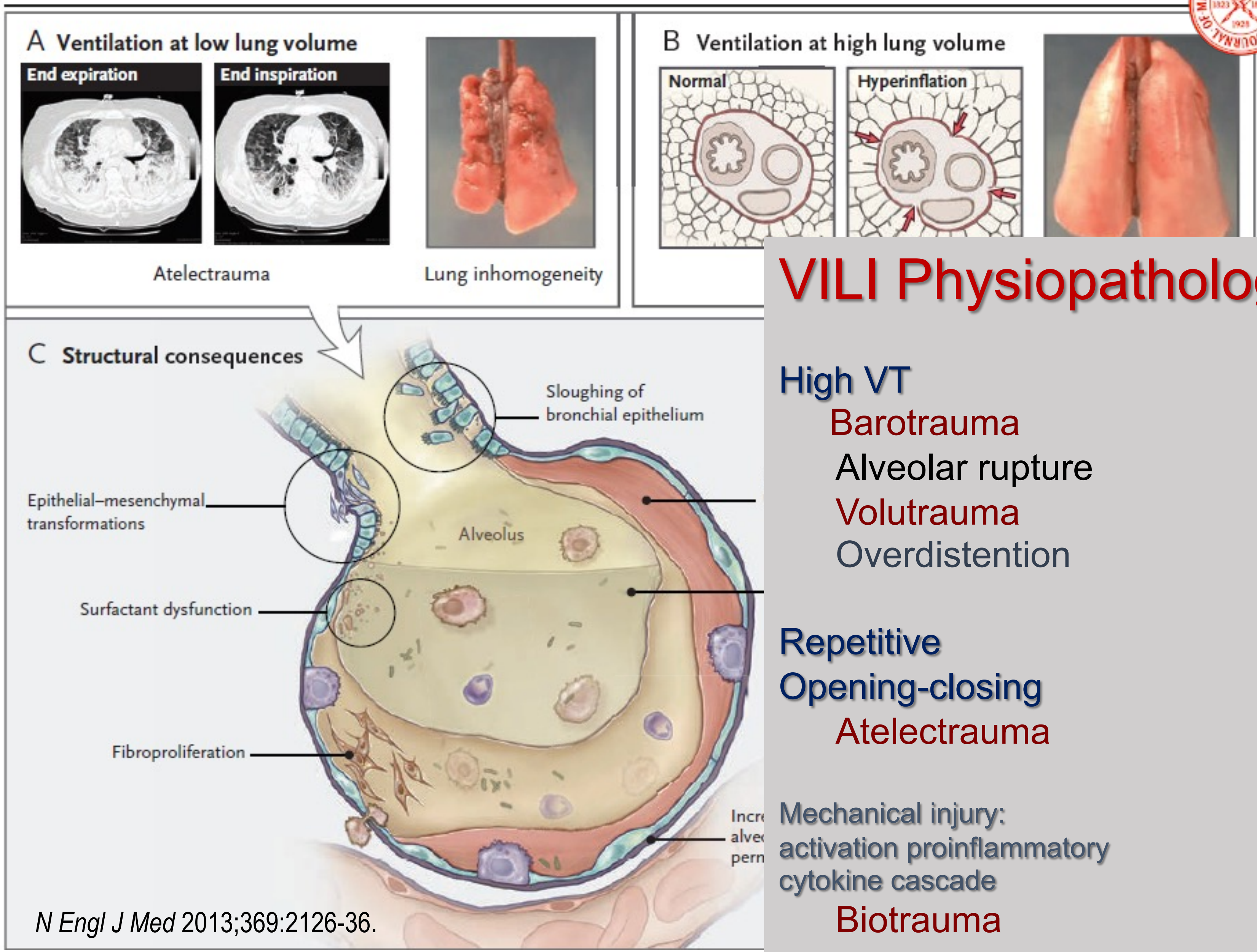


N Engl J Med 2013;369:2126-36.

VILI Physiopathology

High VT
- Barotrauma
- Alveolar rupture
- Volutrauma
- Overdistention

Repetitive Opening-closing
- Atelectrauma

Mechanical injury: activation proinflammatory cytokine cascade
- Biotrauma

Lung protection

Low VT
- Barotrauma
- Alveolar rupture
- Volutrauma
- Overdistention

PEEP
- Atelectrauma

Avoid Mechanical injury: activation proinflammatory cytokine cascade
- Biotrauma

Mechanical ventilation induces lung injury

Lung protective ventilation strategy ARDS

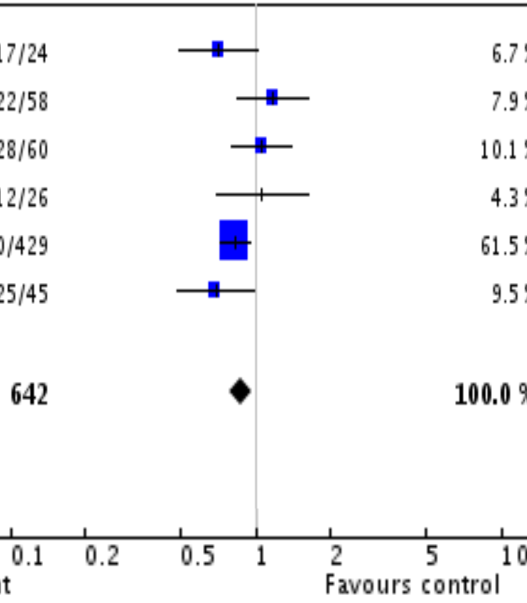
Ventilation with lower VT vs traditional VT in adults for ALI/ARDS

5 Randomized trials: 1297 patients

Review: Lung protective ventilation strategy for the acute respiratory distress syndrome
Comparison: 1 Protective versus conventional
Outcome: 1 Mortality at the end of the follow up period for each trial

Study or subgroup	Protective n/N	Conventional n/N	Risk Ratio M-H,Fixed,95% CI	Weight	Risk Ratio M-H,Fixed,95% CI
Amato 1998	13/29	17/24		6.7 %	0.63 [0.39, 1.02]
Brochard 1998	27/58	22/58		7.9 %	1.23 [0.80, 1.89]
Stewart 1998	30/60	28/60		10.1 %	1.07 [0.74, 1.55]
Brower 1999	13/26	12/26		4.3 %	1.08 [0.62, 1.91]
ARDS Network 2000	133/432	170/429		61.5 %	0.78 [0.65, 0.93]
Villar 2006	17/50	25/45		9.5 %	0.61 [0.38, 0.98]
Total (95% CI)	**655**	**642**		**100.0 %**	**0.83 [0.72, 0.95]**

Total events: 233 (Protective), 274 (Conventional)
Heterogeneity: Chi² = 9.24, df = 5 (P = 0.10); I² =46%
Test for overall effect: Z = 2.69 (P = 0.0072)
Test for subgroup differences: Not applicable



High VT (control)
10-15 ml/Kg: 9.5 ml/kg
Paw: 31-37 cmH_2O

Mortality at day 28: 40%

Low VT (LPV)
$\leq$ 7 ml/kg: 5.2 ml/kg

Paw: 22-30 cmH_2O

Mortality at day 28: 30%

RR: 0.83

Low VT is associated with a 17% lower risk of mortality at 28 days

Cochrane Database of Systematic Reviews 2013/2017

Association Between Use of Lung-Protective Ventilation With Lower Tidal Volumes and Clinical Outcomes Among Patients Without Acute Respiratory Distress Syndrome

A Meta-analysis

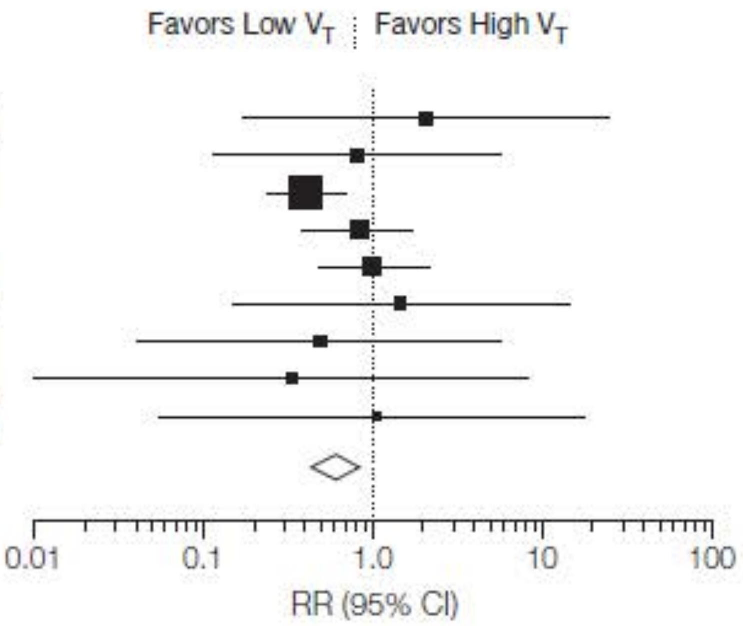
JAMA®

Serpa-Neto A et al. JAMA. 2012;308(16):1651-1659

20 Articles: 2822 study participants VT 6 m/IBW vs 10 ml/IBW

	High V_T, No.		Low V_T, No.			
	Events	Total	Events	Total	Weight, %	RR (95% CI)
Mortality						
Michelet et al,[20] 2006	1	26	2	26	1.0	2.08 (0.18-24.51)
Wolthuis et al,[22] 2007	2	13	3	23	2.5	0.82 (0.12-5.71)
Yilmaz et al,[23] 2007	69	212	27	163	55.7	0.41 (0.25-0.68)
Licker et al,[26] 2009	15	533	13	558	16.7	0.82 (0.39-1.75)
Determann et al,[27] 2010	23	74	24	76	17.7	1.02 (0.51-2.04)
Fernandez-Bustamante et al,[29] 2011	1	75	3	154	1.5	1.47 (0.15-14.38)
Sundar et al,[30] 2011	2	74	1	75	2.2	0.49 (0.04-5.48)
Yang et al,[31] 2011	1	50	0	50	1.7	0.33 (0.01-8.21)
Weingarten et al,[32] 2012	1	20	1	20	1.1	1.00 (0.06-17.18)
Subtotal (95% CI)		1077		1145	100.0	0.64 (0.46-0.86)
Total events	115		74			

Heterogeneity: $\chi^2_8 = 6.94$; $P = .54$, $I^2 = 0\%$
Test for overall effect: $z = 2.68$; $P = .007$



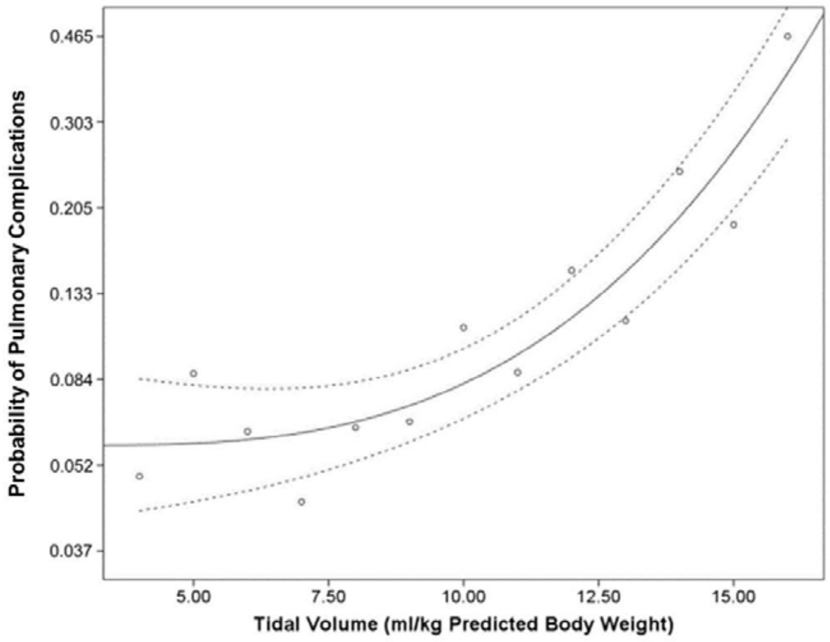
Lung-Protective Ventilation With Low Tidal Volumes and the Occurrence of Pulmonary Complications in Patients Without Acute Respiratory Distress Syndrome: A Systematic Review and Individual Patient Data Analysis*

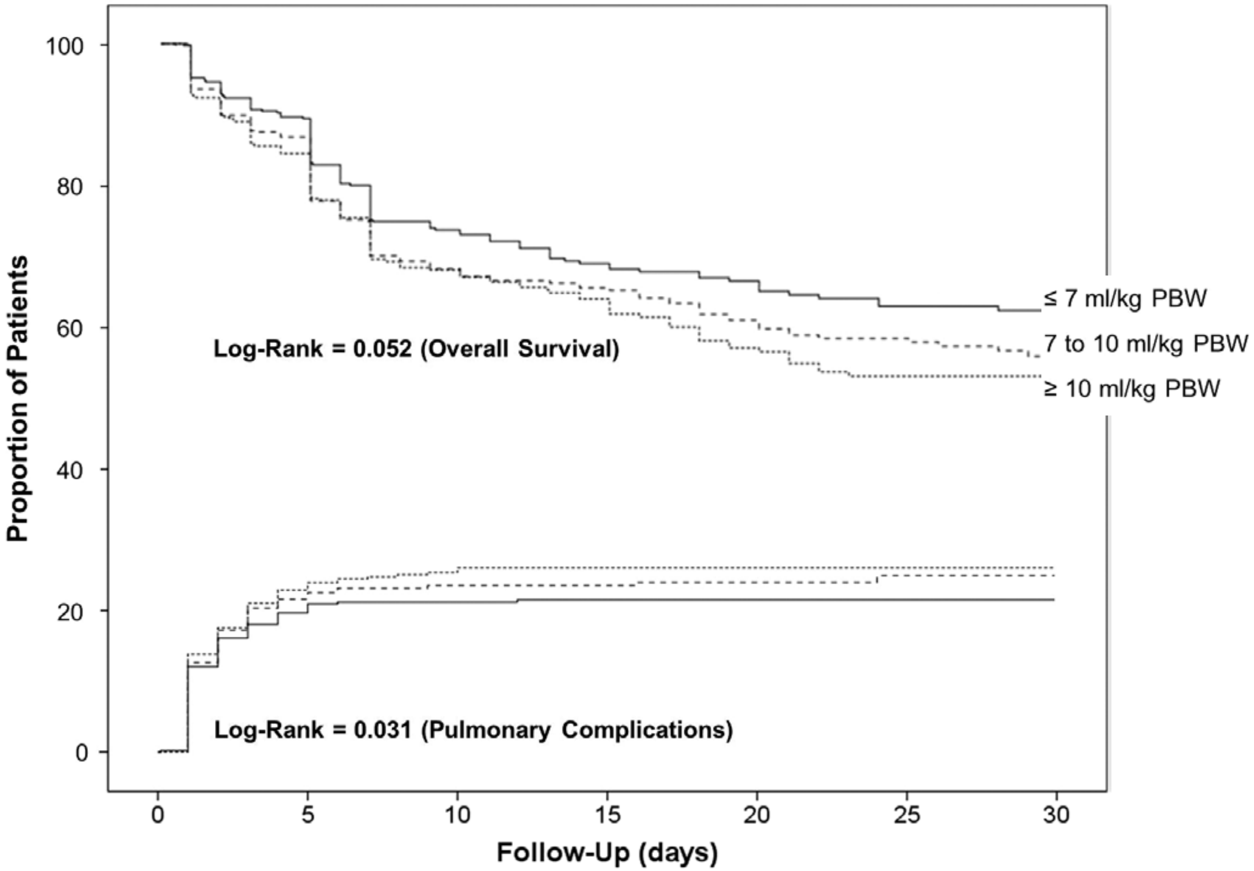
Ary Serpa Neto, MD, MSc, PhD[1,2,3]; Fabienne D. Simonis, MD[1]; Carmen S. V. Barbas, MD, PhD[3];

Critical Care Medicine

Crit Care Med 2015; 43:2155–2163

2,184 patients under MV >2 days.
VT: <7, 7-10, >10 mlPBW
Four observational studies and four RCTs
Composite of occurrence of ARDS or pneumonia





Protective *versus* Conventional Ventilation for Surgery

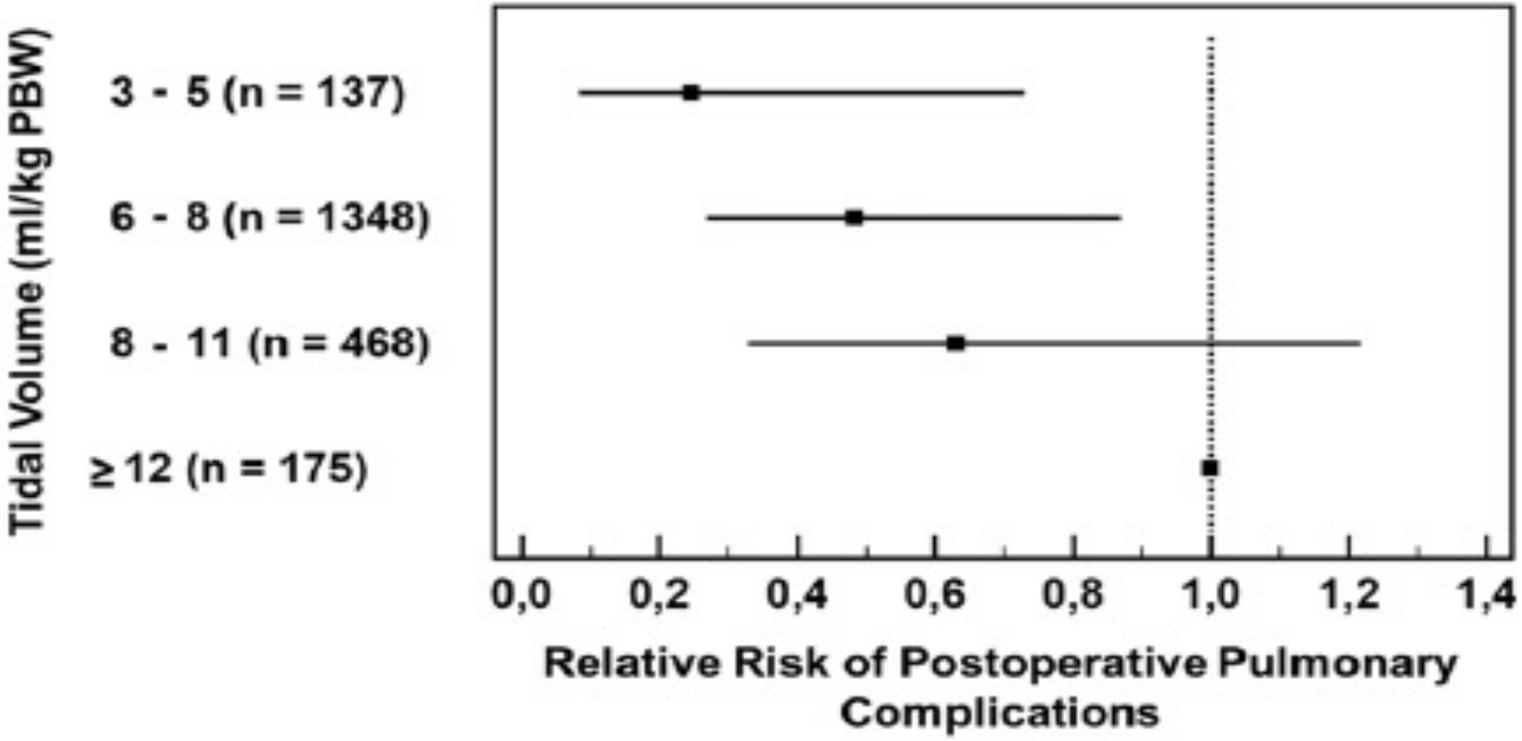
A Systematic Review and Individual Patient Data Meta-analysis

Ary Serpa Neto, M.D., M.Sc., Ph.D., Sabrine N. T. Hemmes, M.D., Carmen S. V. Barbas, M.D., Ph.D., Paolo Pelosi, M.D., F.E.R.S., Marcus J. Schultz, M.D., Ph.D.; for the PROVE Network Investigators

ANESTHESIOLOGY
The Journal of the American Society of Anesthesiologists, Inc. • anesthesiology.org

Anesthesiology 2015; 123:66-78

15 RCT
Abdominal and thoracic surgeries 2127 patients



General surgery
40 years ago

ANESTHESIA & ANALGESIA
1987;66:64-70

Hemodynamic Effects of Infusions of the Emulsion Formulation of Propofol during Nitrous Oxide Anesthesia in Humans

David P. Coates, MBBS, FFARCS, Christopher R. Monk, MBBS, FFARCS,
Cedric Prys-Roberts, DM, PhD, FFARCS, FFARACS, and Mark Turtle, MBBS, FFARCS

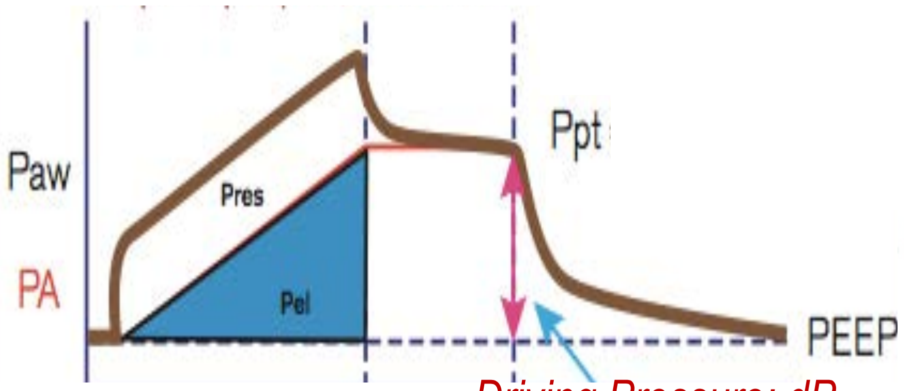
The ventilator was adjusted to deliver a tidal volume 12–15 ml/kg at a frequency of 12 breaths per minute.

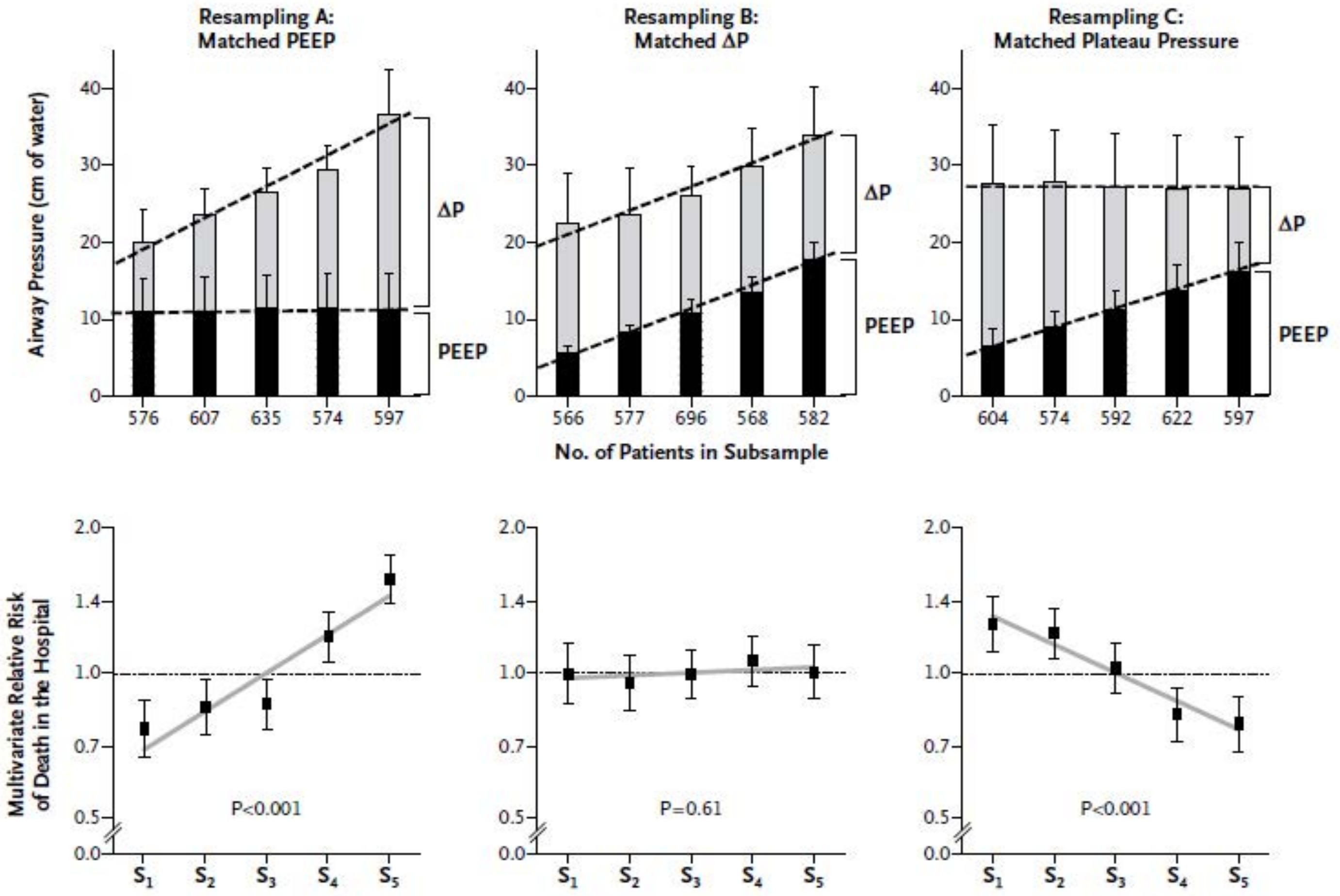
SPECIAL ARTICLE

Driving Pressure and Survival in the Acute Respiratory Distress Syndrome

Amato, N Engl J Med 2015; 372:747-755

9 RCTs individual data from 3562 ARDS patients: dP as independent variable associated with survival





SPECIAL ARTICLE

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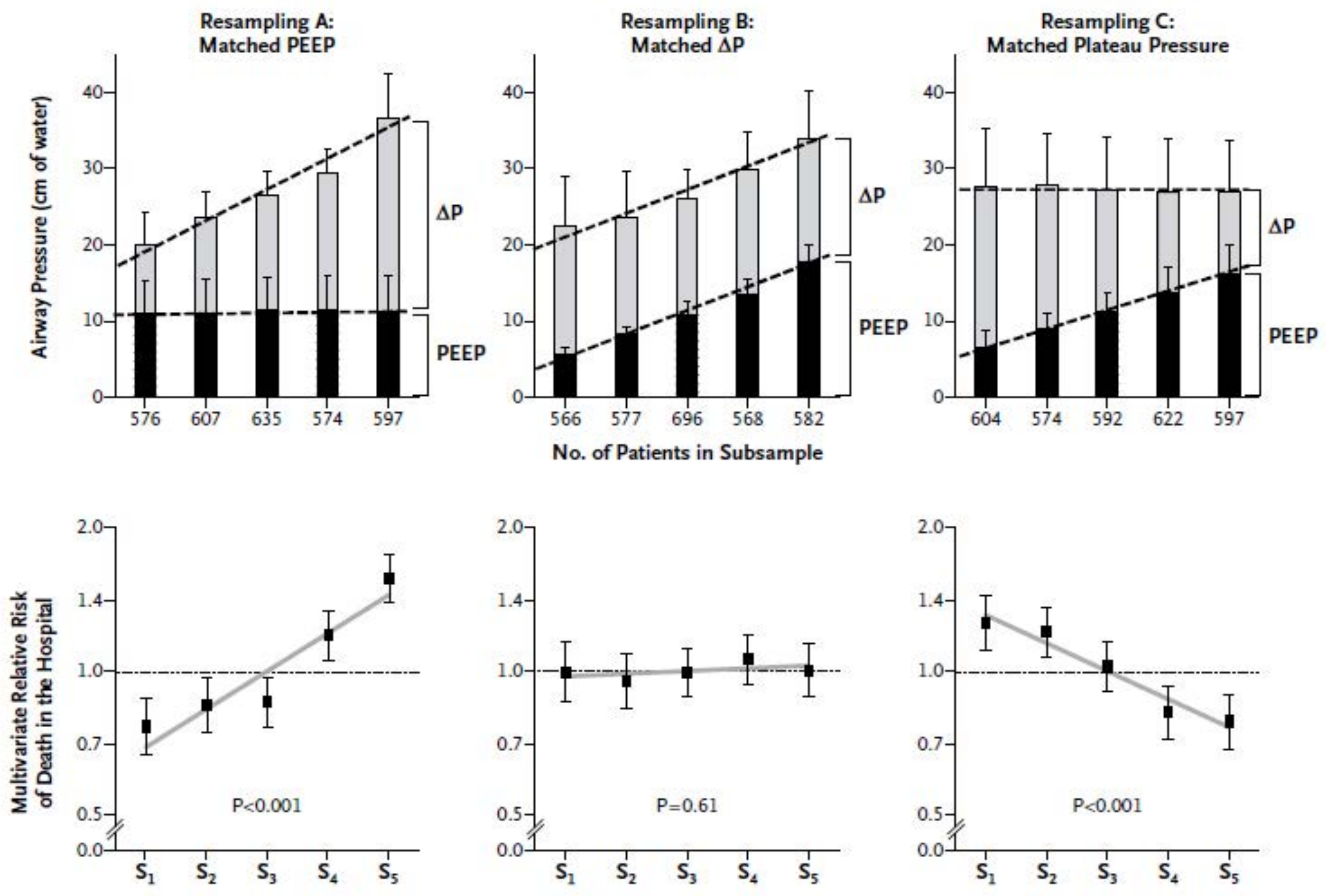
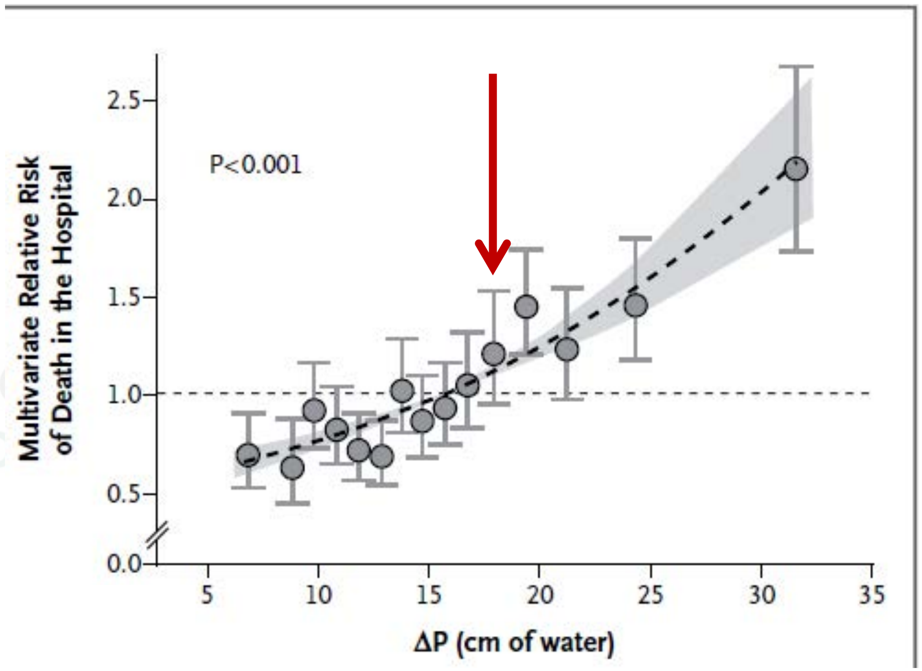




dP > 15 cmH2O
is associated
with increased mortality

Association between driving pressure and development of postoperative pulmonary complications in patients undergoing mechanical ventilation for general anaesthesia: a meta-analysis of individual patient data

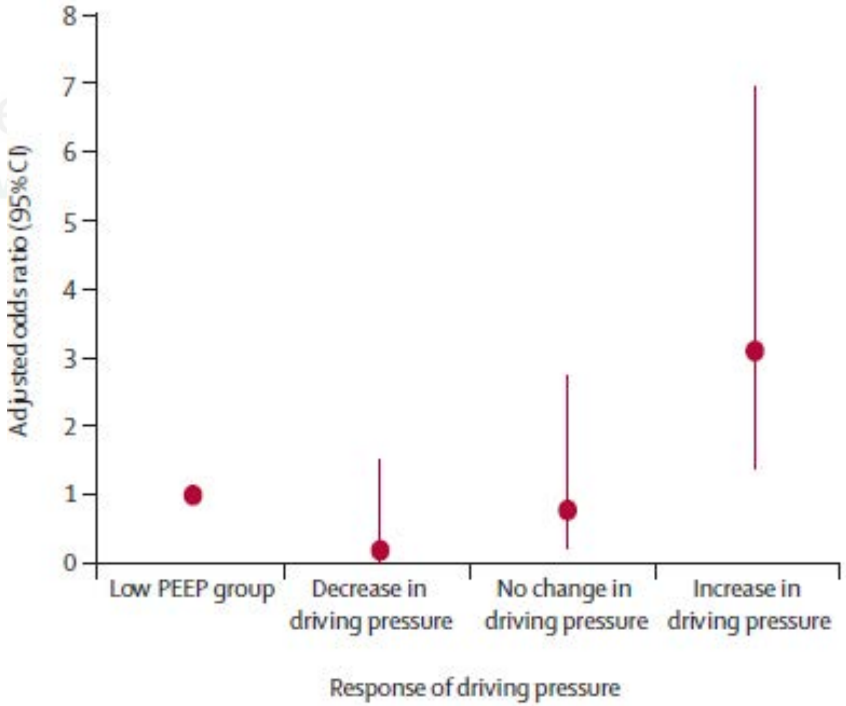
THE LANCET
Respiratory Medicine

Lancet Respir Med 2016

Ary Serpa Neto, Sabrine N T Hemmes, Carmen S V Barbas, Martin Beiderlinden, Ana Fernandez-Bustamante, Emmanuel Futier, Ognjen Gajic, Mohamed R El-Tahan, Abdulmohsin A Al Ghamdi, Ersin Günay, Samir Jaber, Serdar Kokulu, Alf Kozian, Marc Licker, Wen-Qian Lin, Andrew D Maslow, Stavros G Memtsoudis, Dinis Reis Miranda, Pierre Moine, Thomas Ng, Domenico Paparella, V Marco Ranieri, Federica Scavonetto, Thomas Schilling, Gabriele Selmo, Paolo Severgnini, Juraj Sprung, Sugantha Sundar, Daniel Talmor, Tanja Treschan, Carmen Unzueta, Toby N Weingarten, Esther K Wolthuis, Hermann Wrigge, Marcelo B P Amato, Eduardo L V Costa, Marcelo Gama de Abreu, Paolo Pelosi, Marcus J Schultz, for the PROVE Network Investigators

17 randomised controlled trials, including 2250 patients.

	Overall (n=2250)		Protective vs conventional* (n=834)	
	Odds ratio (95% CI)	p value	Odds ratio (95% CI)	p value
Ventilatory parameters				
Tidal volume (mL/kg PBW)	1·05 (0·98–1·13)	0·179	1·21 (1·06–1·38)	0·005
PEEP (cm H_2O)	··	··	0·78 (0·73–0·83)	<0·001
Respiratory rate (movements per min)	··	··	1·11 (0·75–1·65)	0·601
Driving pressure (cm H_2O)	1·16 (1·13–1·19)	<0·0001	1·31 (1·19–1·45)	<0·001
Plateau pressure (cm H_2O)	··	··	1·29 (1·19–1·40)	<0·001
FiO_2 (%)	13·17 (0·43–404·52)	0·140	··	··

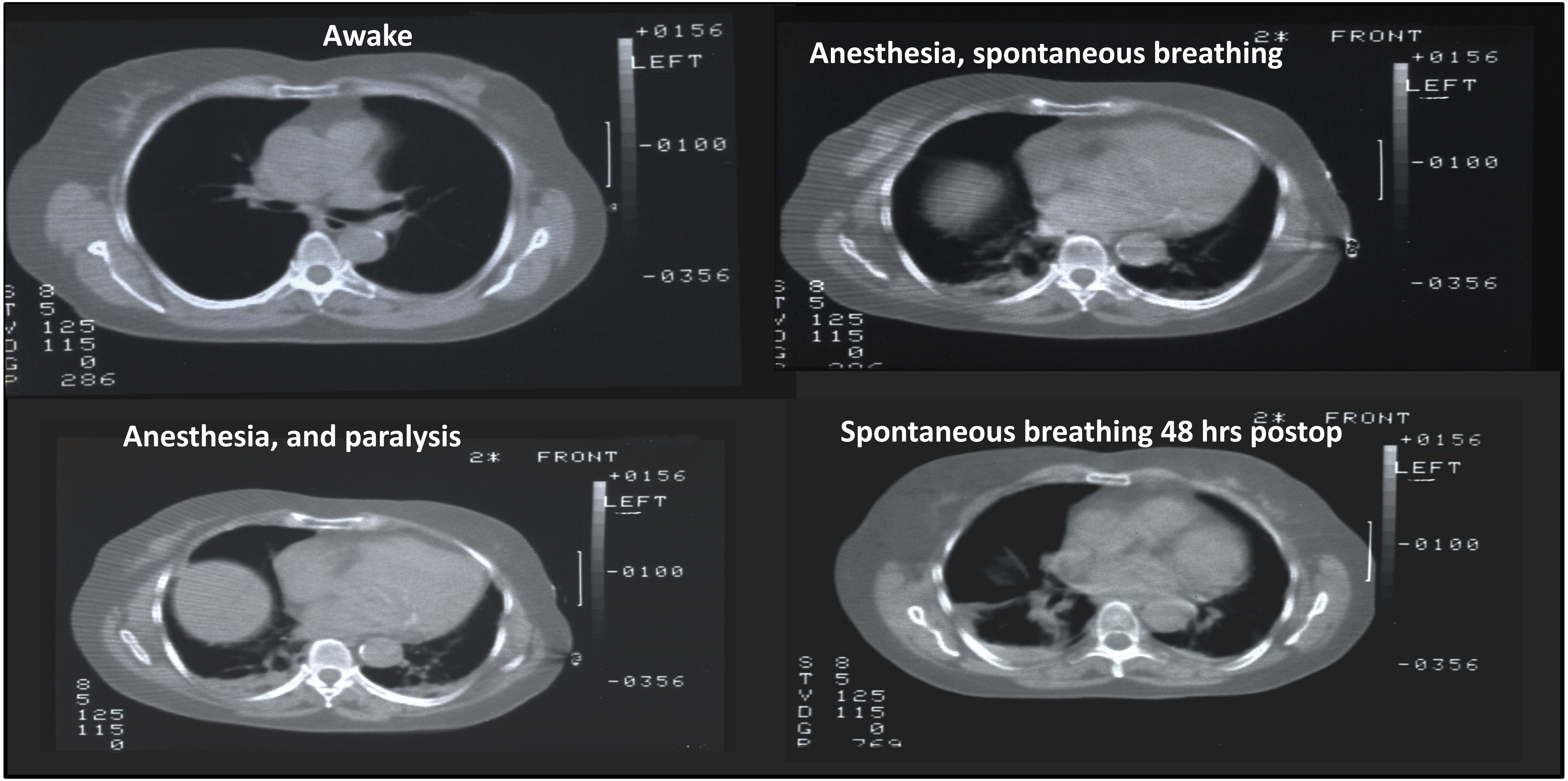


Protective strategy components

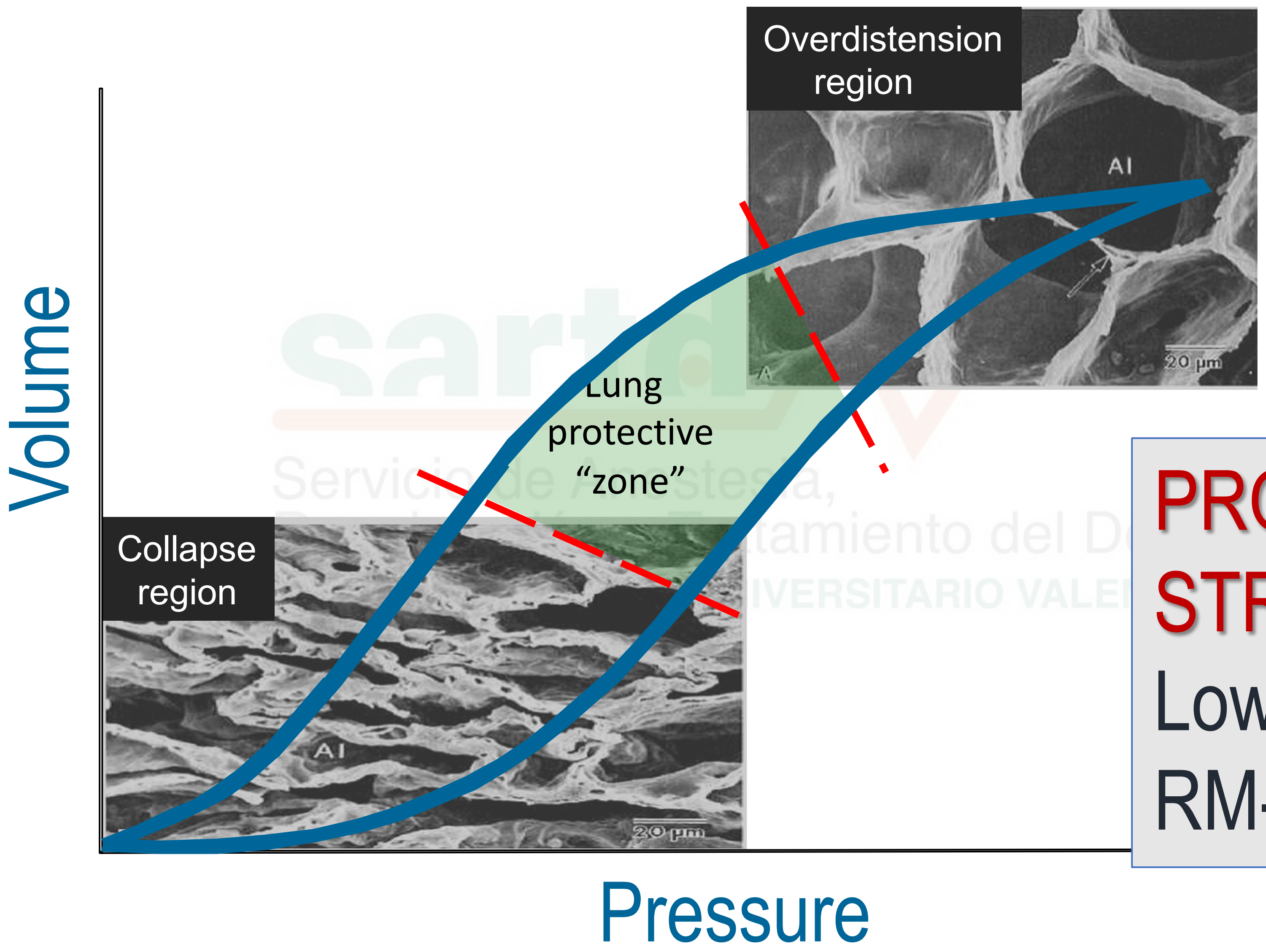
The effects of anesthesia and muscle paralysis on the respiratory system

Göran Hedenstierna
Lennart Edmark

Intensive Care Med (2005) 31:1327–1335



Strandberg A, Hedenstierna G, Tokics L, Lundquist H, Brismar B. Densities in dependent lung regions during anaesthesia: atelectasis or fluid accumulation? Acta Anaesthesiol Scand 1986;30:256-9.



PROTECTIVE STRATEGY

Low VT

RM-PEEP

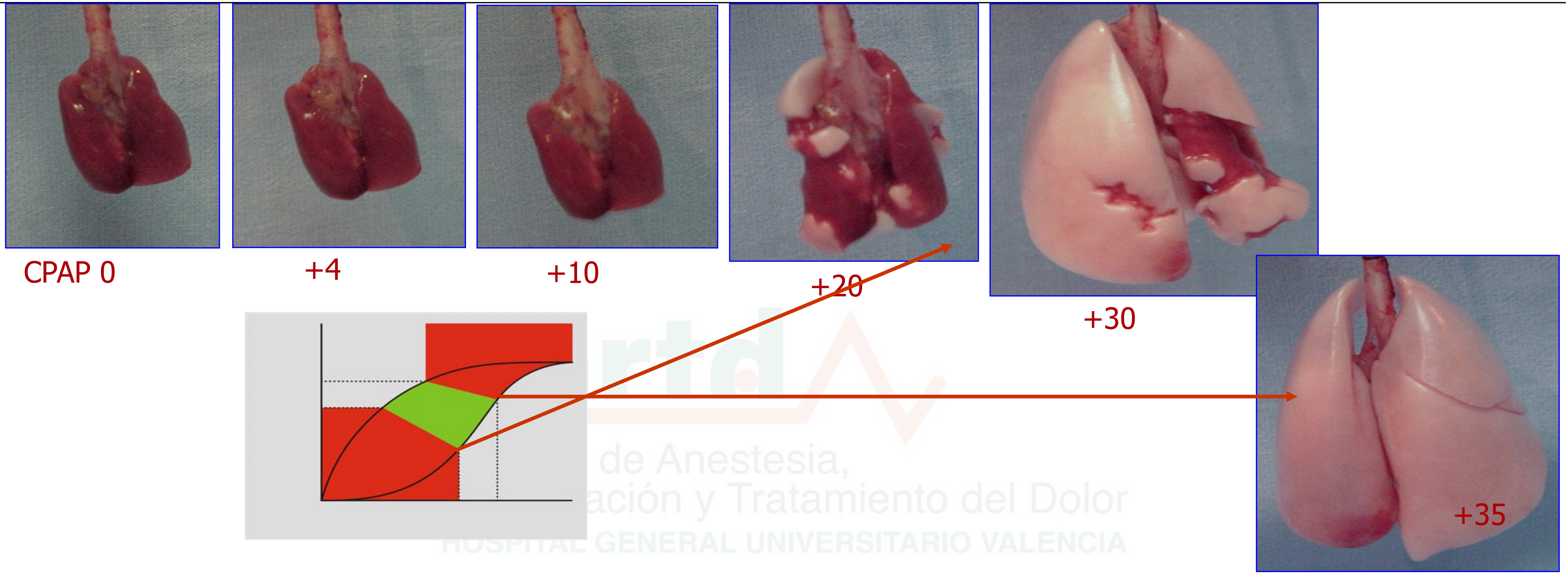
Open Lung Approach

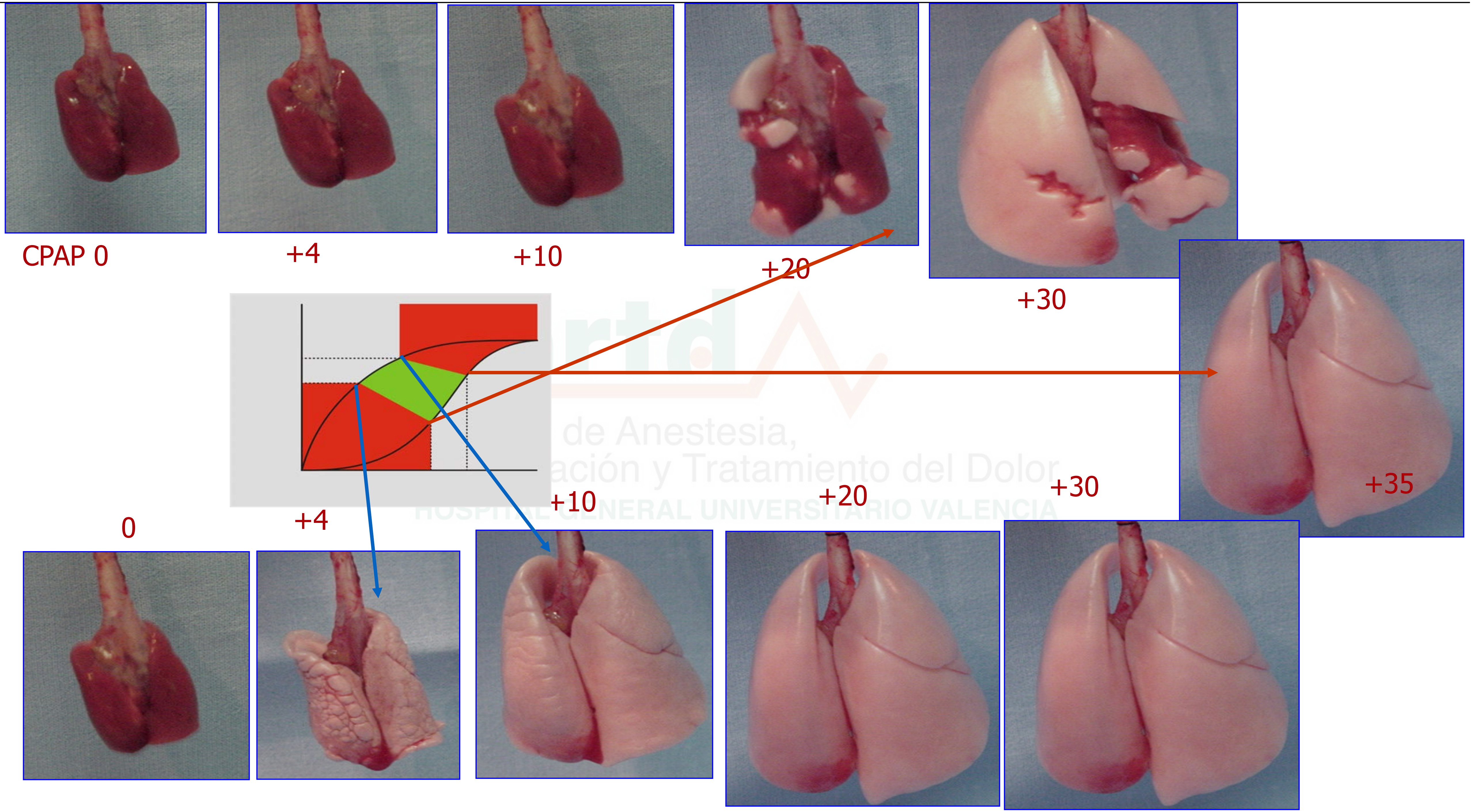
Ventilatory strategy aimed at re-expanding previously collapsed lung tissue by means of a brief and controlled increase in transpulmonary pressure…

Lung Recruitment

…and maintain lung re-expansion by the minimum level of PEEP that avoids end-expiratory lung collapse.

PEEP titration


CPAP 0
+4
+10
+20
+30
+35

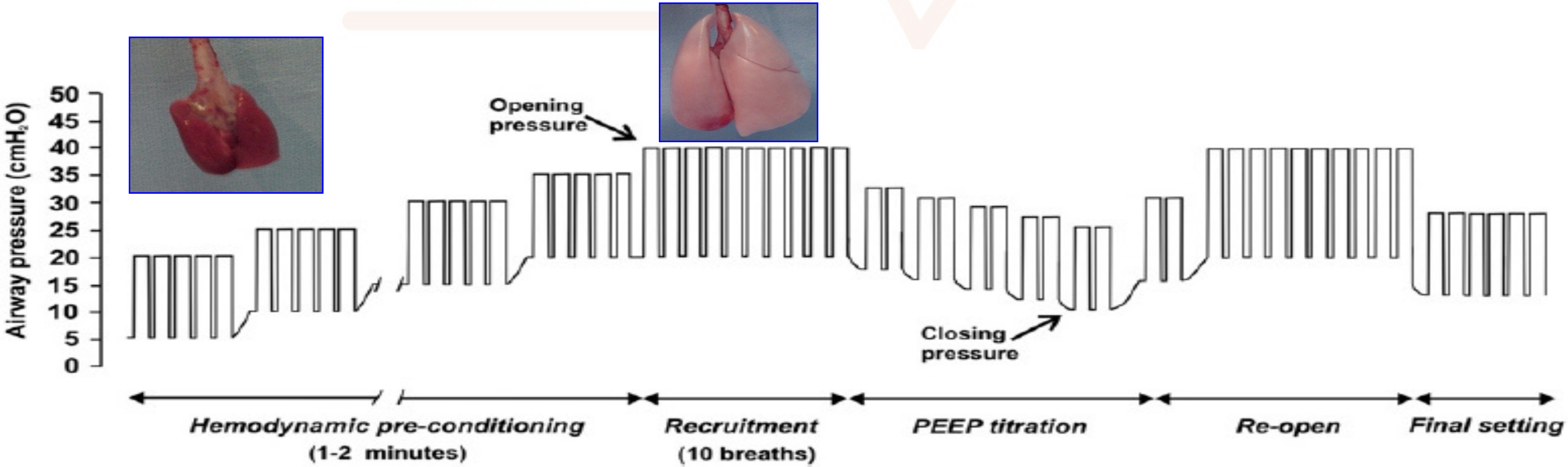

CPAP 0
+4
+10
+20
+30
+35
0
+4
+10
+20
+30

OLA Protocol: RM + PEEP titration

G. Tusman, J.F. Belda / Current Anaesthesia & Critical Care 21 (2010) 244–249

Protocol

PCV (10-15 cmH2O in normal lungs) for VT ≤ 8ml/kg
+ PEEP increments in steps of 5 cmH2O, from 5 to 20.



Csr=V/P	Low	low	maximal
Volume	Low	low	high

OLA Protocol: RM + PEEP titration

G. Tusman, J.F. Belda / Current Anaesthesia & Critical Care 21 (2010) 244–249

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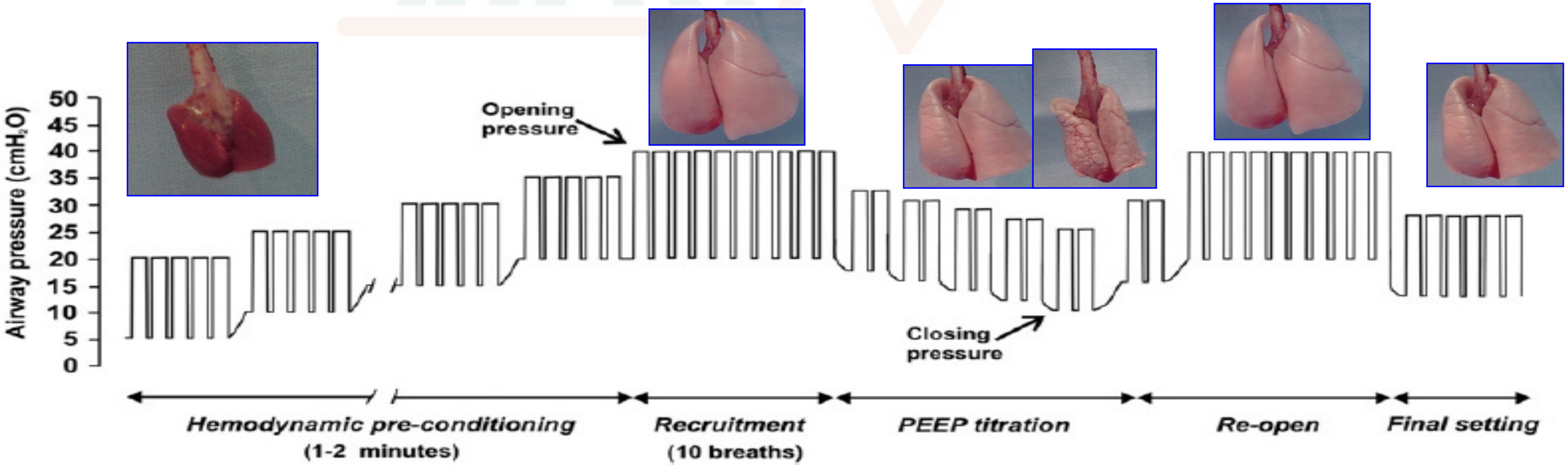


Csr=V/P	Low	low	maximal
Volume	Low	low	high

Use of dynamic compliance for open lung positive end-expiratory pressure titration in an experimental study

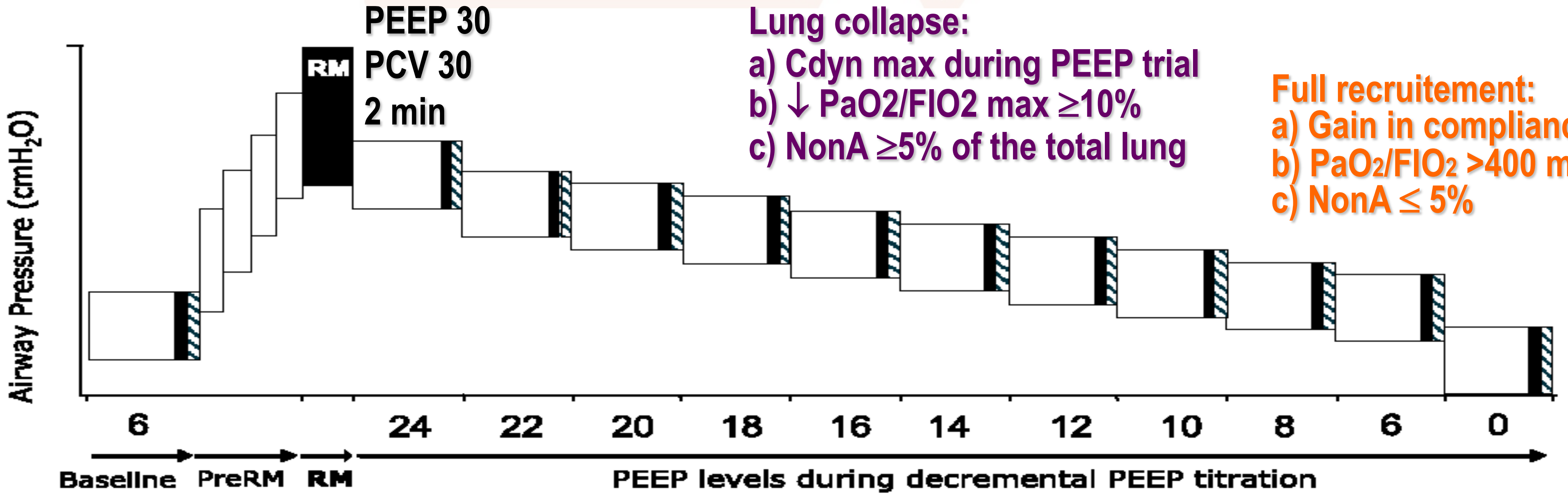
Critical Care Medicine
OFFICIAL JOURNAL OF THE SOCIETY OF CRITICAL CARE MEDICINE

Fernando Suarez-Sipmann, MD; Stephan H. Böhm, MD; Gerardo Tusman, MD; Tanja Pesch; Oliver Thamm; Hajo Reissmann, MD; Andreas Reske, MD; Anders Magnusson, MD, PhD; Göran Hedenstierna, MD, PhD

Crit Care Med 2007; 35:214–221

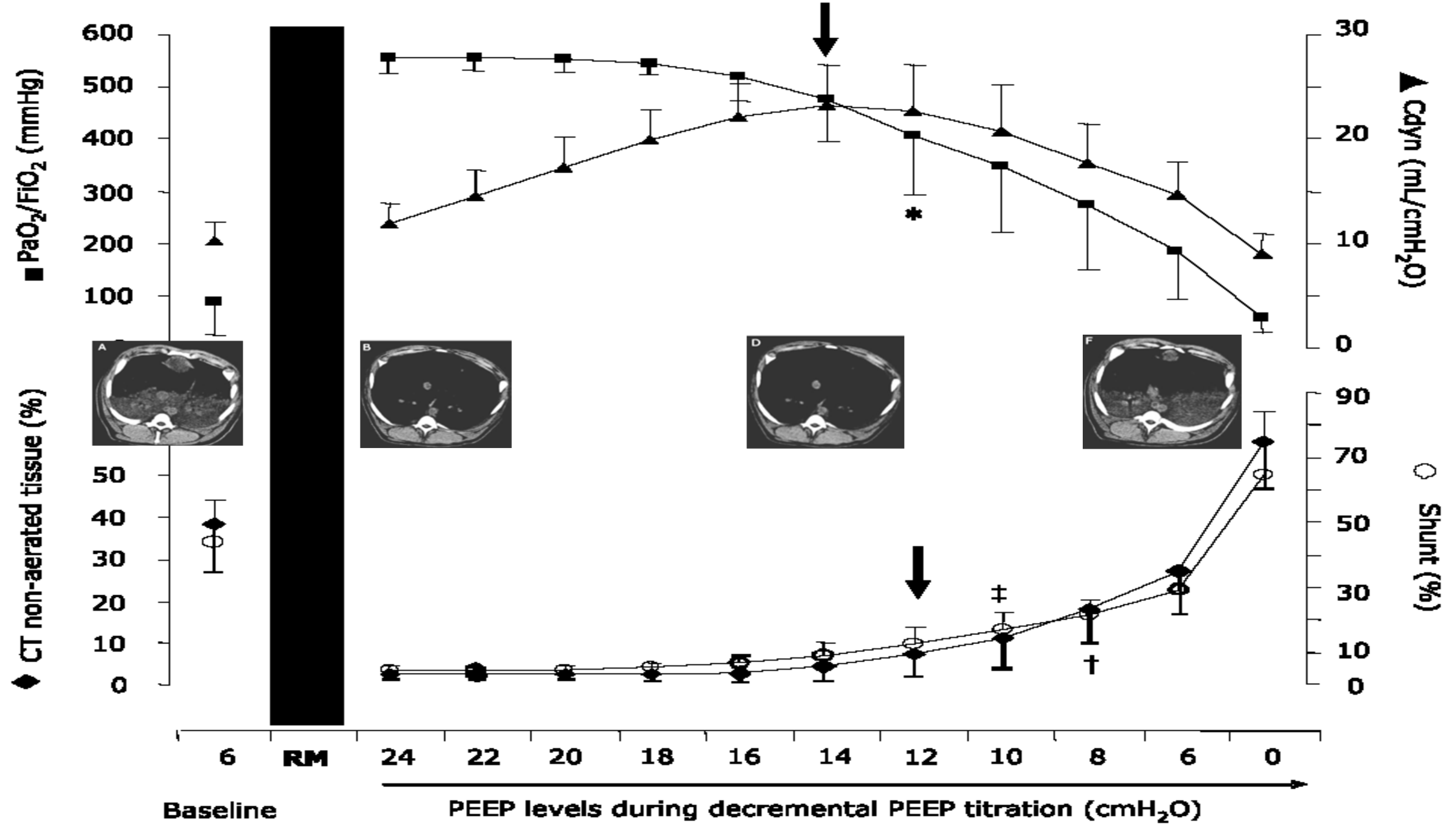
8 pigs with ARDS (lung lavage): RM+ decremental PEEP trial

P/F, Crs, CT-scan

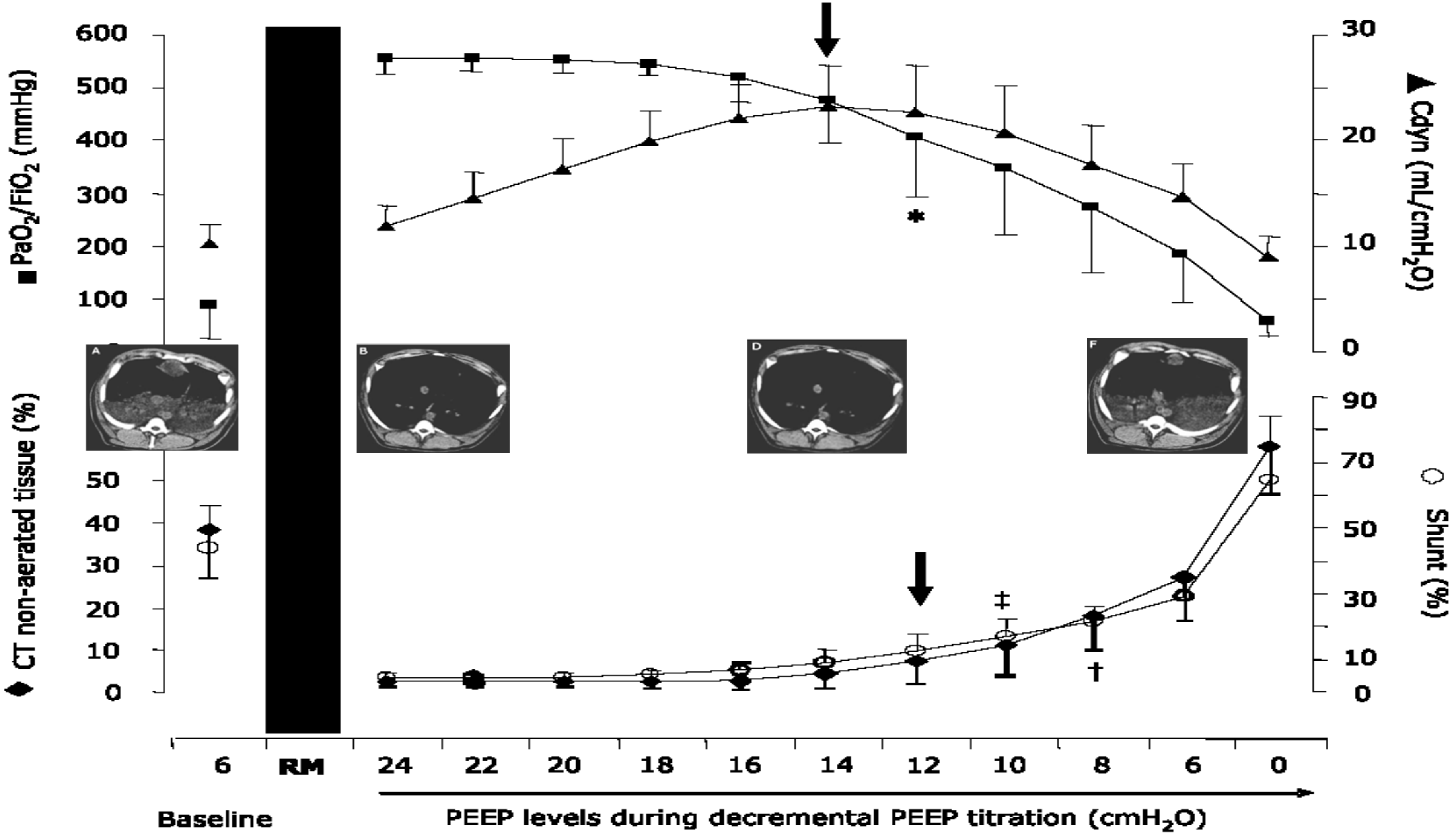


Lung collapse:
a) Cdyn max during PEEP trial
b) ↓ PaO2/FIO2 max ≥10%
c) NonA ≥5% of the total lung

Full recruitement:
a) Gain in compliance > 30%
b) PaO_2/FIO_2 >400 mm Hg
c) NonA ≤ 5%



PaO2/FiO2 (mmHg)
Cdyn (mL/cmH2O)
CT non-aerated tissue (%)
Shunt (%)
600
500
400
300
200
100
0
30
20
10
0
50
40
30
20
10
0
90
70
50
30
10
0
A
B
D
F
*
‡
†
6
RM
24
22
20
18
16
14
12
10
8
6
0
Baseline
PEEP levels during decremental PEEP titration (cmH2O)



Conclusions:

Cdyn identified the beginning of collapse after recruitment.

This is confirmed by oxygenation and CT-scans.

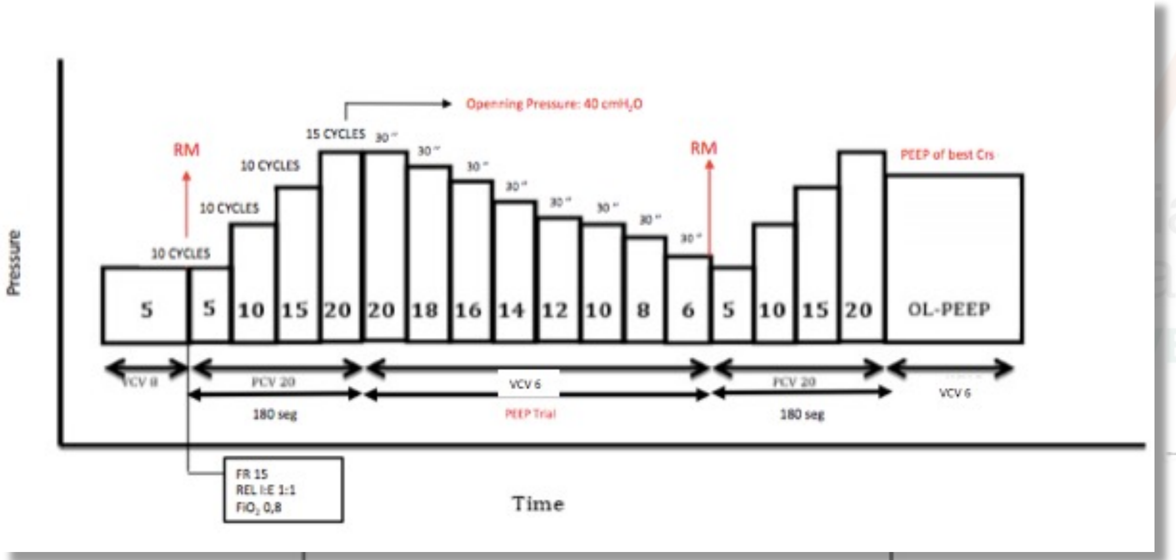
RESEARCH ARTICLE

Open lung approach versus standard protective strategies: Effects on driving pressure and ventilatory efficiency during anesthesia - A pilot, randomized controlled trial

PLOS ONE

PLoS One 2017; 11;12(5):e177399

Carlos Ferrando[1]*, Fernando Suarez-Sipmann[2,3], Gerardo Tusman[4], Irene León[1], Esther Romero[1], Estefania Gracia[1], Ana Mugarra[1], Blanca Arocas[1], Natividad Pozo[5], Marina Soro[1], Francisco J. Belda[1]



RM-5 group (n=18)

Analyzed n=18
Excluded for the analysis of lung efficiency n=3

OLA Group (n=18)

Analyzed n=18
Excluded for the analysis of lung efficiency n=4

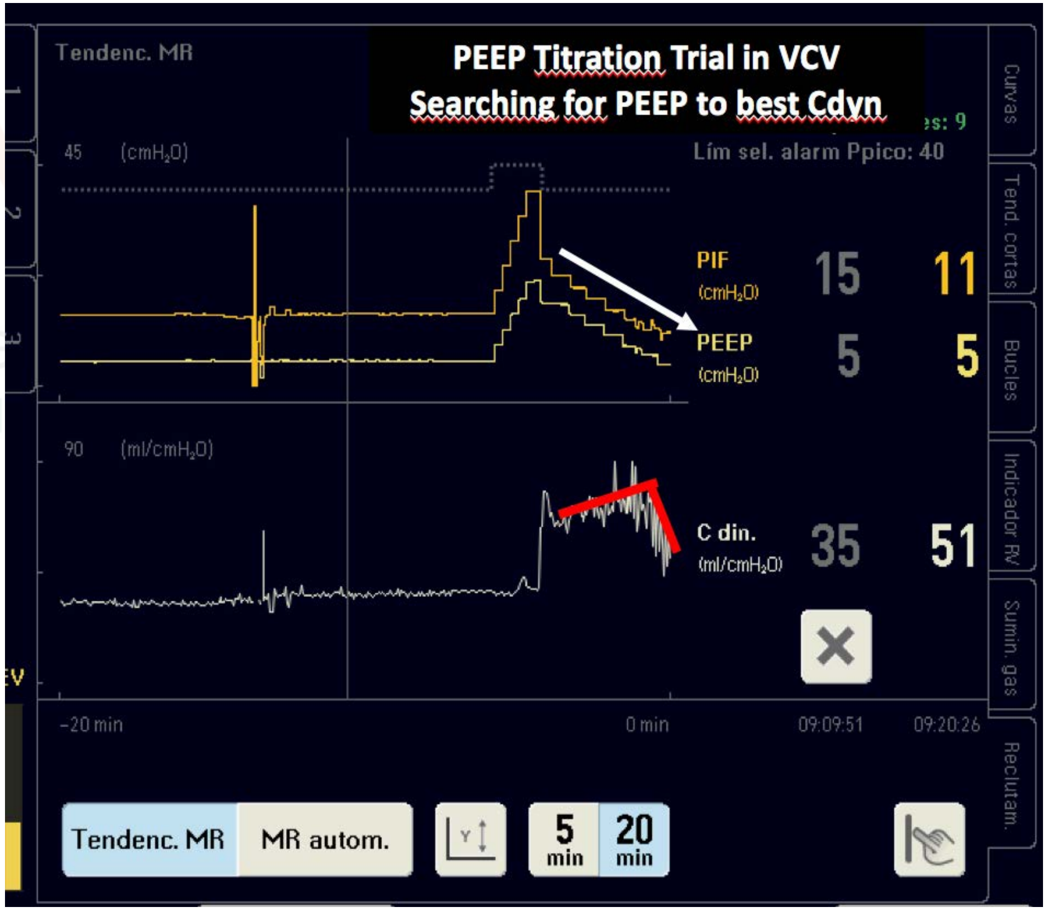


Table 2. Ventilatory parameters, respiratory system mechanics and ventilatory efficiency variables.

Variables		Pre OLA	Pre RM-5	Pre RM-5 vs. Pre OLA p value	OLA	RM-5	RM-5 vs. OLA p value
Ventilatory parameters n = 36	VT (ml)	347±38	361±43	0.491	350 ± 36	361 ± 42	0.491
	PEEP, cmH_2O	5,0 ± 0,0	5,0 ± 0,0	1.00	8,0 ± 2,3	5,0 ± 0,0	<0.001
	RR, bpm	14 ± 2	14 ± 1	0.667	14 ± 2	14 ± 1	0.667
Respiratory system mechanics n = 36	DP (cmH_2O)	7.7 ± 1.0	7.7 ± 1.3	1.00	5.6 ± 1.0	7.4 ± 1.0	<0.001
	Pplat (cmH_2O)	13.3 ±1.2	14.6 ± 1.2	<0.001	13.7 ± 1.9	12.2 ± 0.8	0.131
	Cdyn ($ml \cdot cmH_2O$)	53 ± 13	59 ± 19	0.945	68 ± 25	61 ± 19	0.903
	Raw ($cmH_2O \cdot l \cdot s$)	11 ± 4	12 ± 4	0.314	11 ± 4	11 ± 3	0.272
Ventilatory efficiency n = 29	VDBohr	0.58 ± 0.11	0.59 ± 0.08	0.224	0.56 ± 0.11	0.56 ± 0.09	0.241
	VDaw/VT	0.36 ± 0.12	0.33 ± 0.06	0.314	0.32 ± 0.11	0.31 ± 0.06	0.771
	VDalv/VTalv	0.35 ± 0.16	0.38 ± 0.11	0.050	0.33 ± 0.15	0.37 ± 0.10	0.035

When compared to pre-RM

OLA resulted in a 22% increase in Compliance and a 28% decrease in Driving pressure

Anesthesiology
1999; 91:1221–31

ISOLATED PEEP

Positive End-expiratory Pressure Improves Respiratory Function in Obese but not in Normal Subjects during Anesthesia and Paralysis

Paolo Pelosi, M.D.,* Irene Ravagnan, M.D.,† Gabriella Giurati, M.D.,† Mauro Panigada, M.D.,‡ Nicola Bottino, M.D.,‡ Stefano Tredici, M.D.,‡ Giuditta Eccher, M.D.,‡ Luciano Gattinoni, M.D.§

9 (66 Kg) vs 9 (149 Kg)

VCV Siemens 900C: VT 683±43 and RR:13.8±0.7 bpm

Table 5. Gas Exchange at Different PEEP Levels

	0 cm H_2O		10 cm H_2O	
	Normal	Obese	Normal	Obese
V_E (l/min)	9.41 ± 0.77	9.54 ± 0.53	9.41 ± 0.56	9.16 ± 0.68
FI_{O_2} (%)	50 ± 0	50 ± 0	50 ± 0	50 ± 0
Pa_{O_2} (mmHg)	218.1 ± 47.0	110.2 ± 29.6**	215.3 ± 47.3	130.0 ± 28.0**‡
$\Delta_{(A-a)}O_2$ (mmHg)	110.0 ± 45.6	208.5 ± 30.5**	113.3 ± 86.8	187.3 ± 30.2**‡
Pa_{CO_2} (mmHg)	28.4 ± 3.1	37.8 ± 6.8**	27.8 ± 5.7	39.4 ± 4.9**
pHa	7.45 ± 0.07	7.38 ± 0.06	7.46 ± 0.09	7.38 ± 0.05*
V_D/V_T (%)	28.7 ± 6.6	47.7 ± 22.2*	27.4 ± 4.5	49.0 ± 15.0**

'Alveolar recruitment strategy' improves arterial oxygenation during general anaesthesia

G. Tusman[1]*, S. H. Böhm, G. F. Vazquez de Anda[2], J. L. do Campo[3] and B. Lachmann[2]*

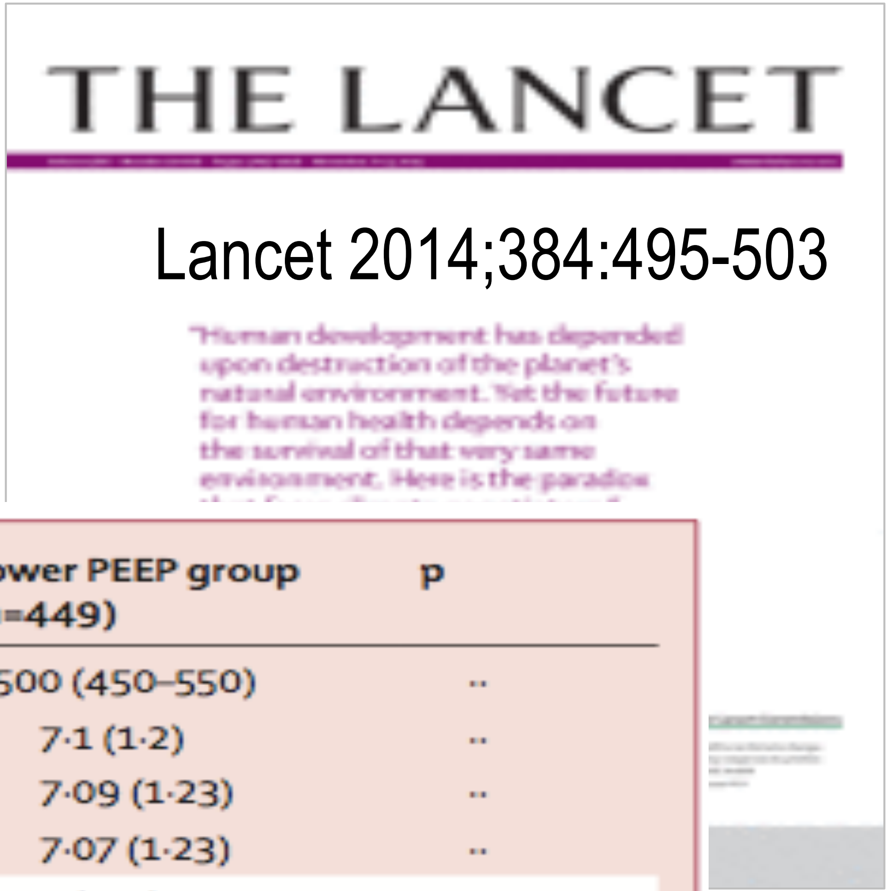
Br J Anaesth. 1999;82:8-13

3 groups of 10 patients: VT 7-9 ml/kg, RF: 10-12 pm
ZEEP - PEEP 5 cmH2O - RM 40 cmH2O + PEEP 5

Variable	Time	ZEEP	PEEP	Recruitment
Pa_{O_2} (kPa)	Basal	18.7 (12.8–26.3)	13.0 (10.2–20.6)	20.4 (10.4–25.3)
	40 min	18.5 (15.0–29.1)	16.2 (12.2–21.4)*	24.4 (13.3–35.2)*
	80 min	18.9 (14.6–27.6)	19.3 (10.5–23.9)	25.5 (18.0–31.1)
	120 min	17.1 (14.9–26.2)	20.3 (11.4–24.5)	25.4 (18.0–36.8)
Compliance	Basal	46.5 (34–76)	47.0 (35–68)	47.5 (28–55)
	40 min	44.5 (26–70)	48.0 (37–66)	50.5 (29–74)*
	80 min	44.0 (33–64)	47.0 (31–67)	57.0 (38–75)
	120 min	43.0 (34–72)	45.5 (36–68)	62.0 (29–68)

High versus low positive end-expiratory pressure during general anaesthesia for open abdominal surgery (PROVHILO trial): a multicentre randomised controlled trial

The PROVE Network Investigators for the Clinical Trial Network of the European Society of Anaesthesiology*



Lancet 2014;384:495-503

900 underwent randomisation

445 available for the primary analysis

449 available for the primary analysis

	Higher PEEP group (n=445)	Lower PEEP group (n=449)	p
Tidal volumes (mL)	500 (450–560)	500 (450–550)	..
PBW (mL/kg)	7·2 (1·5)	7·1 (1·2)	..
After 1 h	7·11 (1·32)	7·09 (1·23)	..
Directly before extubation	6·96 (1·50)	7·07 (1·23)	..
PEEP (cm H_2O)	12 (12–12)	2 (0–2)	..
After 1 h	12 (12–12)	2 (0–2)	..
Directly before extubation	12 (12–12)	2 (0–2)	..

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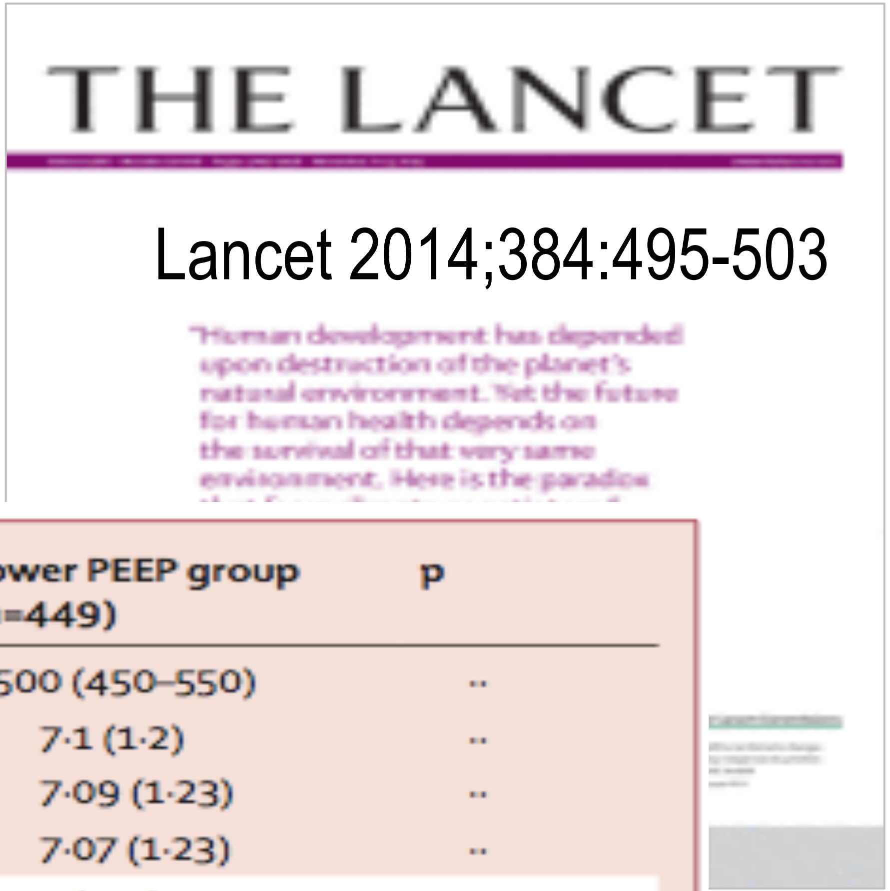

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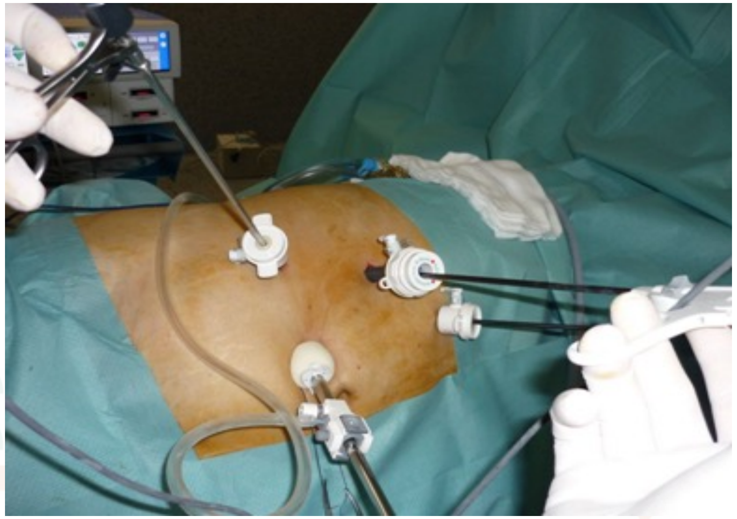
PEEP (cm H_2O)	12 (12–12)	2 (0–2)	..
Af			..
Di			..

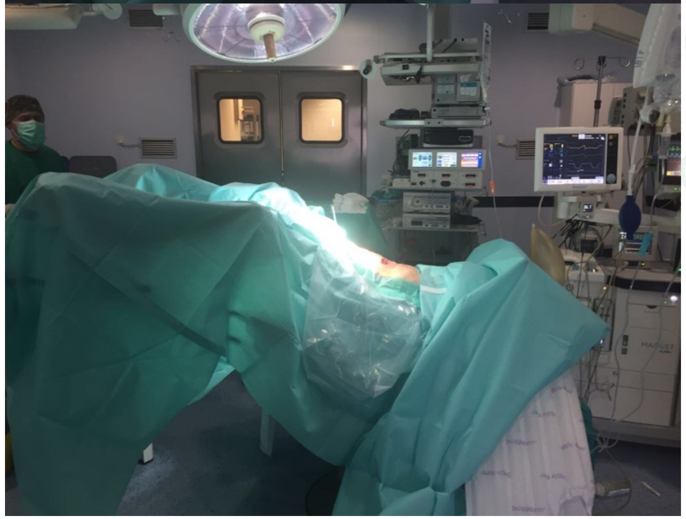
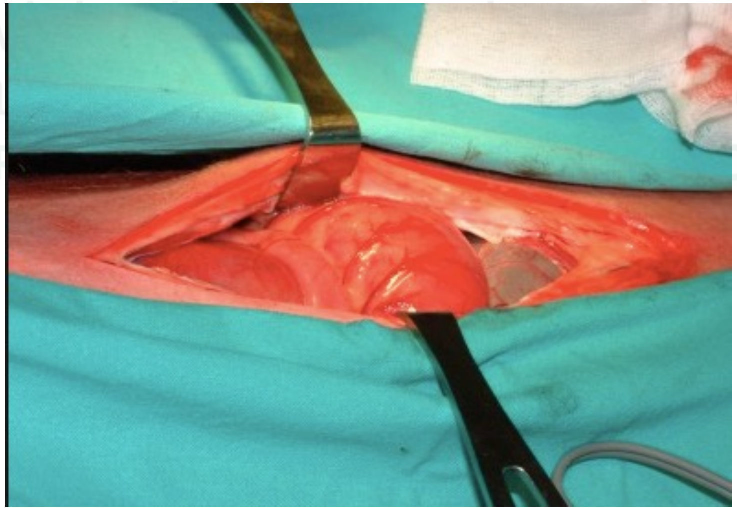
In the higher PEEP group, recruitment manoeuvres consisted of incremental increases in tidal volume directly after induction of anaesthesia, after any disconnection from the ventilator, and just before tracheal extubation

PROVHILO TRIAL. PROVE network investigators. Lancet 2014

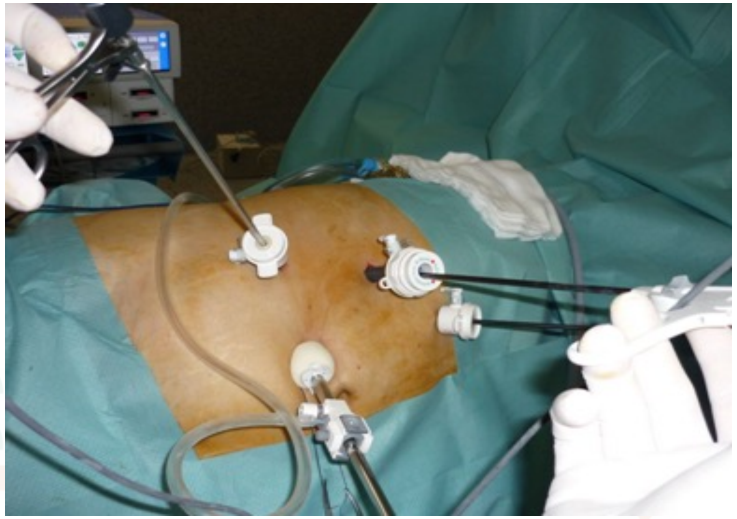
	Higher PEEP group (n=445)	Lower PEEP group (n=449)	Relative risk (95% CI)	p
Postoperative pulmonary complications				
Total*	174/437 (40%)	172/443 (39%)	1·01 (0·85–1·20)	0·84
Total (excluding hypoxaemia)	142/437 (32%)	149/443 (34%)	0·96 (0·78–1·17)	0·66
Hypoxaemia	105/437 (24%)	95/443 (21%)	1·08 (0·92–1·25)	0·36
Severe hypoxaemia	29/437 (7%)	34/443 (8%)	0·92 (0·70–1·21)	0·55
Bronchospasm	18/437 (4%)	18/443 (4%)	1·01 (0·72–1·41)	0·97
Suspected pulmonary infection	68/437 (16%)	75/443 (17%)	0·95 (0·79–1·14)	0·58
Pulmonary infiltrate	35/437 (8%)	32/443 (7%)	1·06 (0·83–1·34)	0·66
Aspiration pneumonitis	1/437 (<1%)	4/443 (1%)	0·40 (0·07–2·32)	0·18
Acute respiratory distress syndrome	5/437 (1%)	8/443 (2%)	0·77 (0·39–1·54)	0·41
Atelectasis	53/437 (12%)	55/443 (12%)	0·99 (0·80–1·21)	0·90
Pleural effusion	90/437 (21%)	92/443 (21%)	0·99 (0·84–1·17)	0·95
Pulmonary oedema caused by cardiac failure	19/437 (4%)	20/443 (5%)	0·98 (0·71–1·36)	0·90
Pneumothorax	15/437 (3%)	12/443 (3%)	1·12 (0·80–1·58)	0·53

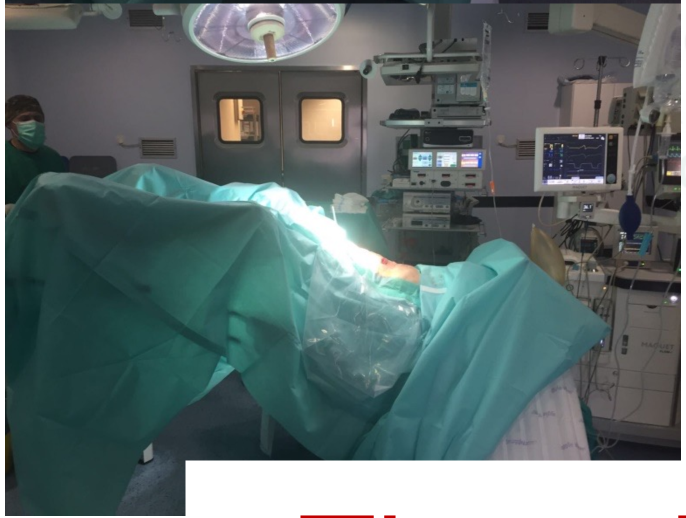
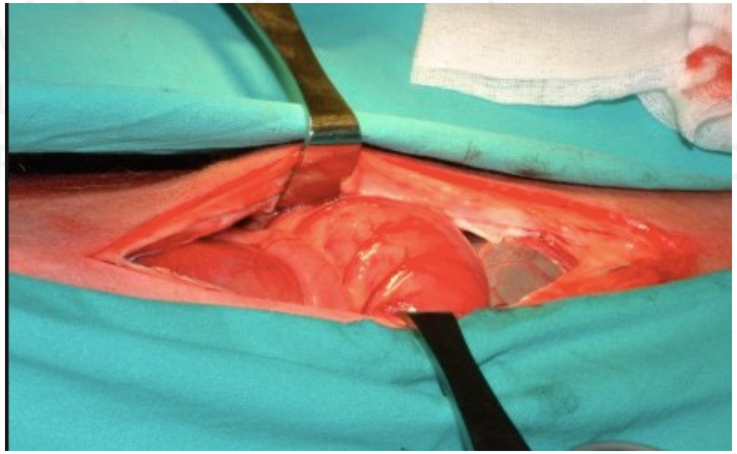
Optimal PEEP


Optimal PEEP

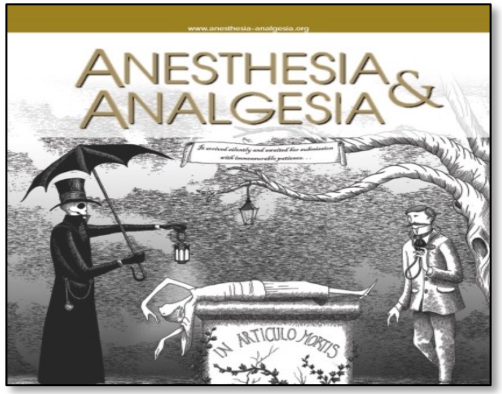




There is not a magic value!!!!

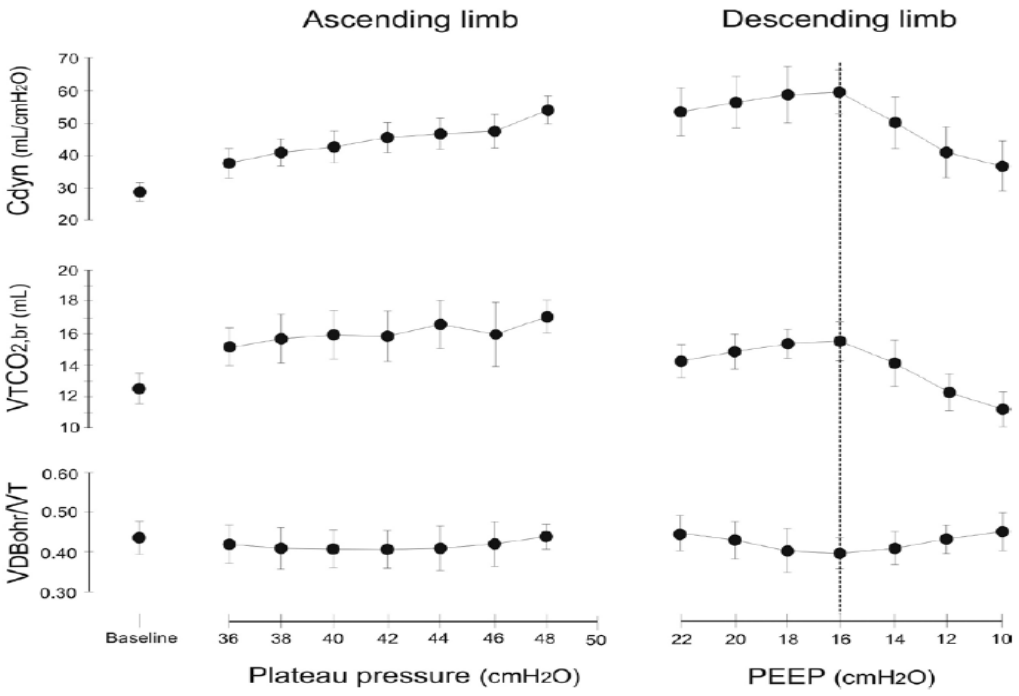
Noninvasive Monitoring of Lung Recruitment Maneuvers in Morbidly Obese Patients: The Role of Pulse Oximetry and Volumetric Capnography

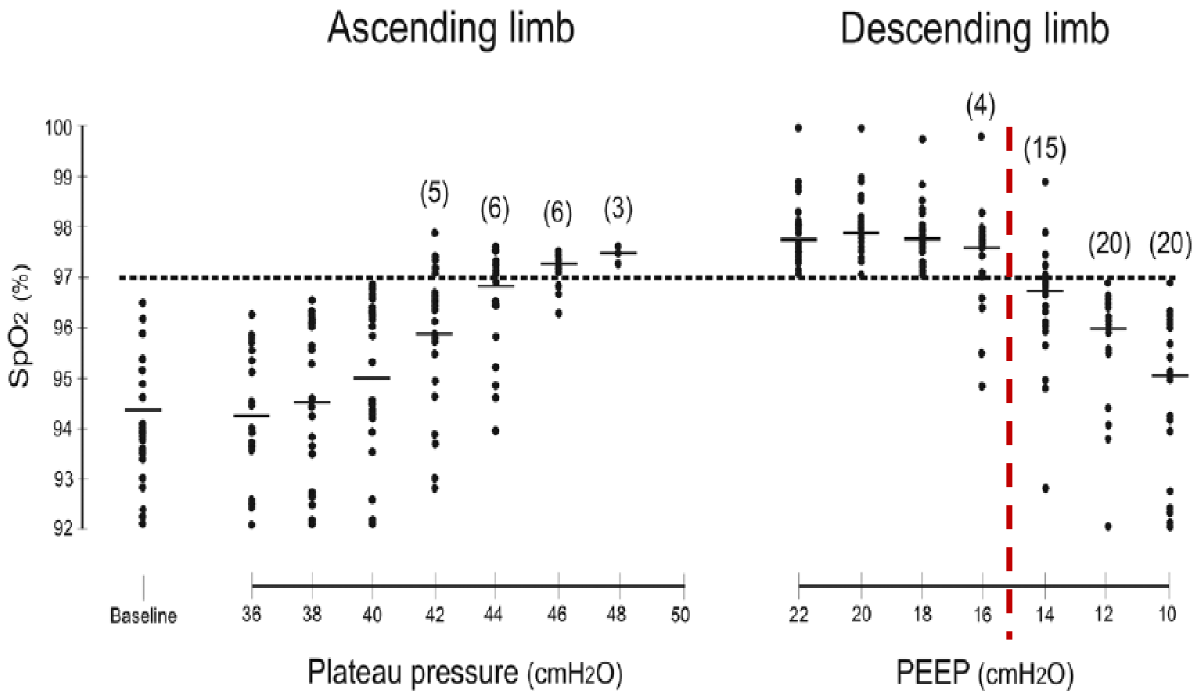
Gerardo Tusman, MD,* Iván Groisman, MD,* Felipe E. Fiolo, MD, FACS,† Adriana Scandurra, PhD,‡
Jorge Martinez Arca,‡ Gustavo Krumrick, MD,* Stephan H. Bohm, MD,§ and
Fernando Suarez Sipmann, MD, PhD||¶

Anesth Analg 2014;118:137–44



20 morbidly obese patients undergoing laparoscopic bariatric surgery





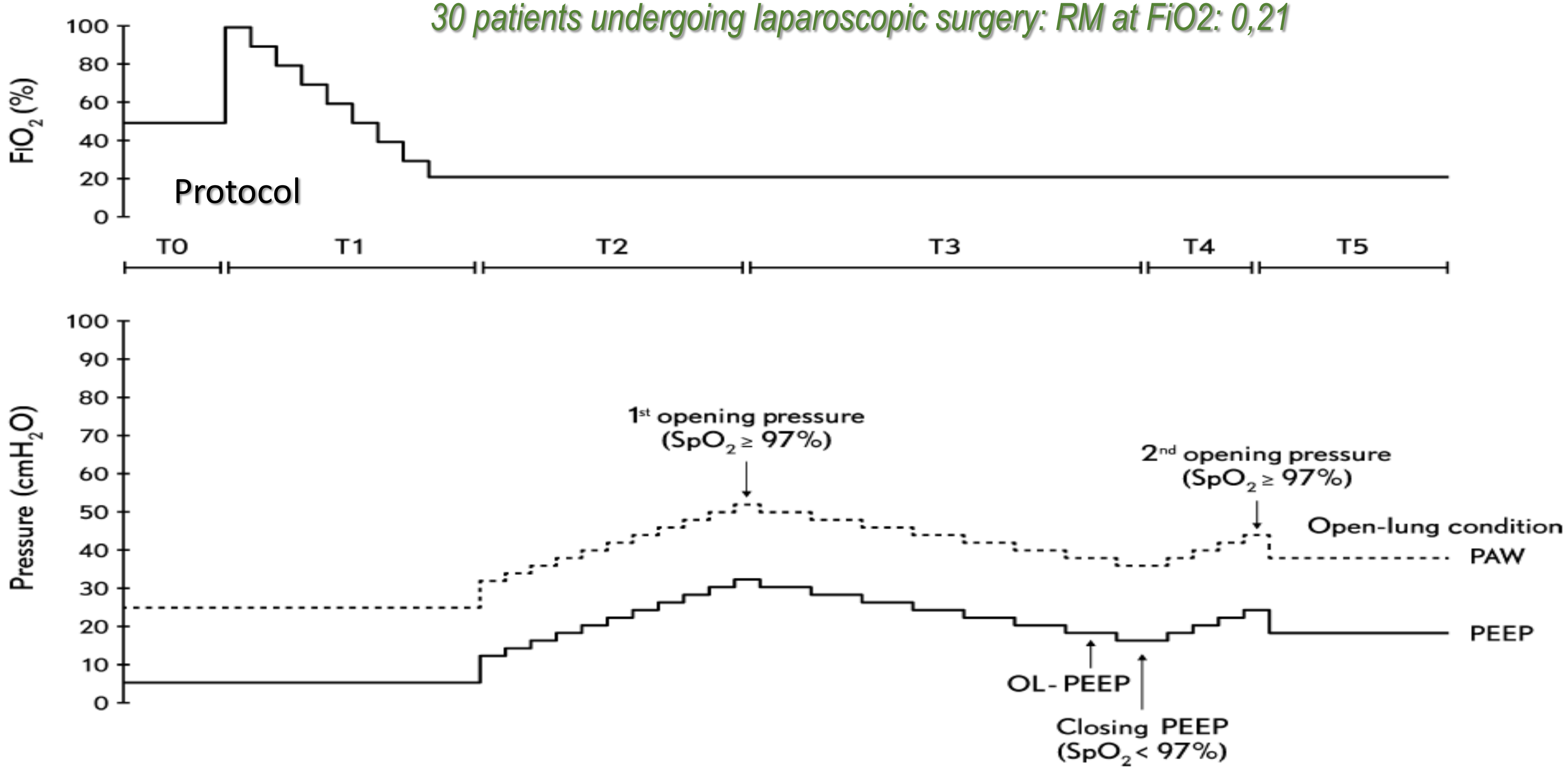
Individualized lung recruitment maneuver guided by pulse-oximetry in anesthetized patients undergoing laparoscopy: a feasibility study

acta Anaesthesiologica Scandinavica

AAS 2018;62:608-619.

C. Ferrando[1,2], G. Tusman[3], F. Suarez-Sipmann[1,4], I. León[1], N. Pozo[1], J. Carbonell[1], J. Puig[1], E. Pastor[1], E. Gracia[1], A. Gutiérrez[1], G. Aguilar[1], F. J. Belda[1] and M. Soro[1]

30 patients undergoing laparoscopic surgery: RM at FiO2: 0,21



Measurements:

Paw, Ppl, Ptp

Csr, cL, Ccw

Vcap

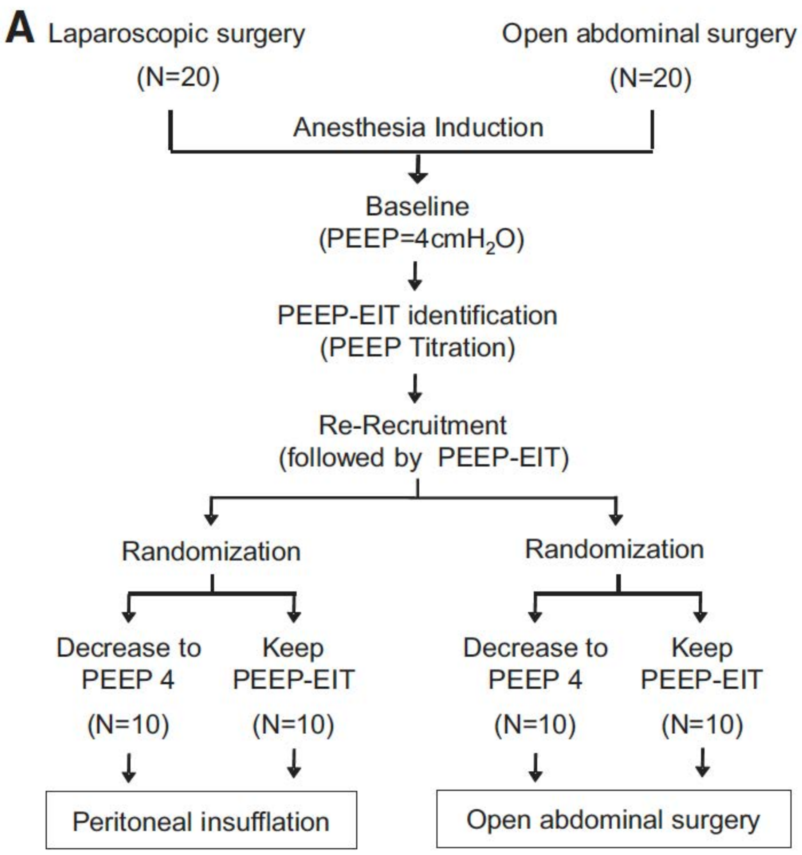
BGA

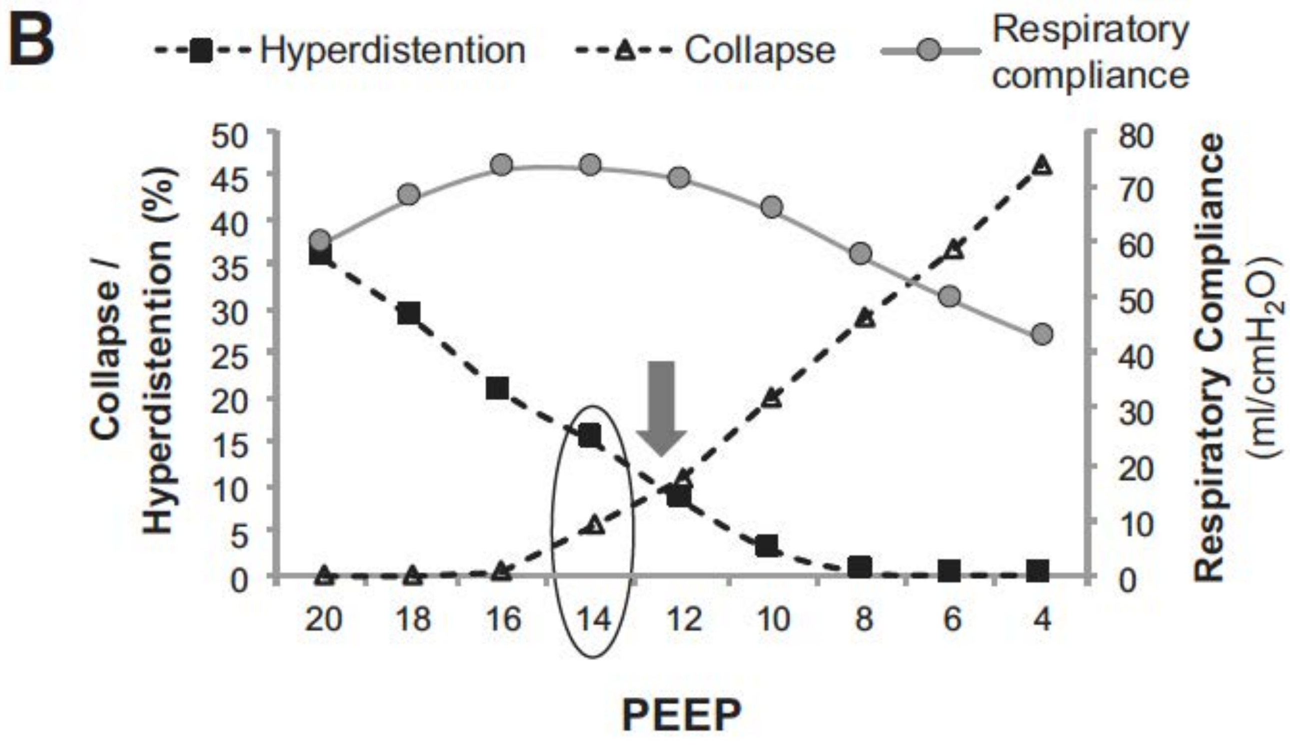
SpO_2

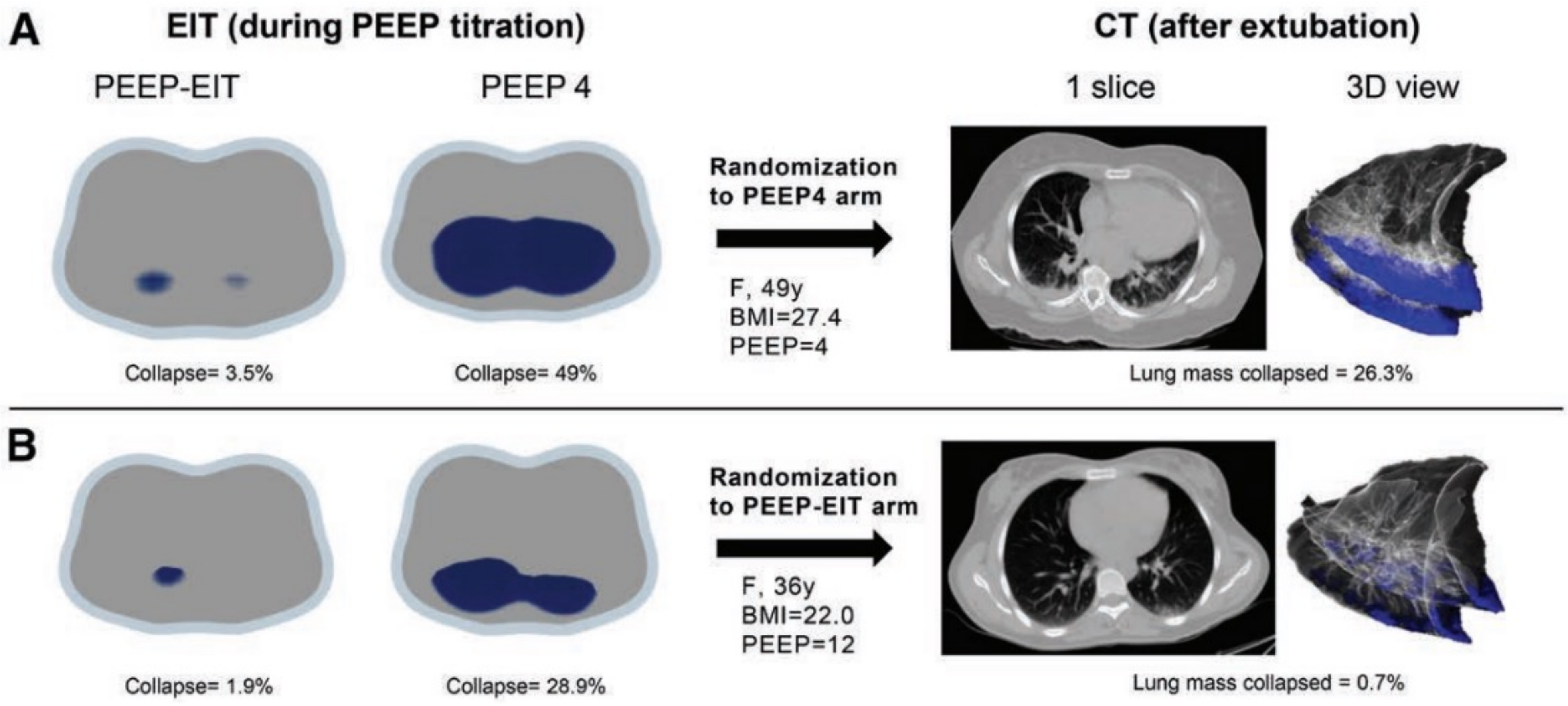
Individual Positive End-expiratory Pressure Settings Optimize Intraoperative Mechanical Ventilation and Reduce Postoperative Atelectasis

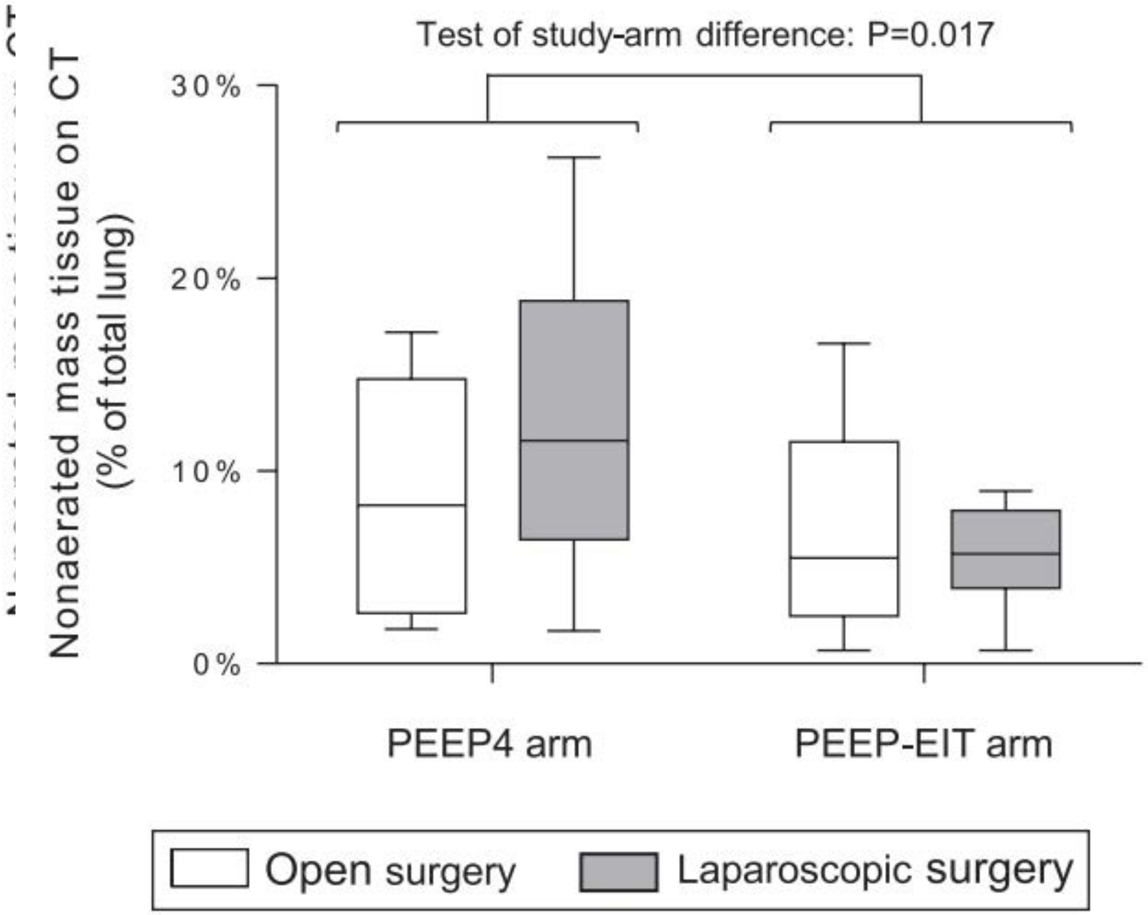
Sérgio M. Pereira, M.D., Mauro R. Tucci, M.D., Ph.D., Caio C. A. Morais, P.T., M.Sc., Claudia M. Simões, M.D., Ph.D., Bruno F. F. Tonelotto, M.D., Michel S. Pompeo, M.D., Fernando U. Kay, M.D., Ph.D., Paolo Pelosi, M.D., F.E.R.S., Joaquim E. Vieira, M.D., Ph.D., Marcelo B. P. Amato, M.D., Ph.D.

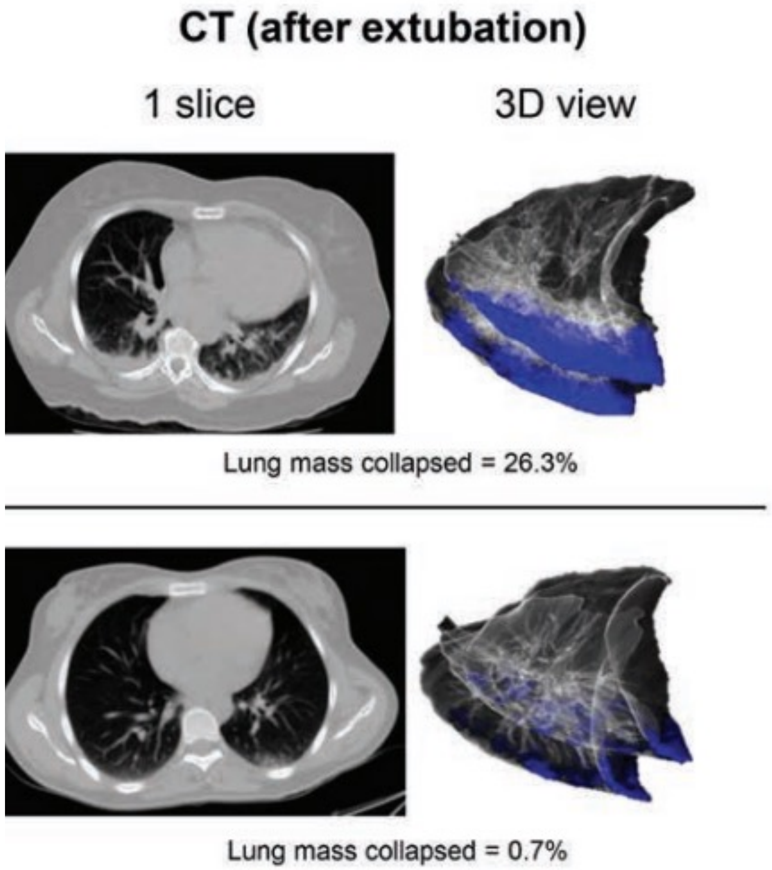
Anesthesiology 2018; 129:1070-81






A
EIT (during PEEP titration)
CT (after extubation)
PEEP-EIT
PEEP 4
1 slice
3D view
Randomization
to PEEP4 arm
F, 49y
BMI=27.4
PEEP=4
Collapse= 3.5%
Collapse= 49%
Lung mass collapsed = 26.3%
B
Randomization
to PEEP-EIT arm
F, 36y
BMI=22.0
PEEP=12
Collapse= 1.9%
Collapse= 28.9%
Lung mass collapsed = 0.7%





ANESTHESIOLOGY
Trusted Evidence: Discovery to Practice®

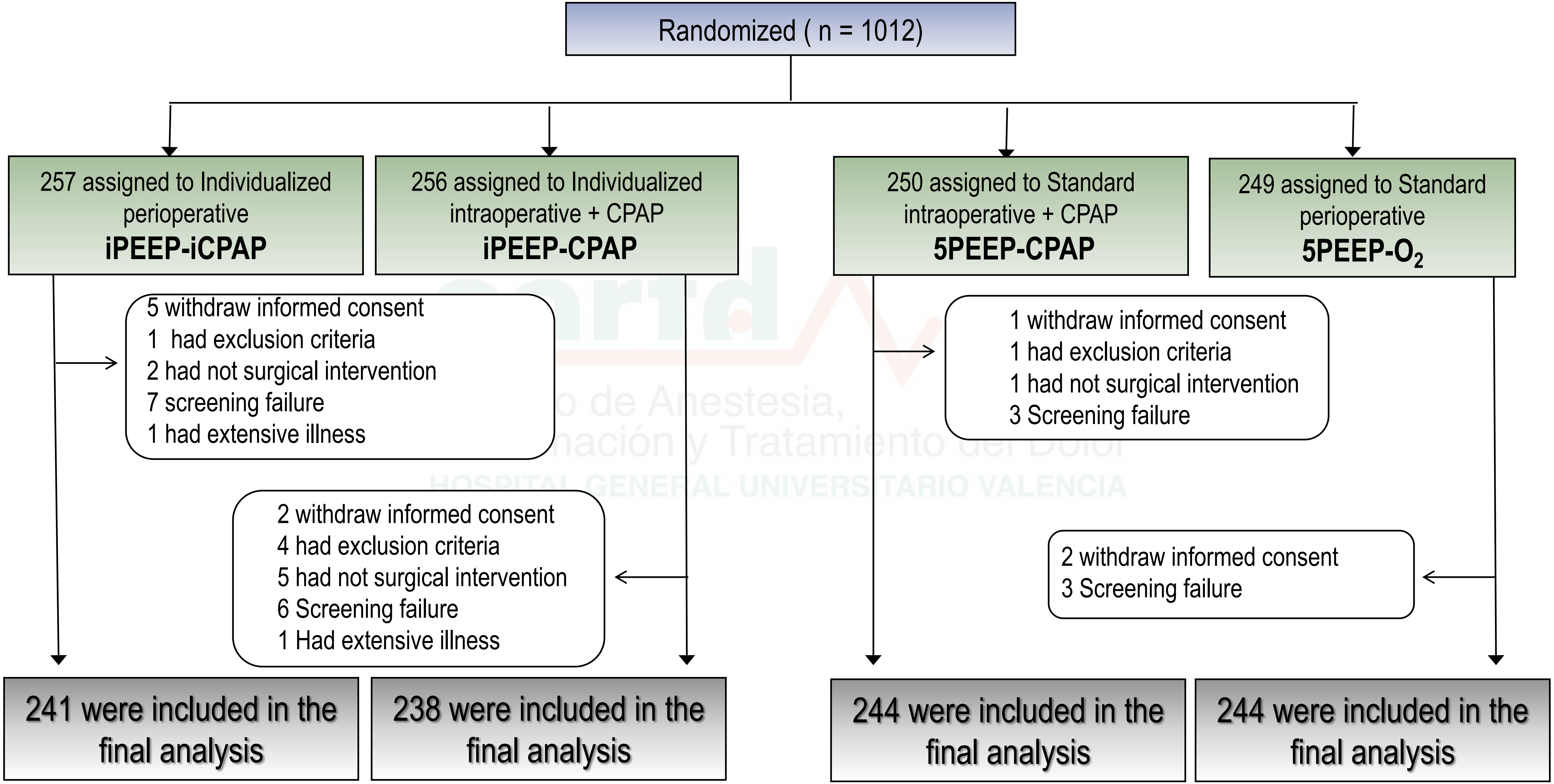
Ferrando et al. Trials (2015) 16:193
DOI 10.1186/s13063-015-0694-1

TRIALS

STUDY PROTOCOL Open Access

Rationale and study design for an individualized perioperative open lung ventilatory strategy (iPROVE): study protocol for a randomized controlled trial

Carlos Ferrando[1*], Marina Soro[1], Jaume Canet[2], Ma Carmen Unzueta[3], Fernando Suárez[4], Julián Librero[5], Salvador Peiró[5], Alicia Llombart[1], Carlos Delgado[1], Irene León[1], Lucas Rovira[6], Fernando Ramasco[7], Manuel Granell[8], César Aldecoa[9], Oscar Diaz[10], Jaume Balust[11], Ignacio Garutti[12], Manuel de la Matta[13], Alberto Pensado[14], Rafael Gonzalez[15], Mª Eugenia Durán[16], Lucia Gallego[17], Santiago García del Valle[18], Francisco J Redondo[19], Pedro Diaz[20], David Pestaña[21], Aurelio Rodríguez[22], Javier Aguirre[23], Jose M García[24], Javier García[25], Elena Espinosa[26], Pedro Charco[27], Jose Navarro[28], Clara Rodríguez[5], Gerardo Tusman[29], Francisco Javier Belda[1], on behalf of the iPROVE investigators (Appendices 1 and 2)

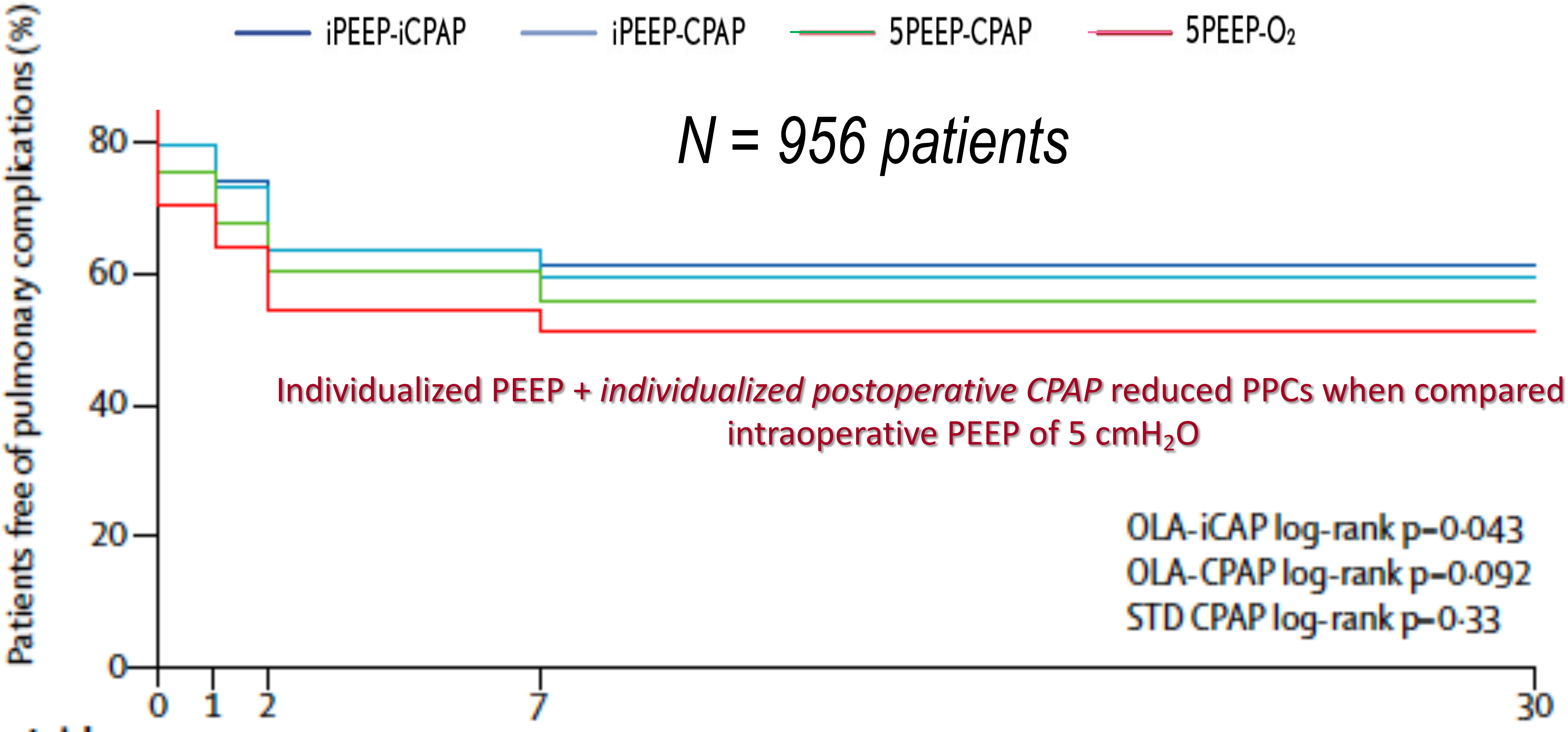

Randomized (n = 1012)
257 assigned to Individualized perioperative
iPEEP-iCPAP
256 assigned to Individualized intraoperative + CPAP
iPEEP-CPAP
250 assigned to Standard intraoperative + CPAP
5PEEP-CPAP
249 assigned to Standard perioperative
5PEEP-O_2
5 withdraw informed consent
1 had exclusion criteria
2 had not surgical intervention
7 screening failure
1 had extensive illness
1 withdraw informed consent
1 had exclusion criteria
1 had not surgical intervention
3 Screening failure
2 withdraw informed consent
4 had exclusion criteria
5 had not surgical intervention
6 Screening failure
1 Had extensive illness
2 withdraw informed consent
3 Screening failure
241 were included in the final analysis
238 were included in the final analysis
244 were included in the final analysis
244 were included in the final analysis

Individualised perioperative open-lung approach versus standard protective ventilation in abdominal surgery (iPROVE): a randomised controlled trial

*Carlos Ferrando, Marina Soro, Carmen Unzueta, Fernando Suarez-Sipmann, Jaume Canet, Julián Librero, Natividad Pozo, Salvador Peiró, Jaume Puig, Gonzalo Azparren, Gerardo Tusman, Jesús Villar, Javier Belda, on behalf of the Individualized PeRioperative Open-lung VEntilation (iPROVE) Network**

THE LANCET Respiratory Medicine
2018;6:193-203

N = 956 patients



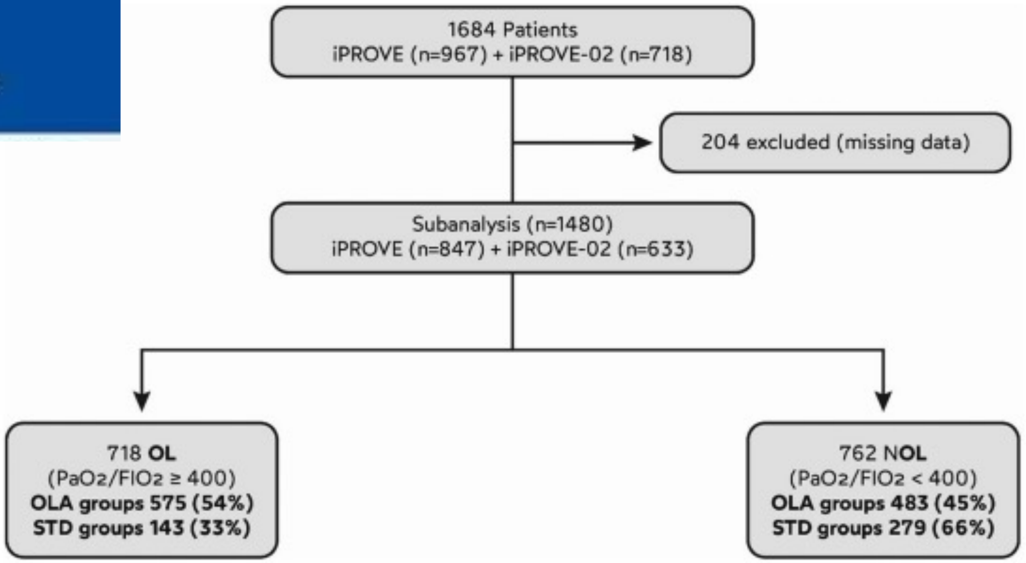
Individualized PEEP + *individualized postoperative CPAP* reduced PPCs when compared to an intraoperative PEEP of 5 cmH_2O

Received: 25 June 2021 | Revised: 9 August 2021 | Accepted: 16 August 2021
DOI: 10.1111/aas.13979

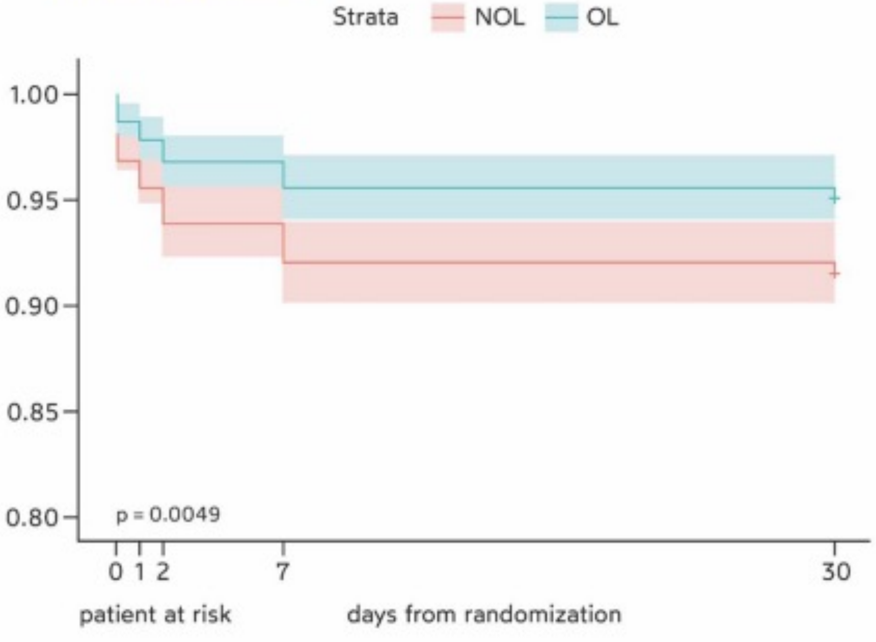
RESEARCH ARTICLE

Intraoperative open lung condition and postoperative pulmonary complications. A secondary analysis of iPROVE and iPROVE-O2 trials

Carlos Ferrando[1,2] | Julian Librero[3] | Gerardo Tusman[4] | Ary Serpa-Neto[5,6,7] | Jesús Villar[2,8,9] | Francisco J. Belda[6] | Eduardo Costa[10,11] | Marcelo B. P. Amato[10] | Fernando Suarez-Sipmann[2,12,13] | the iPROVE Network Group

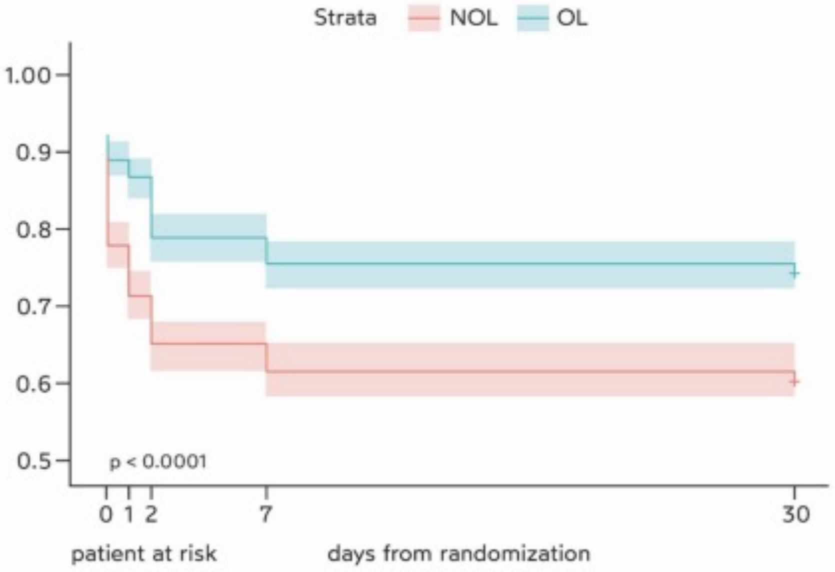


Severe PPCs



NOL	755	731	721	709	695
OL	711	702	696	688	680

Any PPCs



NOL	755	589	540	491	467
OL	711	634	617	561	537

Individualized lung recruitment maneuver guided by pulse-oximetry in anesthetized patients undergoing laparoscopy: a feasibility study

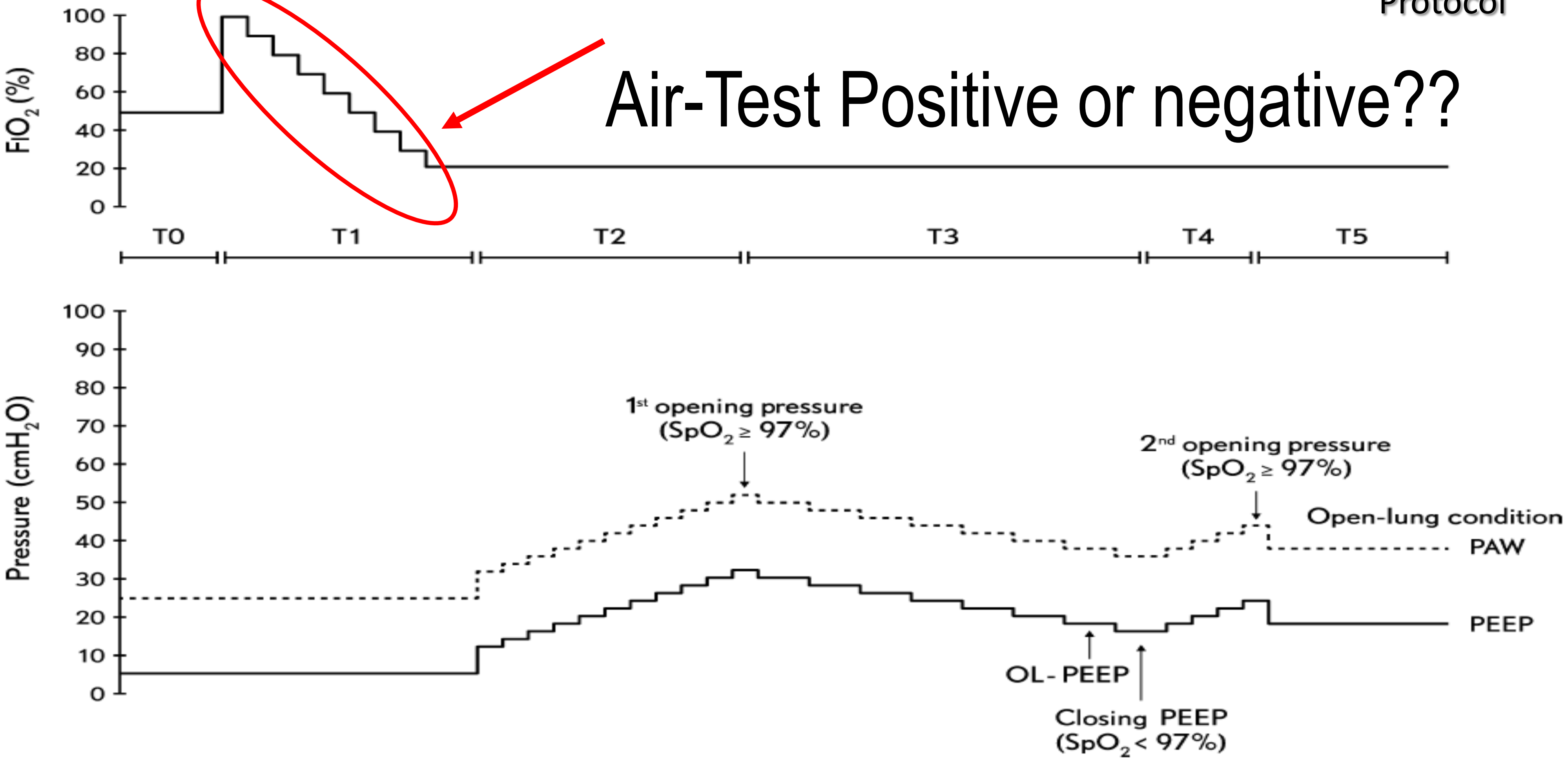
acta Anaesthesiologica Scandinavica

AAS 2018;62:608-619.

C. Ferrando[1,2], G. Tusman[3], F. Suarez-Sipmann[1,4], I. León[1], N. Pozo[1], J. Carbonell[1], J. Puig[1], E. Pastor[1], E. Gracia[1], A. Gutiérrez[1], G. Aguilar[1], F. J. Belda[1] and M. Soro[1]

30 patients undergoing laparoscopic surgery: RM at FiO2: 0,21

Protocol



Measurements:

Paw, Ppl, Ptp

Csr, CL, Ccw

Vcap

BGA

SpO2

Individualized lung recruitment maneuver guided by pulse-oximetry in anesthetized patients undergoing laparoscopy: a feasibility study

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Variables	Open-Lung without RM n=6	Open-Lung WITH RM n=20	P-Value
SpO_2	97	98	0.98
PaO_2/FIO_2	397	435	0.27
Ptp_{EE}	1.6	1.2	0.66
DP_{EE}	10.1	10.0	0.98
Cdyn	23	35	0.09
C_Ldyn	56	53	0.41
VDBöhr	0.38	0.33	0.36

No differences in oxygention, lung efficiency and mechanics between those patients SpO_2 >96% (FIO_2 0.21) vs those patients SpO_2 < 96% in whose an OLA was applied

New frontiers: art and innovation for intraoperative ventilatory management

Ferrando C, Belda FJ.

MINERVA ANESTESIOLOGICA

Minerva Anestesiol 2017; 83:1007-1009

iPROVE algorithm

Alveolar collapse
LUS, Air-Test

→ No (**42%**) → **Keep PEEP level**

↓ Yes

Check hemodynamic stability

→ No →
1. **Vasopressors**
2. **Fluids**
3. **ionotropes**

↓ Yes

Individualized Recruitment Maneuver **32%**
Opening pressure (LUS, SpO_2)

↓

Individualized PEEP (PEEP Trial)
Closing pressure (Cdyn, LUS, SpO_2)

↓

Re-evaluation Open-lung condition **10%**
(Cdyn, Air-Test)

Air-Test (5 min breathing 0.21 FIO_2)
- **Positive** (shunt induced by lung collapse): $SpO_2 \leqq 96\%$
- **Negative**: $SpO_2 \geqq 97\%$

Summary

We learned setting protective ventilation in OR:

To reduce postoperative complications

Lung protective ventilation:

Individualized way: VT 6-8 ml/Kg IBW

- iPROVE algoritm: Air-test
- RM + PEEP at the best Compliance-Oxygenation
- During and after surgery

Invasive and non invasive

THE BEATLES

THE BEATLES

Thank you very much for your attention