RECRUITMENT MANEUVER IN THE OPERATING ROOM:

FROM BASIC TO ONE LUNG VENTILATION

SALUS SCIENTIA
AZIENDA OSPEDALIERO - UNIVERSITARIA
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UNIVERSITA
DEGLI STUDI
DI TORINO

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Disclosure:

- Lectures grant:
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- Travels Grant:
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  - Draeger
  - Ambu
  - Praesidia

- Basic of RM
  - What
  - Why
  - How much
  - How long
  - Where
  - How
  - When
  - After RM
- Trials RM & OLV
- REMATO Study
- Conclusion

What

Intensive Care Med (2016) 42:908–911
DOI 10.1007/s00134-015-4025-5

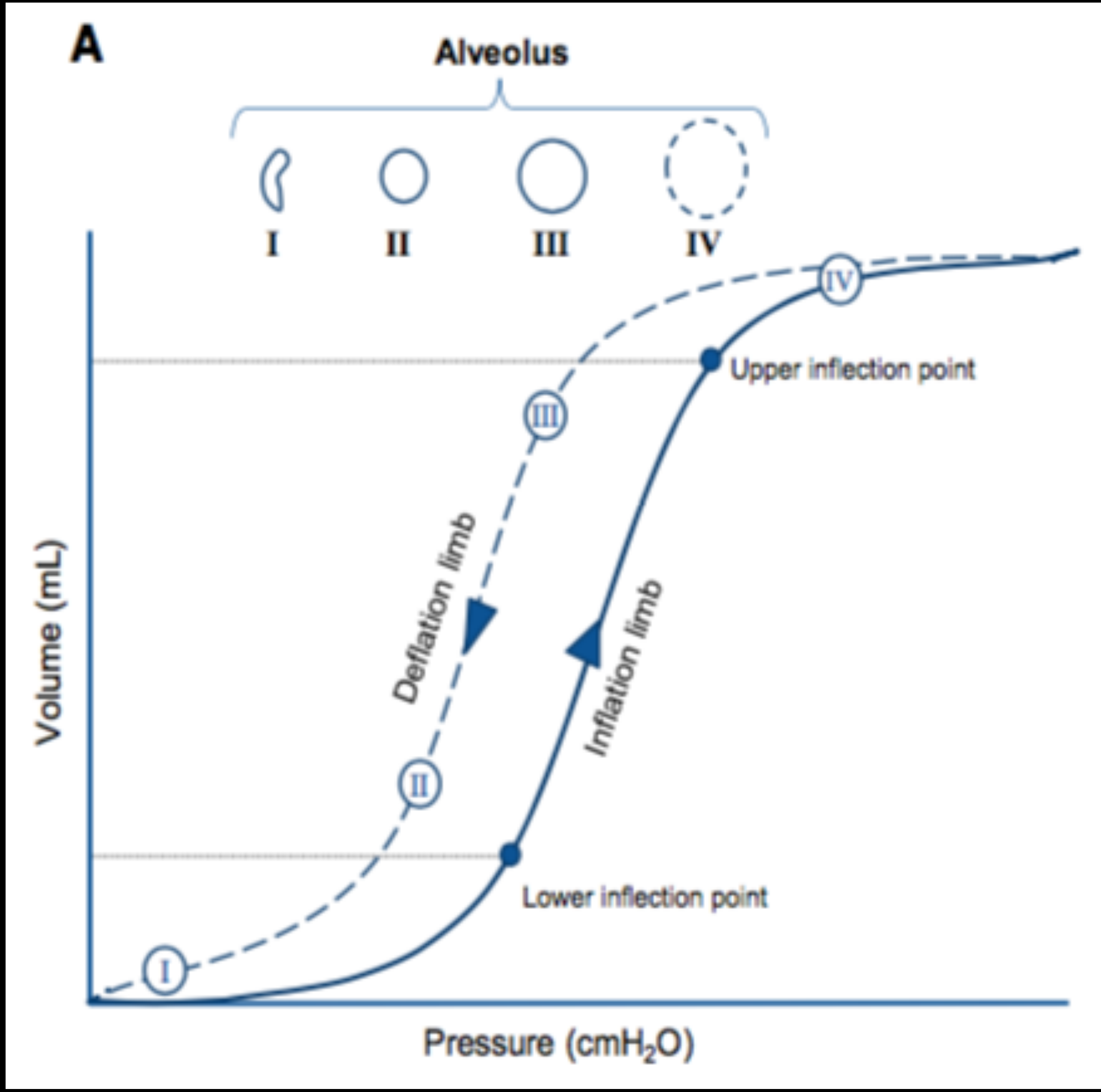
UNDERSTANDING THE DISEASE

Erica Aranha Suzumura
Marcelo Britto Passos Amato
Alexandre Biasi Cavalcanti

Understanding recruitment maneuvers

A recruitment maneuver is the process of inducing an intentional transient increase in transpulmonary pressure aimed at reopening non-aerated or poorly aerated alveoli.

Transpulmonary pressure should overcome the critical opening pressure of at least a substantial proportion of closed alveoli.



Why

Anesthetic factors
* Muscle dysfunction
* Muscle disruption
* Low phrenic nerve output
* Pain
* Mucociliary dysfunction
* Blood displacement between thorax and abdomen
* Fluid therapy

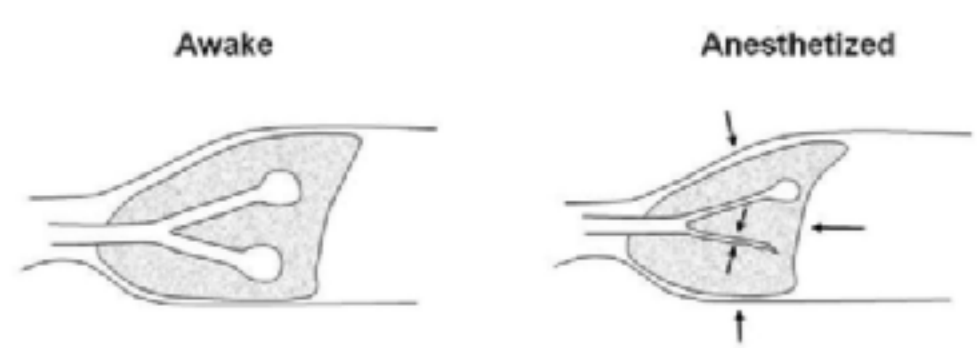
Surgical factors
* Thoraco-abdominal surgeries
* Surgical retractors
* Faulty surgical techniques
* Pneumoperitoneum
* Body positioning

Patient factors
* Age
* Body weight
* Smoking
* Previous respiratory diseases
* Meteorism –abdominal compartment syndrome.

Respiratory restrictive pattern
(↓ FRC-FVC)

↓

Lung collapse
* airway closure
* atelectasis



↓

Postoperative pulmonary complications

Hypoxemia
* Decreased DO_2
* Systemic ischemia-reperfusion injury
* Delirium
* Wound infection
* Arrhythmias
* Myocardial ischemia

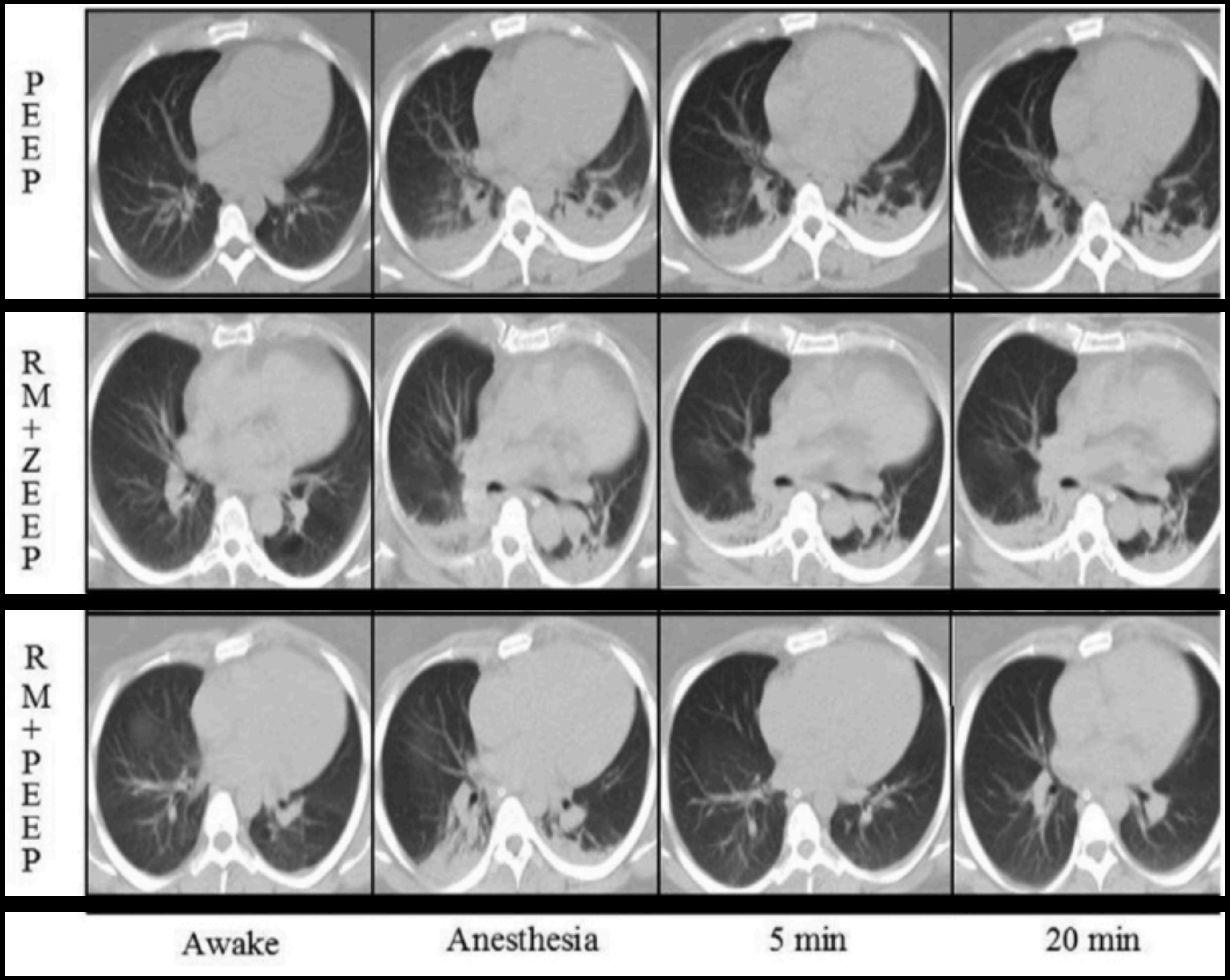
Pneumonia
* Macrophage dysfunction
* Loss of surfactant
* Bacterial growth
* Bacterial translocation

Local inflammatory response
* Local hypoxia or hyperoxia
* Local mechanical parenchymal stress
* Biotrauma

Ventilator induced lung injury
* Cyclic tidal recruitment
* Tidal overdistension
* Time-prolonged ventilation

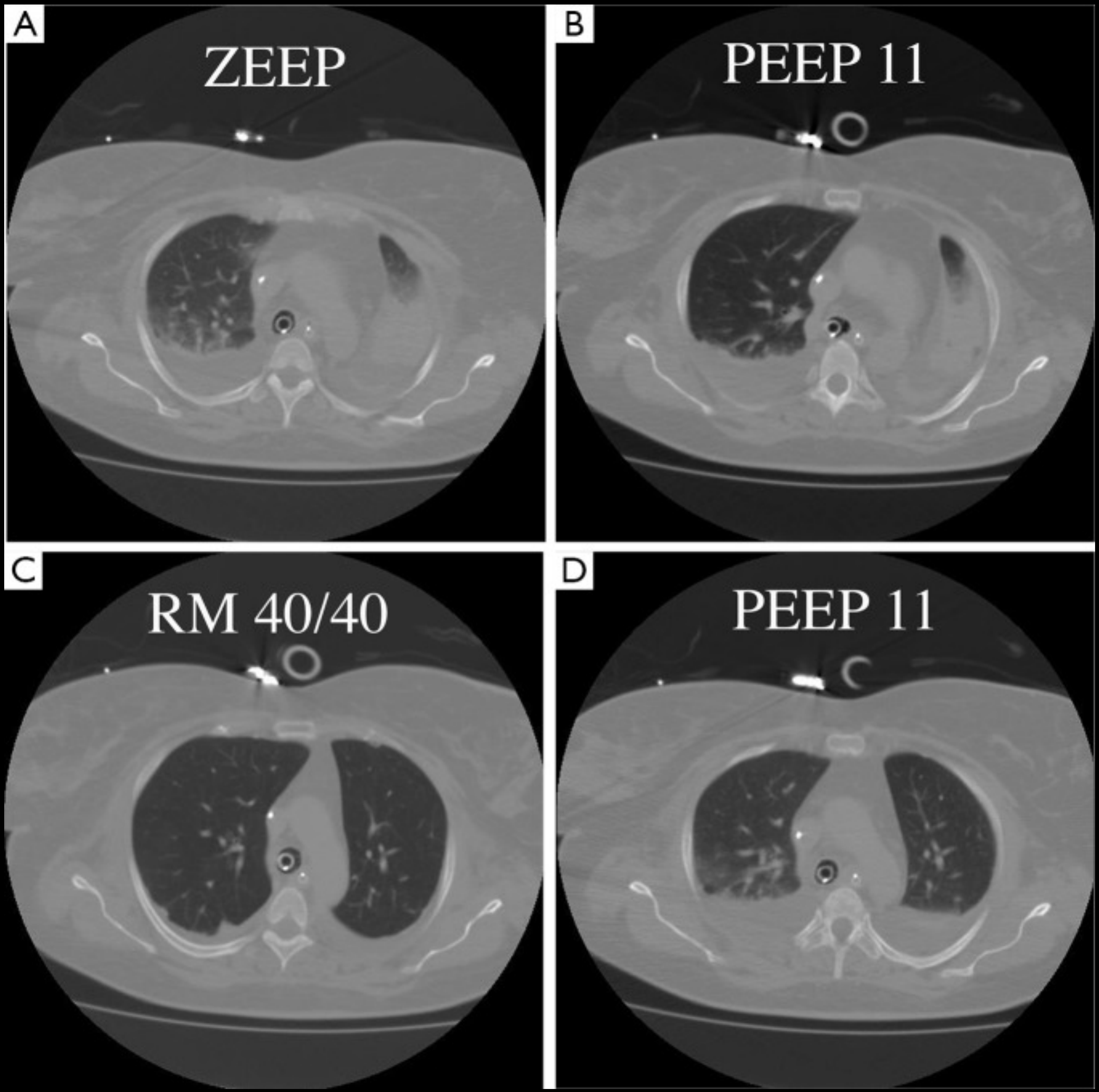
[Tusman Curr Opin Anesth 2012]

Why



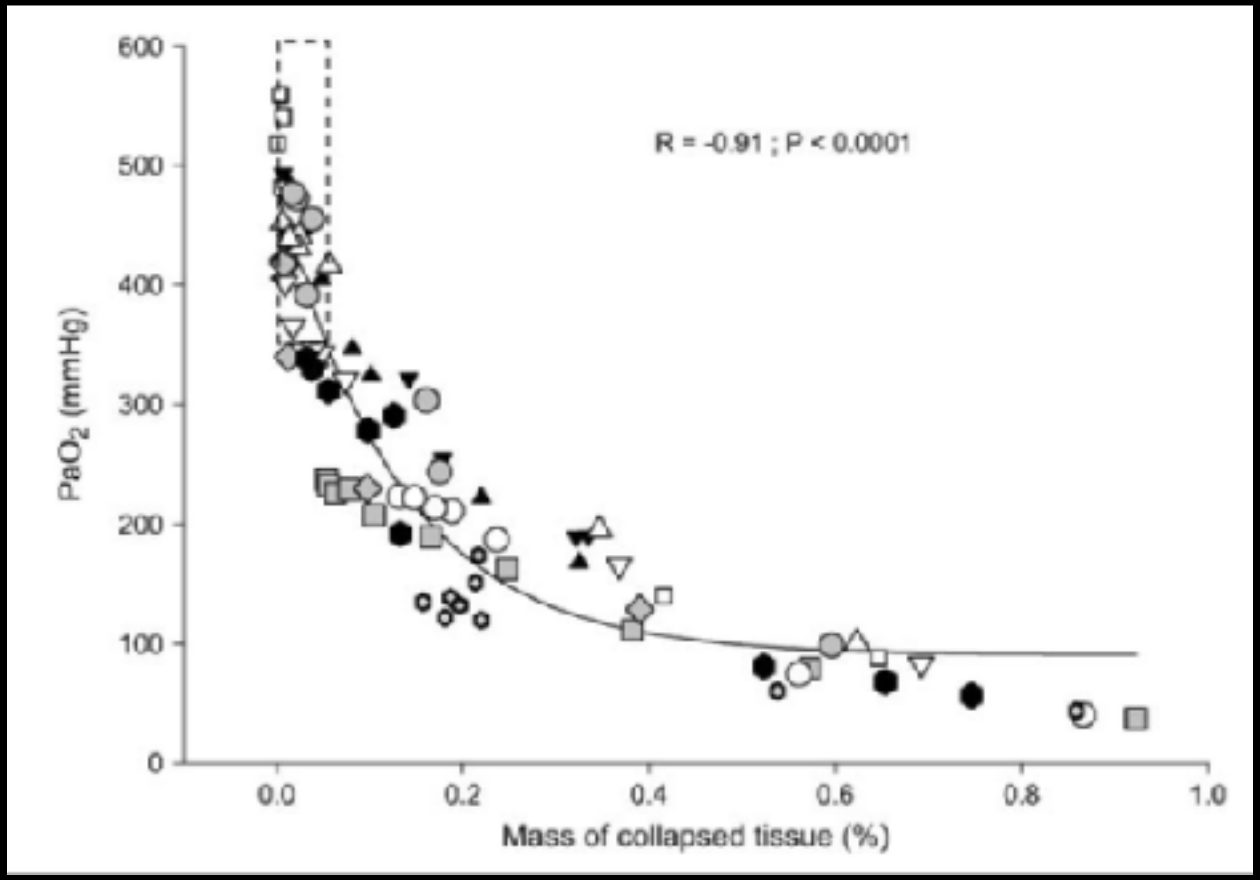
[Hedenstierna Acta Anesth Scan 2012]

Why



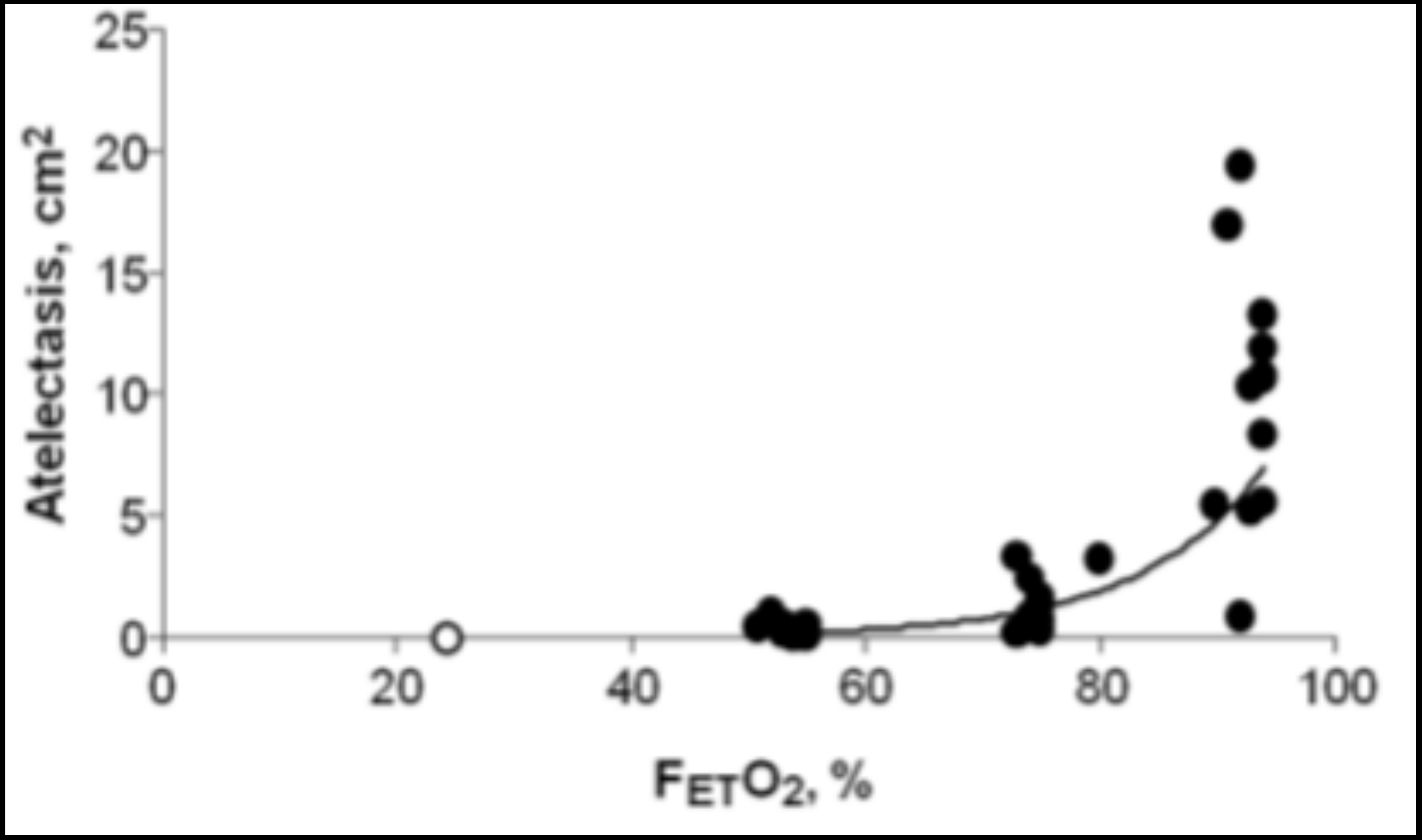
[Constantin ATM 2017]

Why



Correlation between Atelectasis and Hypoxemia

Correlation between FiO2 and Atelectasis



Why

AMERICAN THORACIC SOCIETY DOCUMENTS

An Official American Thoracic Society/European Society of Intensive Care Medicine/Society of Critical Care Medicine Clinical Practice Guideline: Mechanical Ventilation in Adult Patients with Acute Respiratory Distress Syndrome

Eddy Fan, Lorenzo Del Sorbo, Ewan C. Goligher, Carol L. Hodgson, Laveena Munshi, Allan J. Walkey, Neill K. J. Adhikari, Marcelo B. P. Amato, Richard Branson, Roy G. Brower, Niall D. Ferguson, Ognjen Gajic, Luciano Gattinoni, Dean Hess, Jordi Mancebo, Maureen O. Meade, Daniel F. McAuley, Antonio Pesenti, V. Marco Ranieri, Gordon D. Rubenfeld, Eileen Rubin, Maureen Seckel, Arthur S. Slutsky, Daniel Talmor, B. Taylor Thompson, Hannah Wunsch, Elizabeth Uleryk, Jan Brozek, and Laurent J. Brochard; on behalf of the American Thoracic Society, European Society of Intensive Care Medicine, and Society of Critical Care Medicine

This official clinical practice guideline of the American Thoracic Society (ATS), European Society of Intensive Care Medicine (ESICM), and Society of Critical Care Medicine (SCCM) was approved by the ATS, ESICM, and SCCM, March 2017

Recommendation:

We suggest that adult patients with ARDS receive RMs

[ATS-SCCM-ESICM Am J Respir Crit Care Med 2017]

Why

Table 6. Outcomes[a]

Outcomes	No. (%) Lung Open Ventilation (n = 475)	Control Ventilation (n = 508)	Relative Risk (95% Confidence Interval)	*P* Value
Death in hospital	173 (36.4)	205 (40.4)	0.90 (0.77-1.05)	.19
Death in intensive care unit	145 (30.5)	178 (35.0)	0.87 (0.73-1.04)	.13
Death during mechanical ventilation	136 (28.6)	168 (33.1)	0.87 (0.72-1.04)	.13
Death during first 28 d	135 (28.4)	164 (32.3)	0.88 (0.73-1.07)	.20
Barotrauma[b]	53 (11.2)	47 (9.1)	1.21 (0.83-1.75)	.33
Refractory hypoxemia	22 (4.6)	52 (10.2)	0.54 (0.34-0.86)	.01
Death with refractory hypoxemia	20 (4.2)	45 (8.9)	0.56 (0.34-0.93)	.03
Refractory acidosis	29 (6.1)	42 (8.3)	0.81 (0.51-1.31)	.39
Death with refractory acidosis	27 (5.7)	38 (7.5)	0.85 (0.51-1.40)	.52
Refractory barotrauma	14 (3.0)	12 (2.4)	1.10 (0.54-2.26)	.80
Death with refractory barotrauma	8 (1.7)	8 (1.6)	1.00 (0.41-2.40)	.99
Eligible use of rescue therapies[c]	24 (5.1)	47 (9.3)	0.61 (0.38-0.99)	.045
Total use of rescue therapies[c]	37 (7.8)	61 (12.0)	0.68 (0.46-1.00)	.05
Days of mechanical ventilation[d]	10 (6-17)	10 (6-16)		.92
Days of intensive care[d]	13 (8-23)	13 (9-23)		.98
Days of hospitalization[d]	28 (17-48)	29 (16-51)		.96

[LOV Trial JAMA 2006]

How much

The amount of atelectasis:

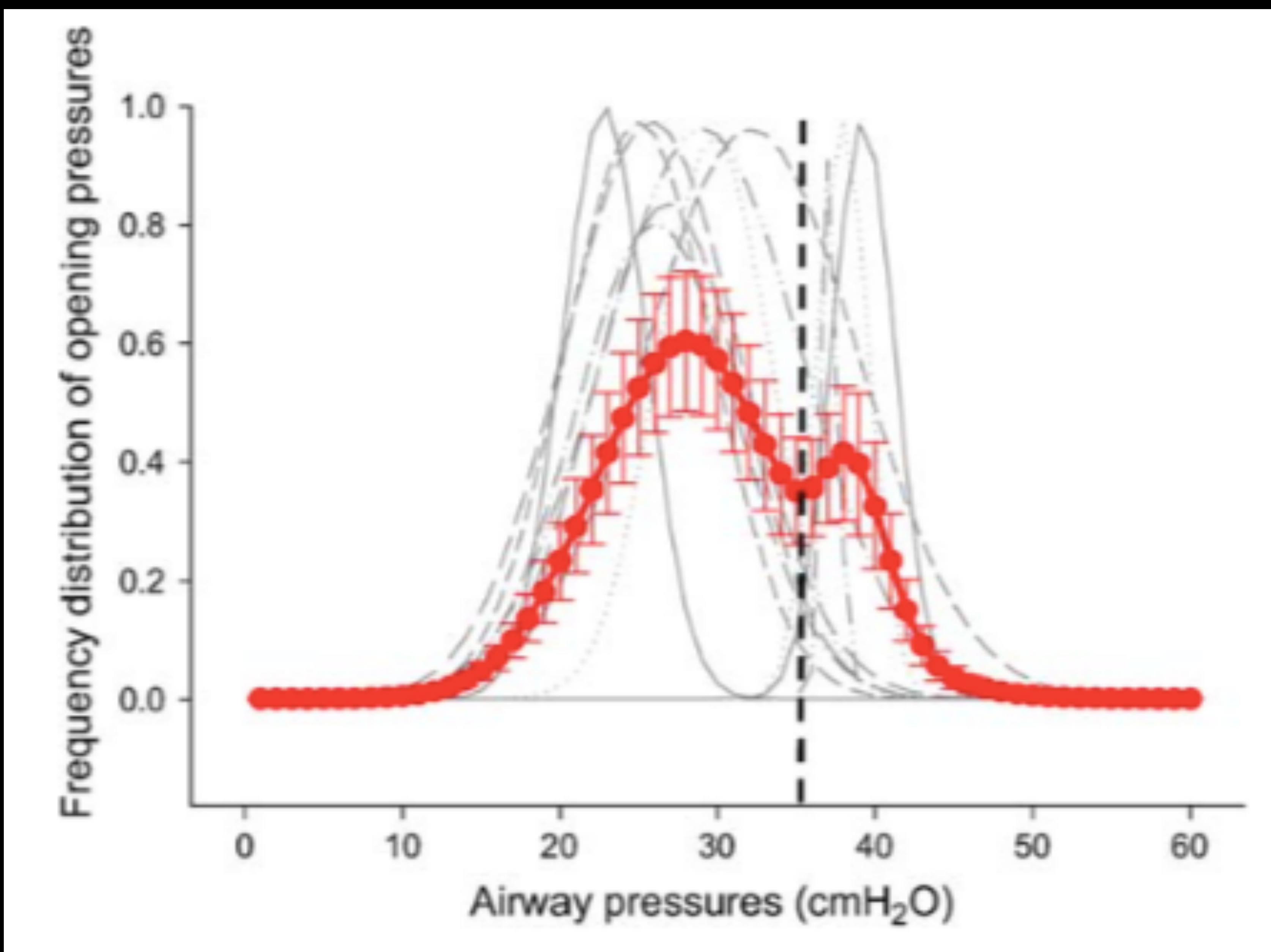
- does not change during normal tidal breathing or by a "sigh" using an airway-pressure of up to 20 cm H_2O;
- decreases to the half at a sustained inflation of the lungs to an airway-pressure of 30 cm H_2O;
- does not change for any additional inflations of the lung to the same airway-pressure (30 cm H_2O)
- goes approx to 0 at an airway pressure of 40 cm H_2O in normal lungs
- goes approx to 0 at an airway pressure of 55 cm H_2O in lungs of pts BMI > 45

[Rothen BJA 1993]
[Reinius Anesthesiology 2009]

How much

Reversibility of Lung Collapse and Hypoxemia in Early Acute Respiratory Distress Syndrome

João B. Borges, Valdelis N. Okamoto, Gustavo F. J. Matos, Maria P. R. Caramez, Paula R. Arantes, Fabio Barros, Ciro E. Souza, Josué A. Victorino, Robert M. Kacmarek, Carmen S. V. Barbas, Carlos R. R. Carvalho, and Marcelo B. P. Amato



With PEEP set 2 cmH2O above the critical opening pressure 20–30 % of the lung is still collapsed.

After RM less than 5% of the total lung mass remains collapsed.

How long

Time constant (τ)

=

Compliance (C) x Resistance (R)

=

Time necessary to inflate 63% of its Vt is called the Time constant (τ)

1 τ = 63% Vt exhaled/inhaled

2 τ = 86 % Vt exhaled/inhaled

3 τ = 95% Vt exhaled/inhaled

5 τ = 100% Vt exhaled/inhaled

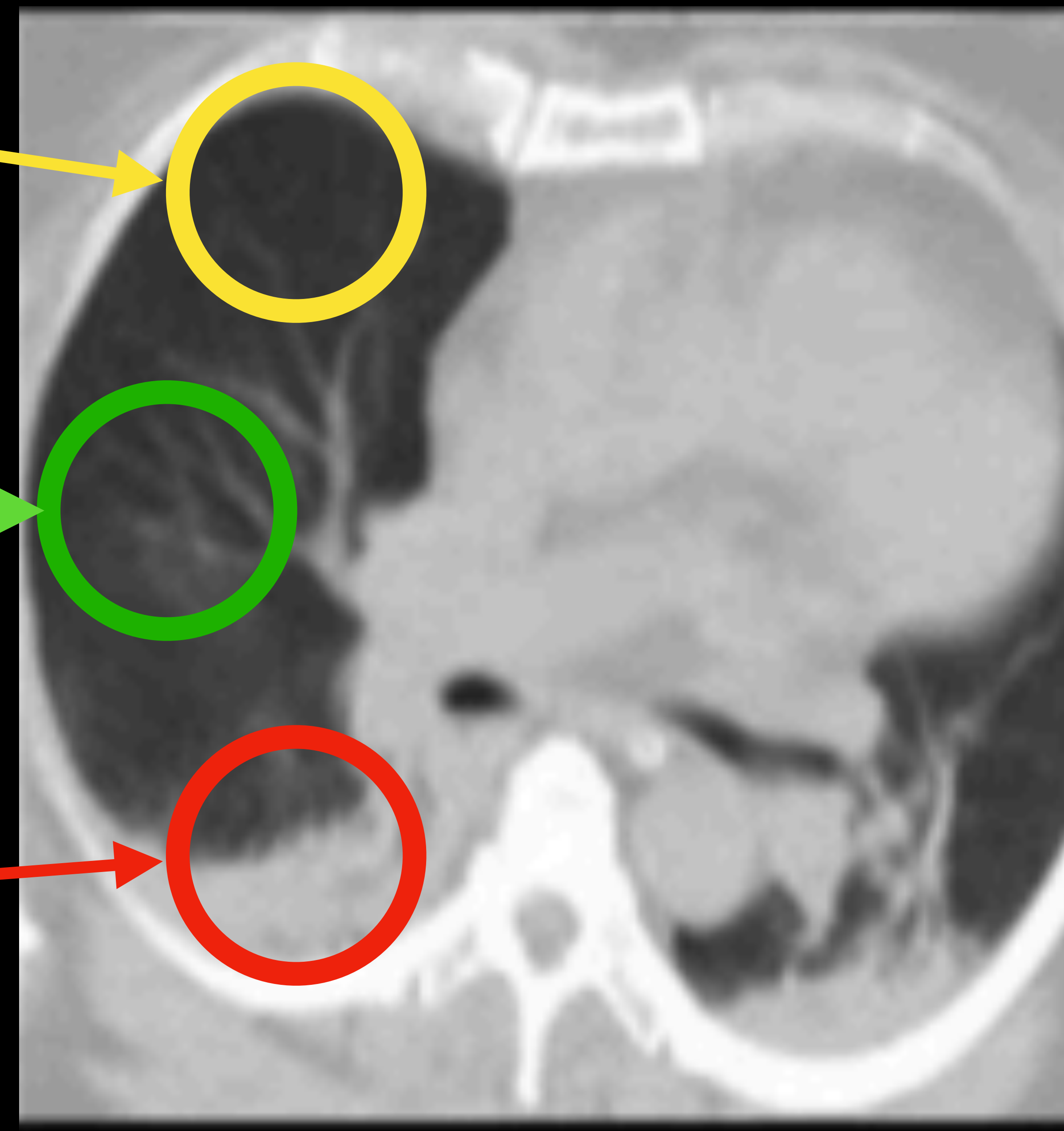
Steady state only after 5 τ (whatever is the Vt)

Where

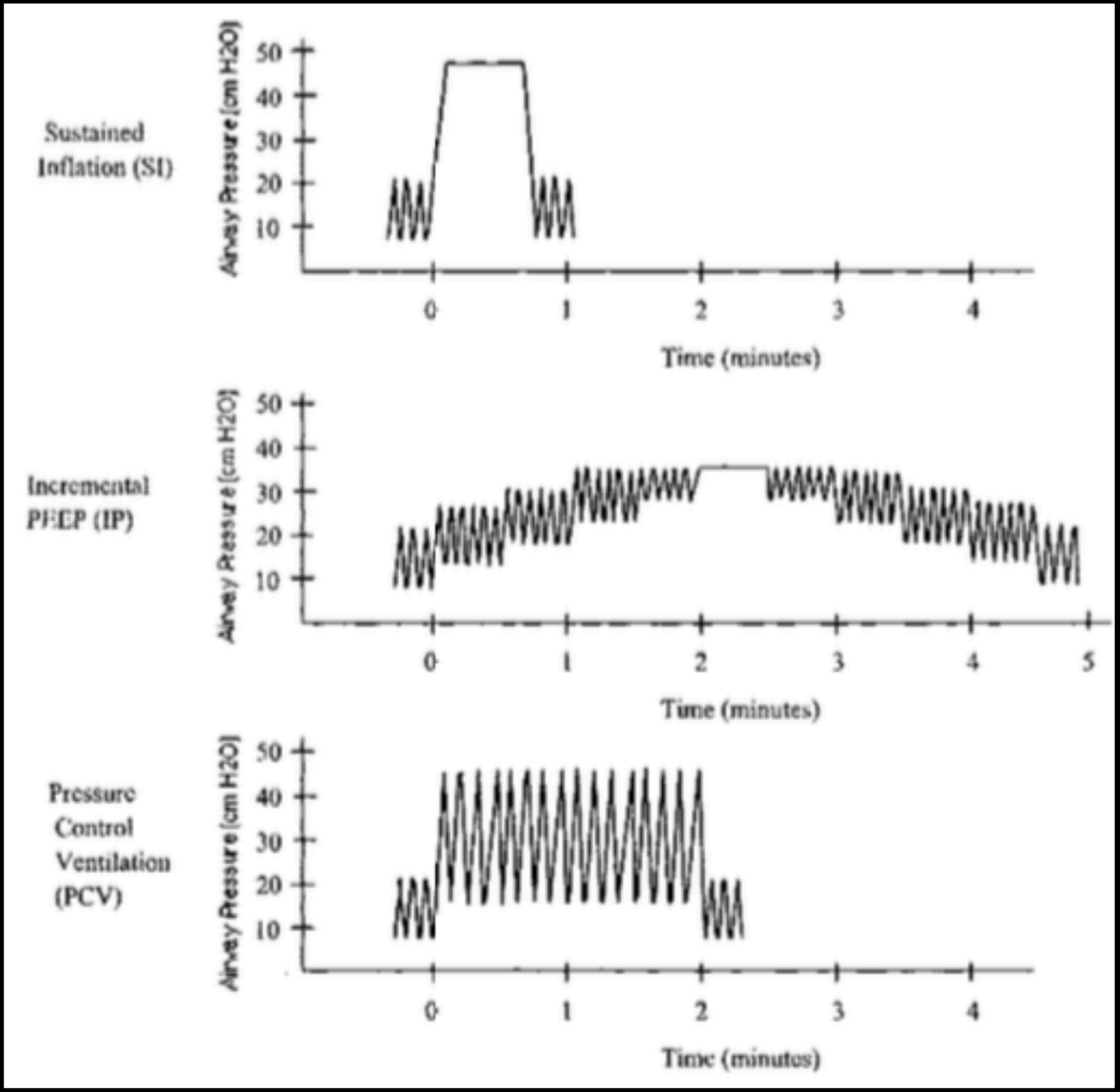
Hyperinflated area
V/Q >>> 1

Normoareated area
V/Q = 1

Atelectasis area
V/Q <<< 1



How



CPAP

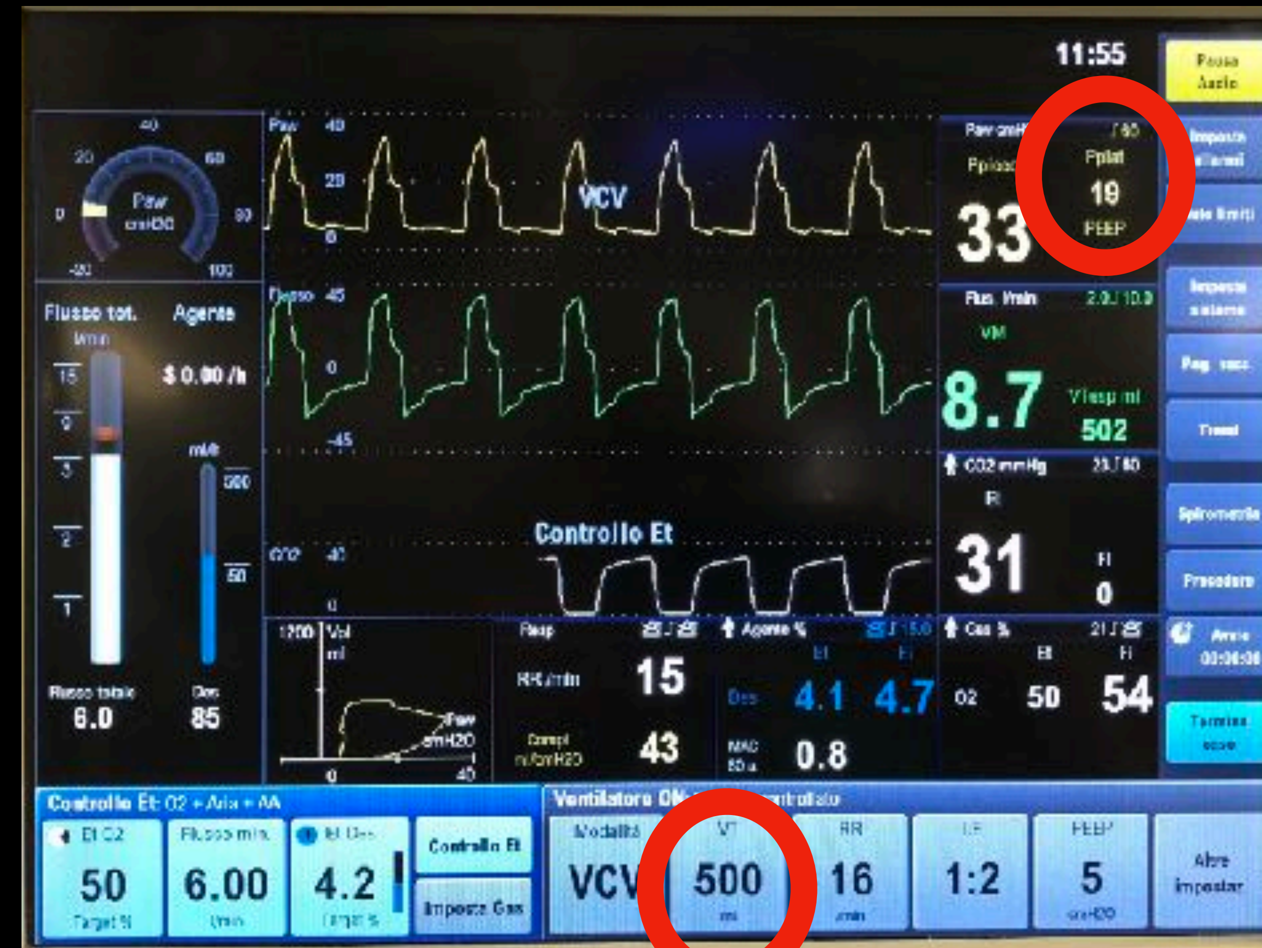
PEEP Increase

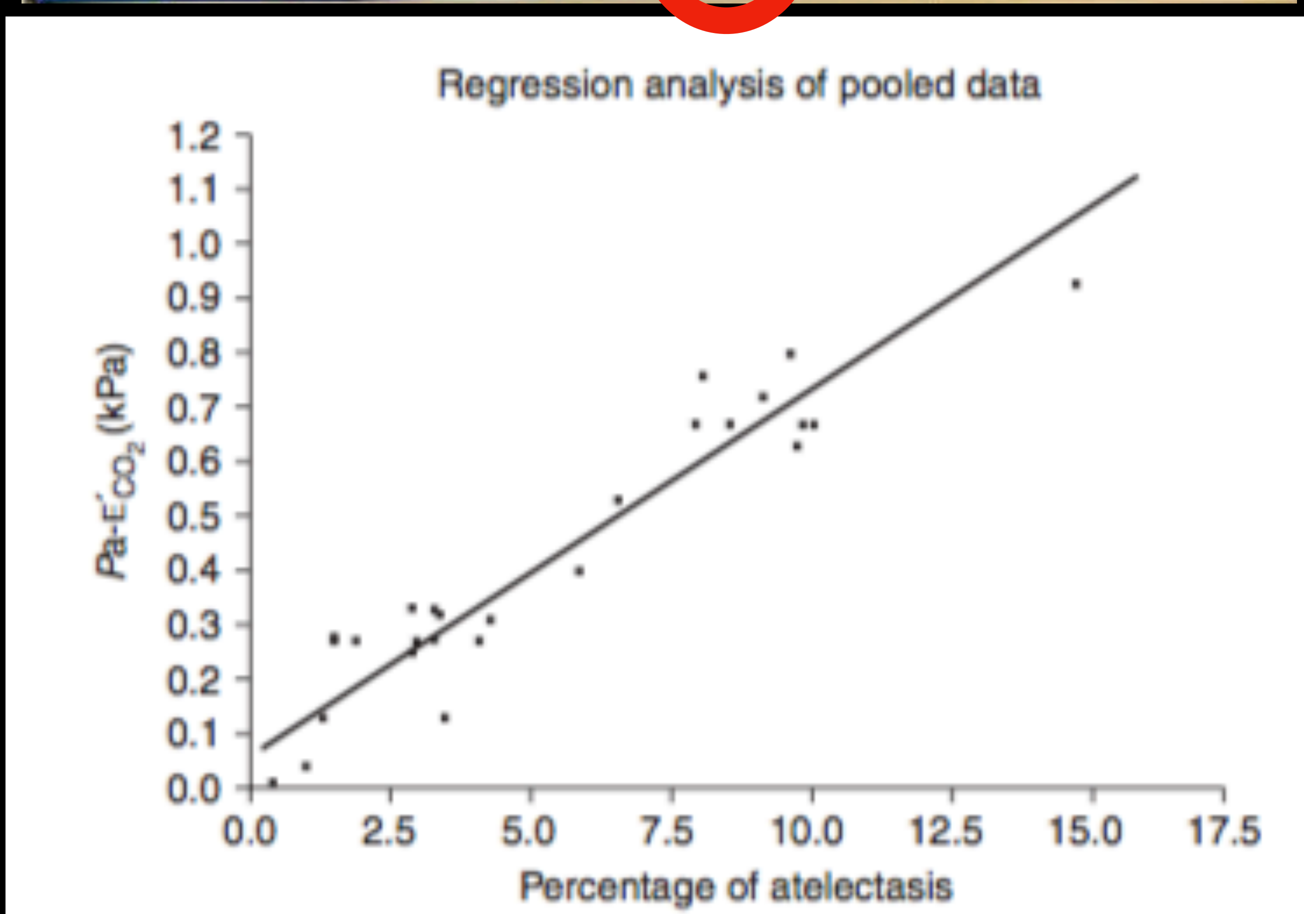
PCV "Tusman" RM

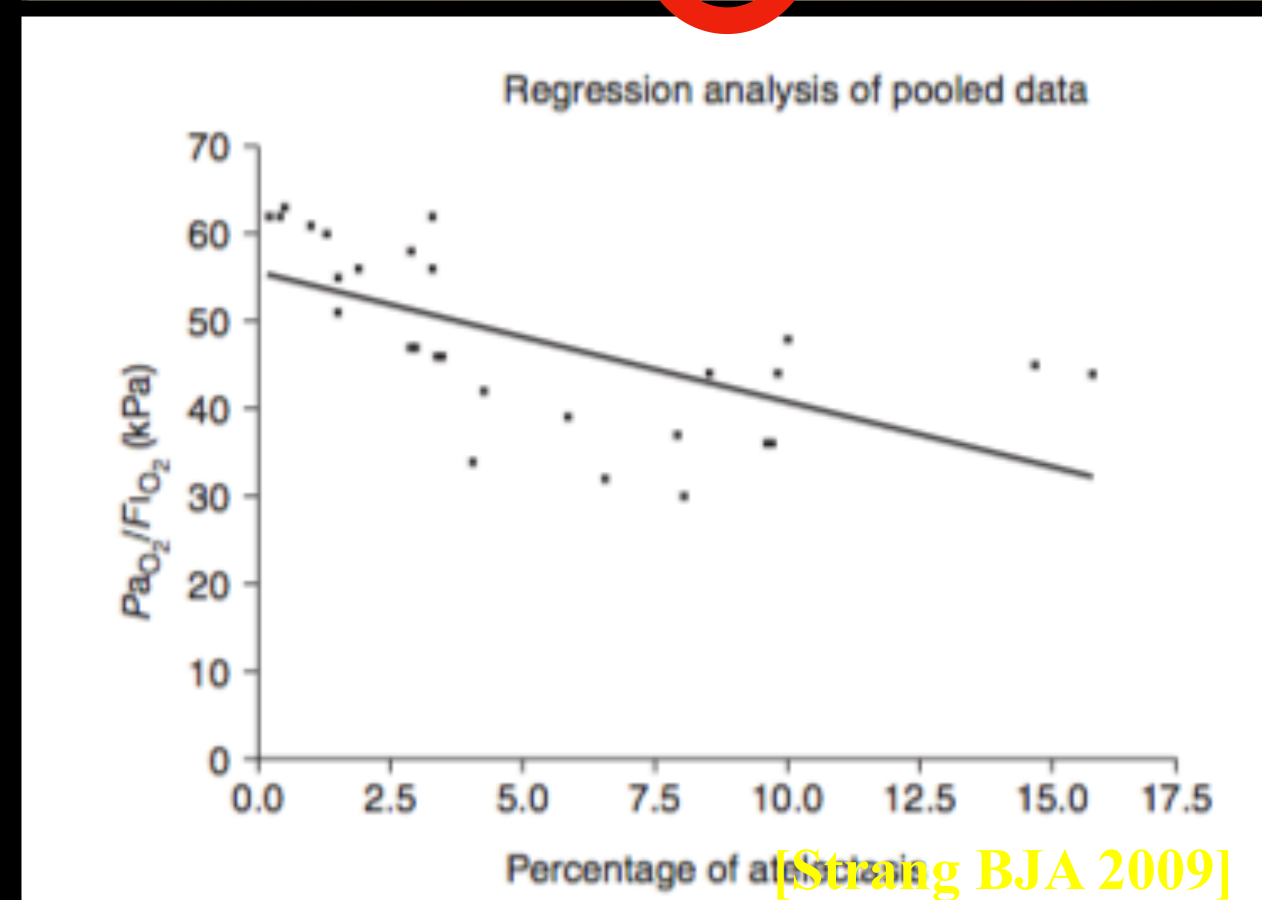
[Lim Crit Care Med 2004]

When - How detect

RM

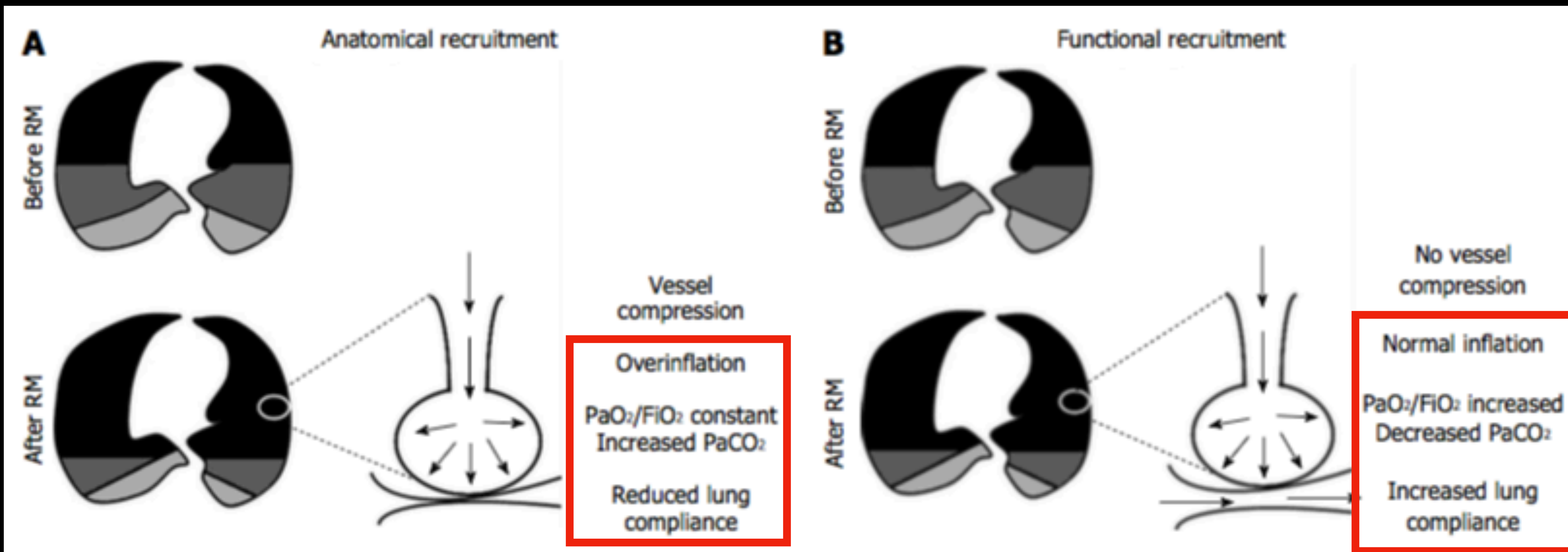






[Strang BJA 2009]

When - How detect

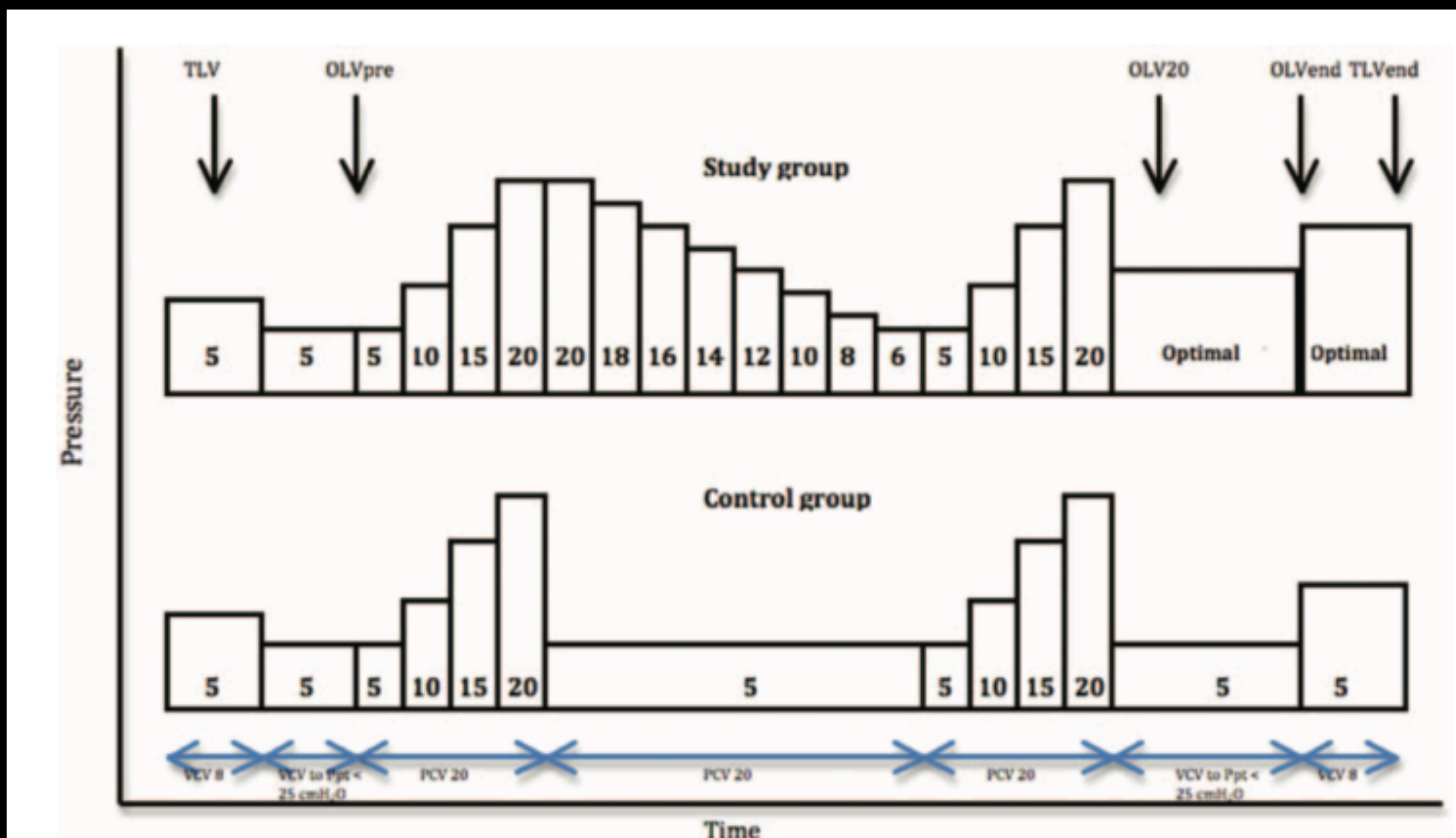


[Santos World J Crit Care Med 2015]

After RM

Setting Individualized Positive End-Expiratory Pressure Level with a Positive End-Expiratory Pressure Decrement Trial After a Recruitment Maneuver Improves Oxygenation and Lung Mechanics During One-Lung Ventilation

Carlos Ferrando, MD, PhD,* Ana Mugarra, MD,* Andrea Gutierrez, MD,* Jose Antonio Carbonell, MD,* Marisa García, MD,* Marina Soro, MD, PhD,* Gerardo Tusman, MD,† and Francisco Javier Belda, MD, PhD*



[Ferrando A&A 2014]

After RM

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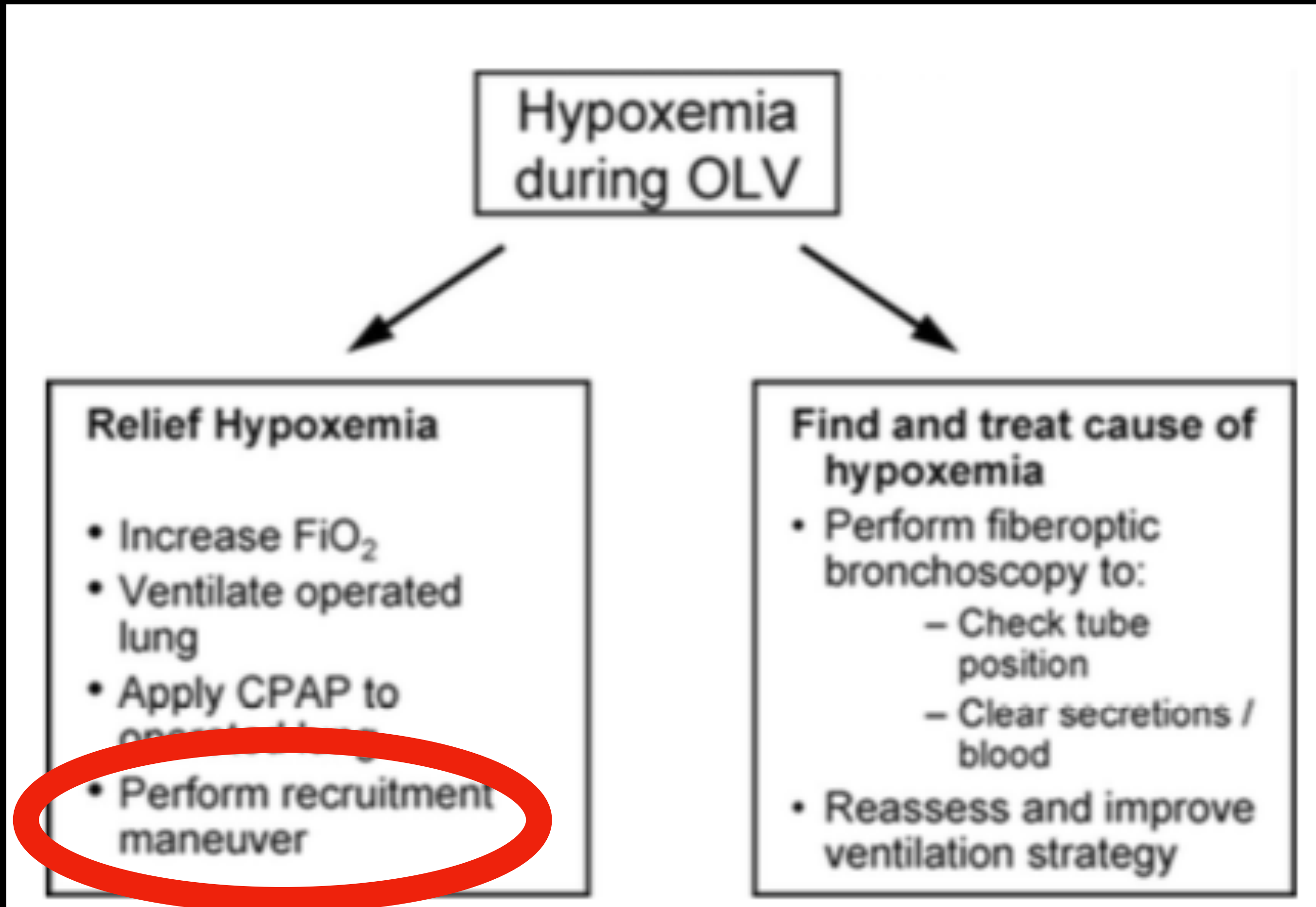
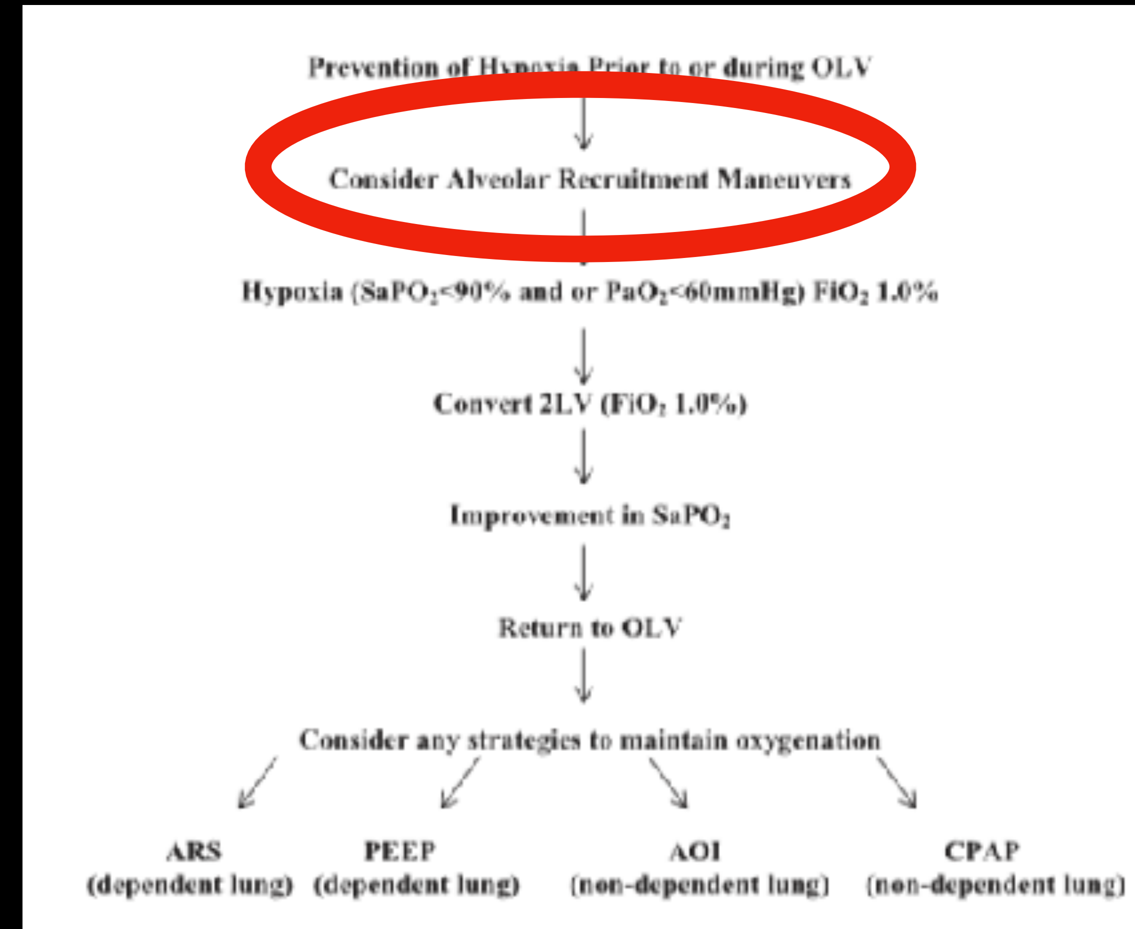
- During OLV, oxygenation was maintained in the study group but decreased in the control group.
- After OLV, arterial oxygenation was higher in the study group (306 vs 231 mm·Hg, $P = 0.007$).
- Static compliance increased signicantly only in the study group ($P < 0.001$) after the RM and optimal PEEP adjustment.
- RM did not decrease cardiac index in any patient.

[Ferrando A&A 2014]

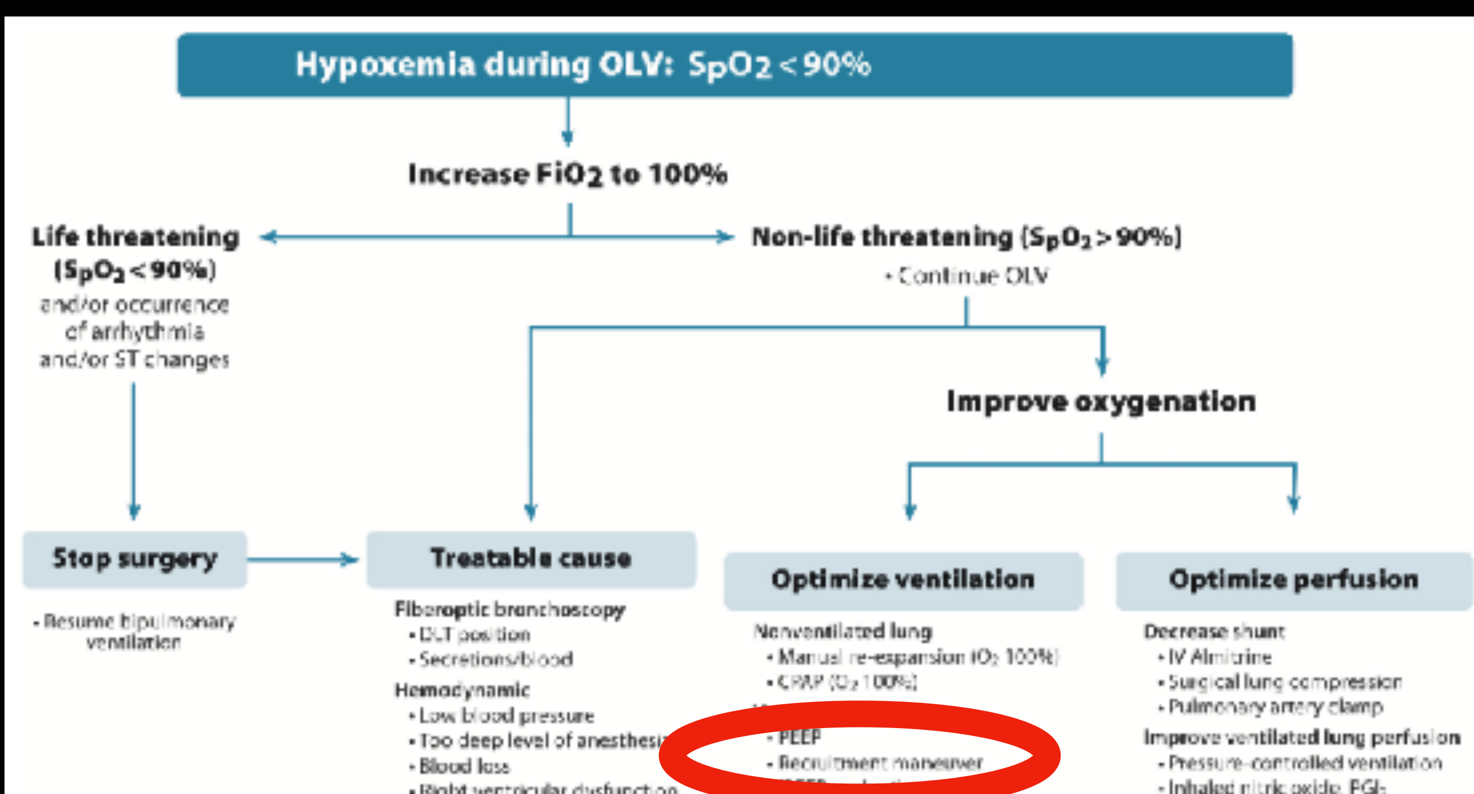
TRIALS RM & OLV



[Karzai Anesthesiology 2009]



[Campos J Cardiothor Vasc Anesth 2018]



[Rozè Anesthesiology 2011]

Table 6.4. Approach to hypoxemia during one-lung ventilation.

Mild hypoxemia (90–95%)
Confirm position of lung isolation device
Recruit ventilated lung
Ensure [illegible] cardiac output
Increase F_iO_2 towards 1.0
Optimize PEEP to nonoperative lung (up or down; towards lower inflection point)
CPAP/HFJV/O_2 insufflation to operative lung (IPAP, FOB)
Consider reduction in vapor anesthetic and/or total intravenous anesthesia
Ensure adequate oxygen carrying capacity (hemoglobin)
Severe (<<90%) or refractory hypoxemia
Resume TLV with 100% O_2
If not possible, consider
Pulmonary artery clamp on operative side during pneumonectomy, transplant
Inhaled NO and/or infusions of almitrine/phenylephrine
Extracorporeal support during lung transplantation (Nova-lung, CPB)

[Slinger Princ Pract Anesth 2011]

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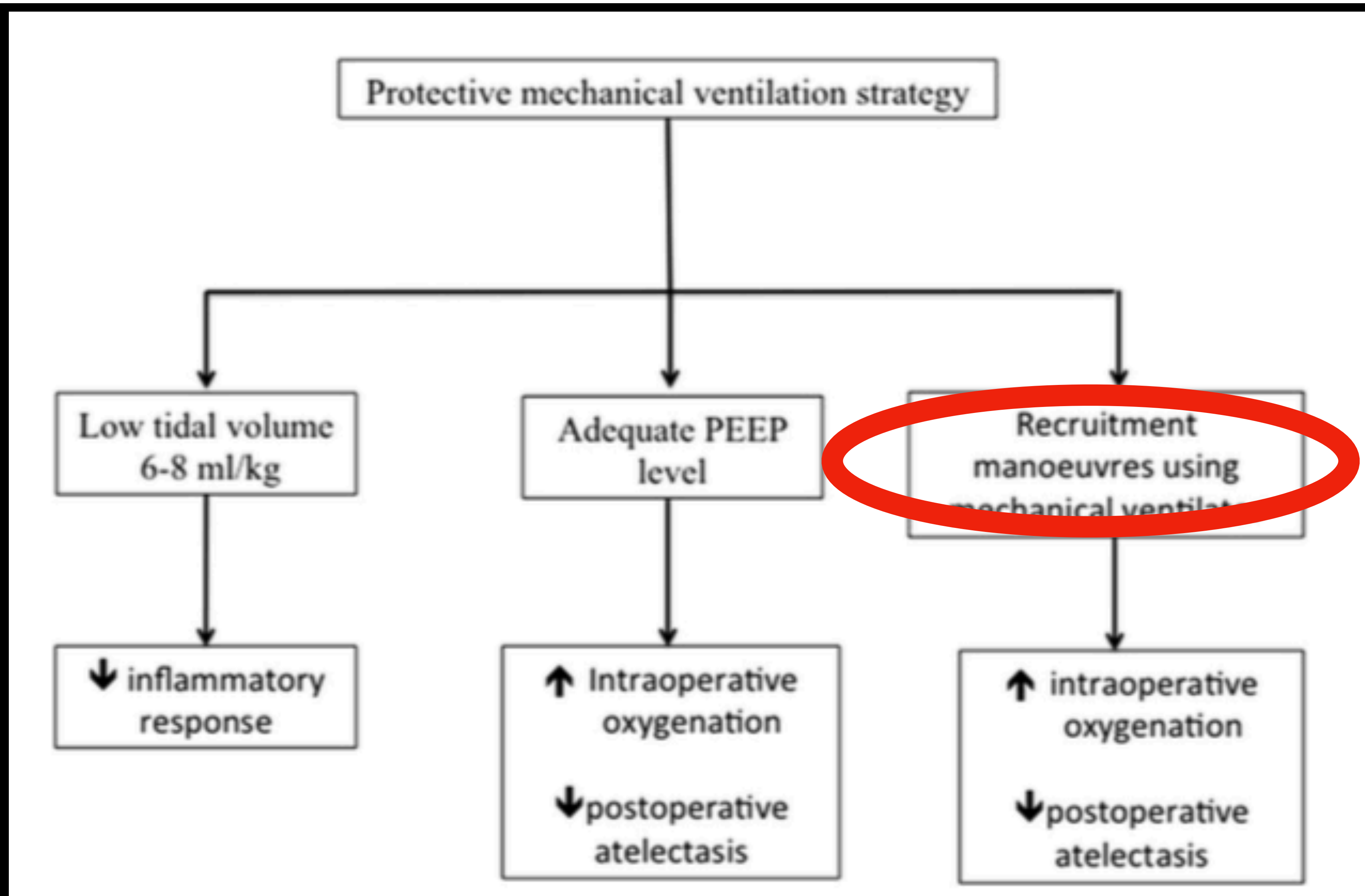
REVIEW

Protective mechanical ventilation during general anaesthesia

Maria Vargas, Iole Brunetti, Paolo Pelosi*

Department of Anaesthesia and Intensive Care Medicine, IRCCS AOU San Martino – IST, Genoa, Italy

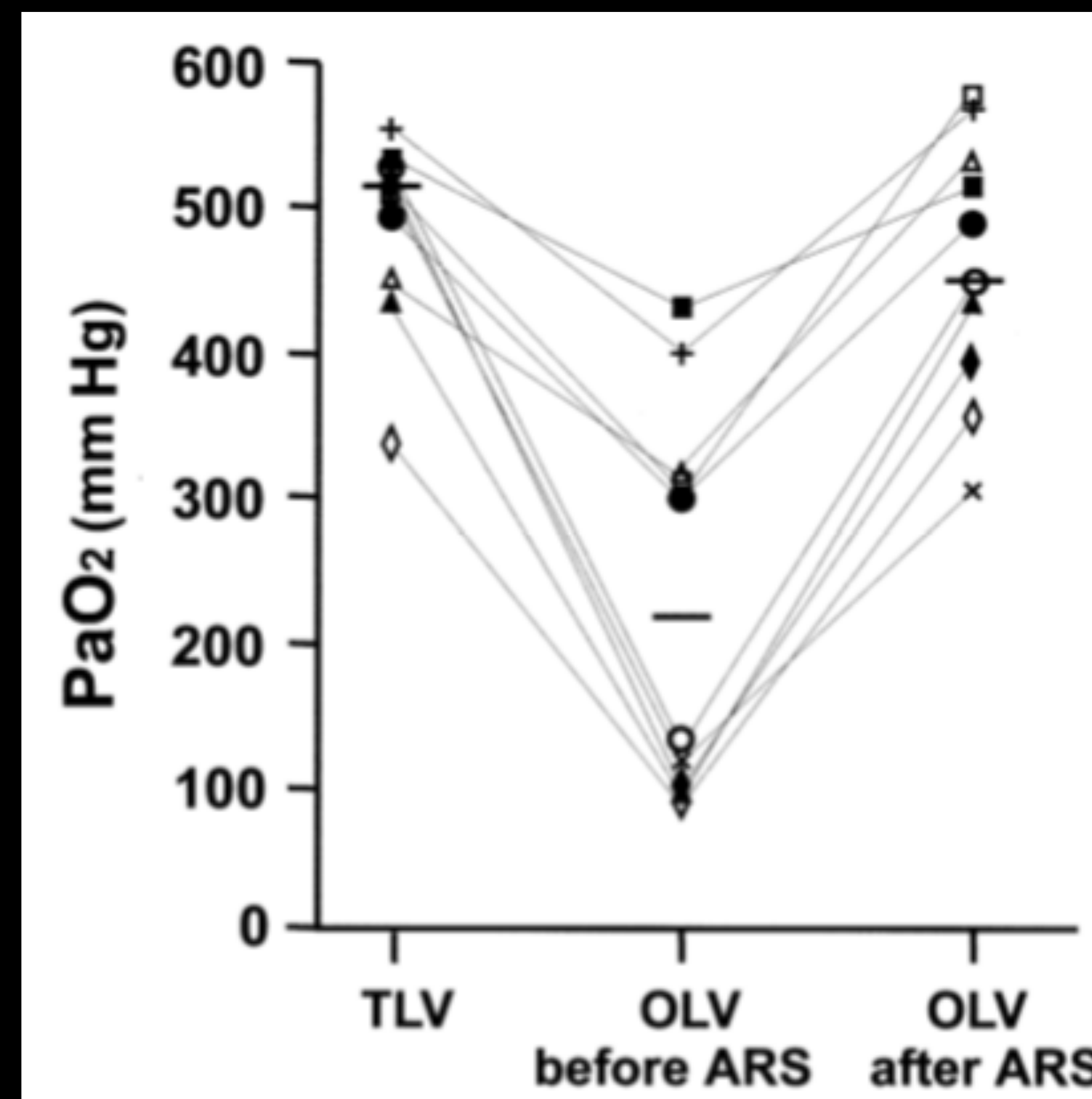


[Vargas Trends Anesth Crit Care 2013]

Alveolar Recruitment Strategy Increases Arterial Oxygenation During One-Lung Ventilation

Gerardo Tusman, MD, Stephan H. Böhm, MD, Fernando Melkun, MD, Daniel Staltari, MD, FACS, Carlos Quinzio, MD, Carlos Nador, MD, and Elsio Turchetto, MD

10 pts
Prospective Observational Study
"Tusman" RM



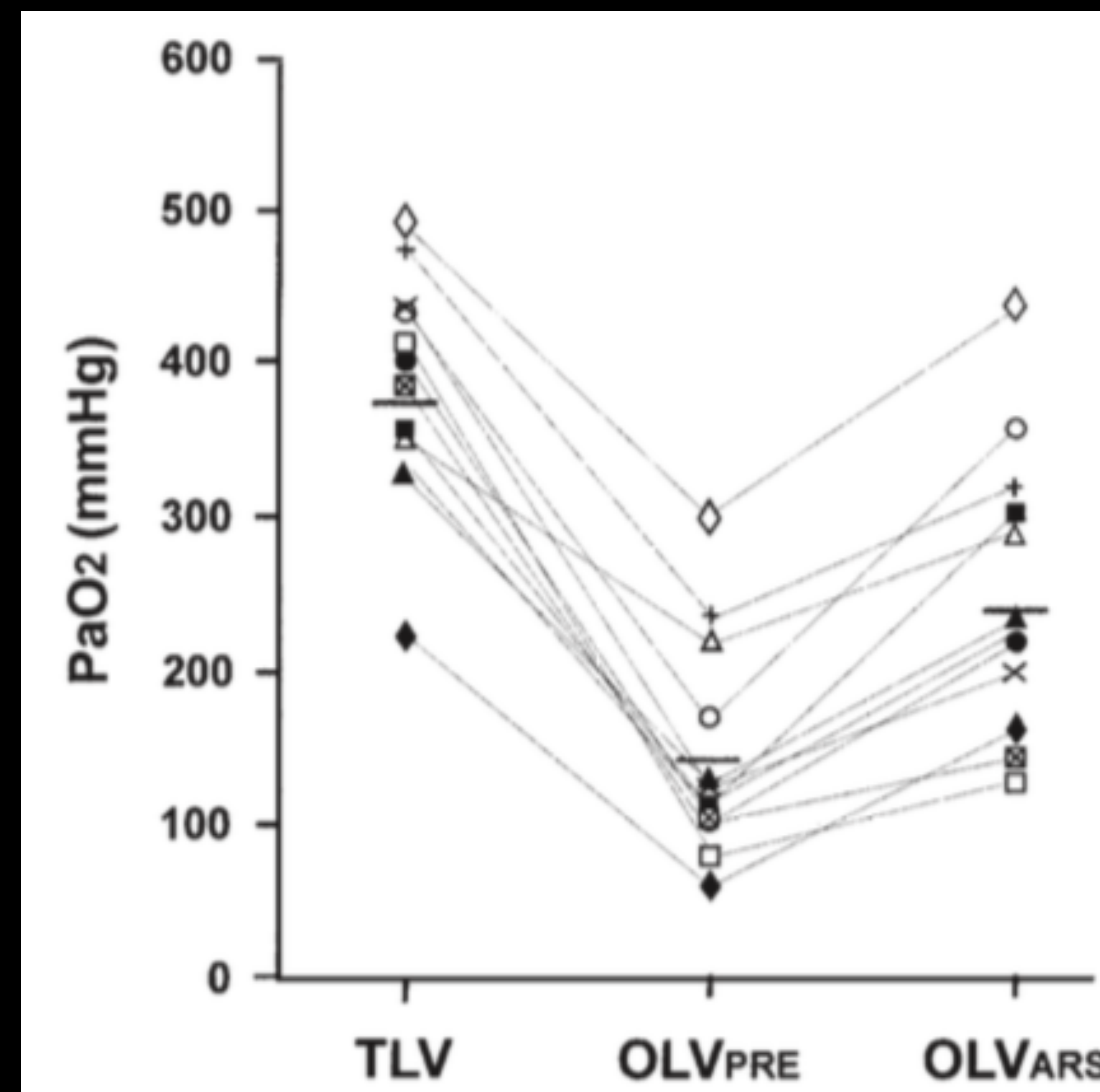
[Tusman Ann Thorac Surg 2002]

Lung Recruitment Improves the Efficiency of Ventilation and Gas Exchange During One-Lung Ventilation Anesthesia

Gerardo Tusman, MD*, Stephan H. Böhm, MD†, Fernando Suárez Sipmann, MD‡, and Stefan Maisch, MD†

12 pts
Prospective Observational Study
“Tusman” RM

	Before RM	Afer RM
pO2	144 ± 73	244 ± 89
VD/VT	0.6 ± 0.05	0.5 ± 0.04

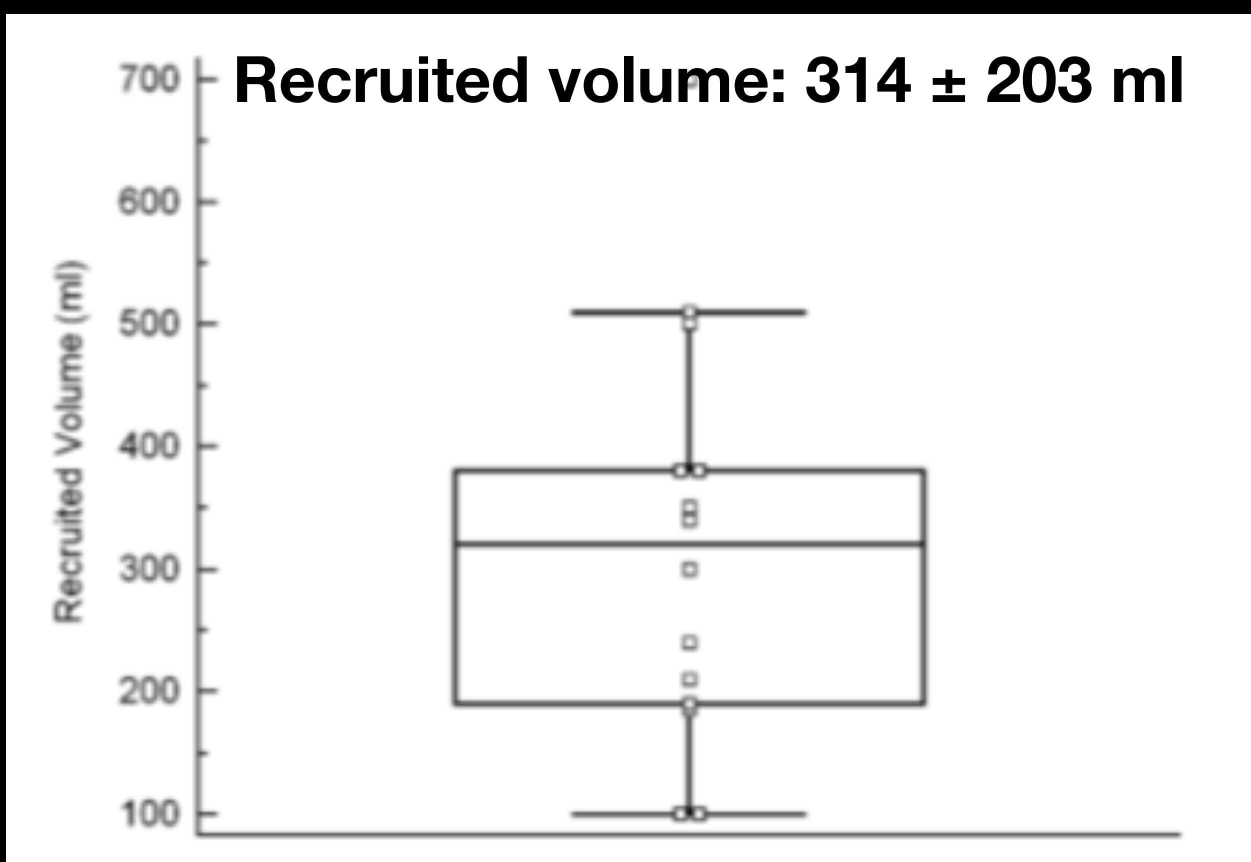


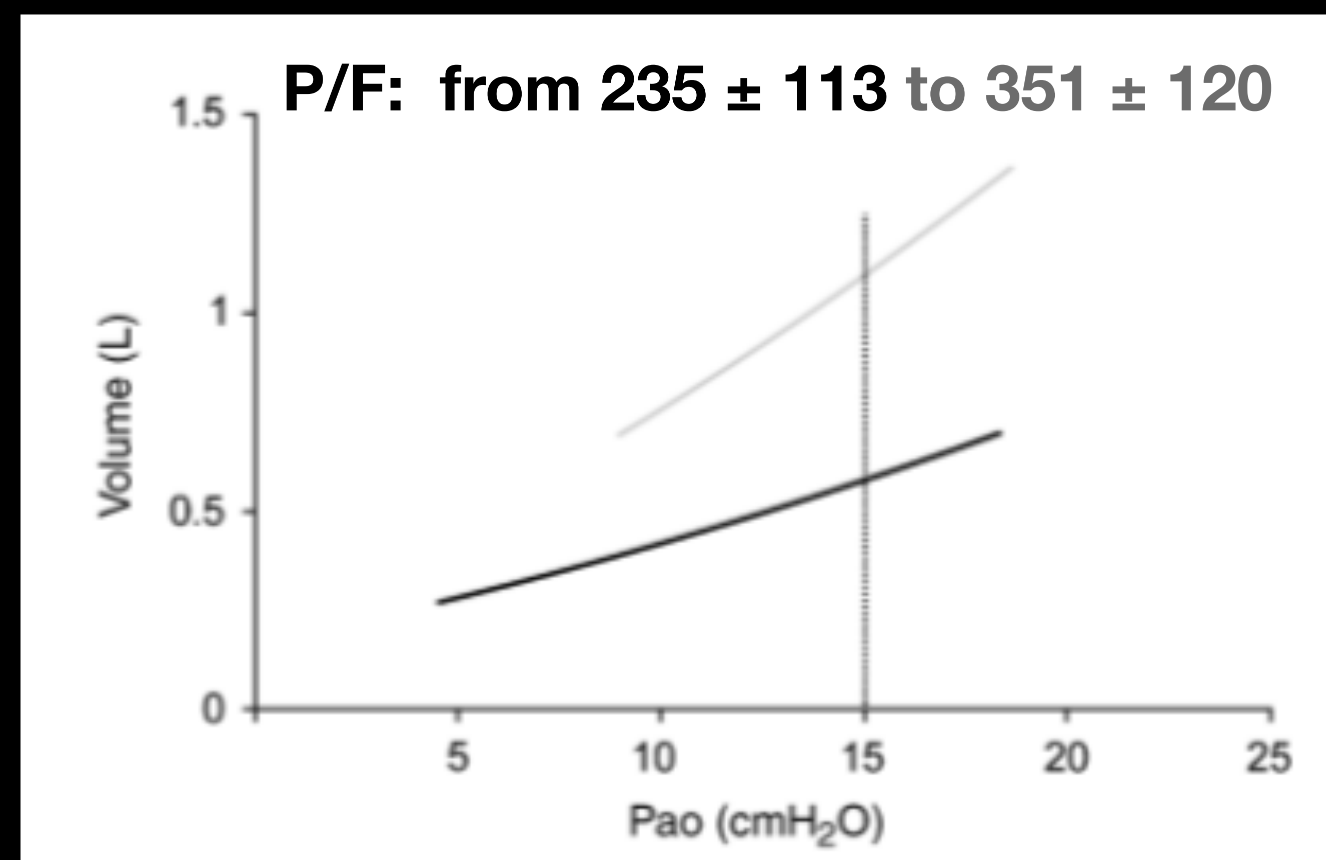
[Tusman A&A 2004]

Physiological effects of a lung-recruiting strategy applied during one-lung ventilation

G. Cinnella[1], S. Grasso[2], C. Natale[1], F. Sollitto[3], M. Cacciapaglia[1], M. Angiolillo[3], G. Pavone[1], L. Mirabella[1] and M. Dambrosio[1]

13 pts
Prospective Observational Study
"Tusman" RM





[Cinnella Acta Anesth Scan 2008]

The Impact of Lung Recruitment on Hemodynamics During One-Lung Ventilation

Ignacio Garutti, PhD, MD, Guillermo Martinez, PhD, Patricia Cruz, PhD, Patricia Piñeiro, PhD, Luis Olmedilla, PhD, MD, and Francisco de la Gala, PhD, MD

40 pts
Prospective Observational Study
“Tusman” RM

Table 3. Gasometric (Arterial and Venous) Values Before and After Alveolar Recruitment Maneuver

	Before ARM	After 10 min ARM	*p* Value
PaO_2 (mmHg)	99.37 (38)	130.65 (58)	<0.001
PvO_2 (mmHg)	47.00 (5.7)	48.11 (7.6)	0.079
SaO_2 (%)	95.30 (4.6)	97.15 (3.2)	<0.001
$ScvO_2$ (%)	78.89 (6.3)	80.46 (6.6)	0.125
$PaCO_2$ (mmHg)	41.88 (7.1)	40.15 (7.8)	<0.001
$PvCO_2$ (mmHg)	46.46 (6.7)	45.98 (7.5)	0.594

NOTE. *p* Value was compared before with after ARM. Values are mean (standard deviation).

Table 2. Hemodynamic Values Before and After Alveolar Recruitment Maneuver

	CI (L/min/m²)	SVI (mL/beat/m²)	SVV (%)	HR (beats/min)	SAP (mmHg)	MAP (mmHg)	DAP (mmHg)	$SvcO_2$ (%)
Baseline	2.68 (0.6)	35.8 (7.6)	9.1 (4.0)	74.4 (15.5)	109.0 (28)	79.1 (19.2)	62.0 (14.8)	72.5 (9.0)
1 min	2.48 (0.7)*	32.4 (7.0)†	13.2 (6.8)†	76.0 (14.3)*	102.3 (29)†	73.1 (19.4)†	58.1 (14.7)*	69.2 (9.6)*
2 min	2.55 (0.7)	33.4 (7.2)*	12.6 (7.5)†	76.4 (14.7)	103.8 (28)	73.4 (18.6)	60.0 (12.7)	68.5 (10)*
3 min	2.70 (0.6)	35.3 (5.8)	9.9 (4.7)	76.9 (14.1)	106.6 (24)	74.8 (17.6)	59.9 (11.4)	72.0 (9.5)
4 min	2.73 (0.5)	36.1 (6.2)	9.8 (4.5)	76.9 (14.2)	109.4 (22)	78.2 (14.7)	61.4 (11.2)	72.9 (8.5)
5 min	2.73 (0.5)	36.3 (7.7)	10.6 (8.0)	76.3 (13.4)	109.8 (22)	78.0 (14.9)	61.4 (10.3)	73.9 (8.4)
10 min	2.76 (0.5)	36.5 (6.4)	10.4 (5.6)	76.8 (13.1)	109.7 (21)	79.4 (15.1)	62.8 (11.4)	74.2 (8.6)

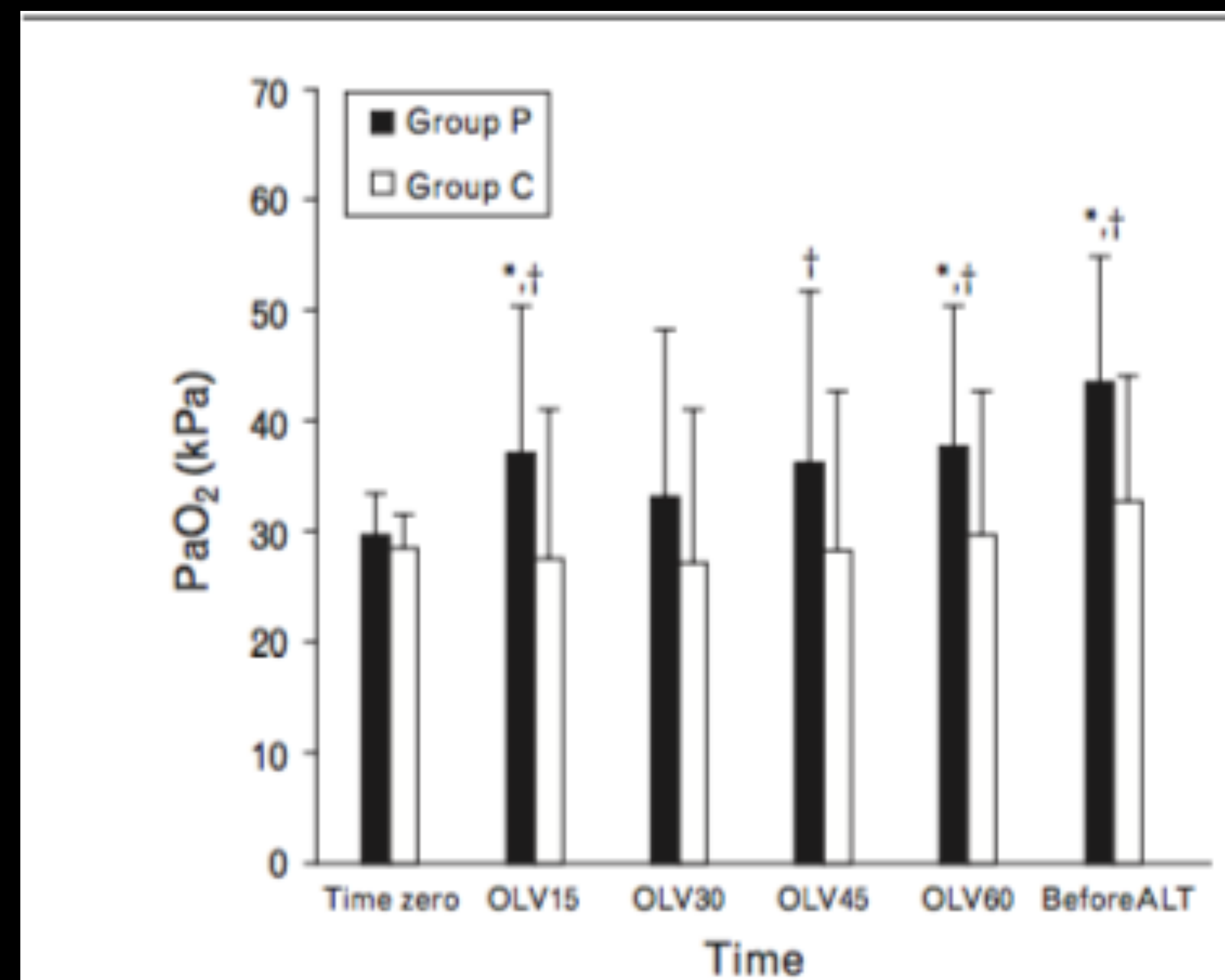
[Garutti Acta Anesth Scan 2009]

A preemptive alveolar recruitment strategy before one-lung ventilation improves arterial oxygenation in patients undergoing thoracic surgery: a prospective randomised study

Sang-Heon Park, Young-Tae Jeon, Jung-Won Hwang, Sang-Hwan Do, Ju-Hee Kim and Hee-Pyoung Park

42 pts
RCT
Bag Squeeze

	Group C ($n = 21$)	Group P ($n = 21$)
Static compliance (ml cmH$_2$O^{-1})		
Baseline	50 ± 8	51 ± 8
ARS	49 ± 8	$57 \pm 16^{*}$
OLV15	$31 \pm 8^{\dagger}$	$35 \pm 9^{\dagger}$
OLV30	$30 \pm 8^{\dagger}$	$35 \pm 8^{\dagger}$
OLV45	$30 \pm 8^{\dagger}$	$35 \pm 8^{\dagger}$
OLV60	$31 \pm 8^{\dagger}$	$35 \pm 9^{\dagger}$
End of OLV	$31 \pm 8^{\dagger}$	$36 \pm 9^{\dagger}$



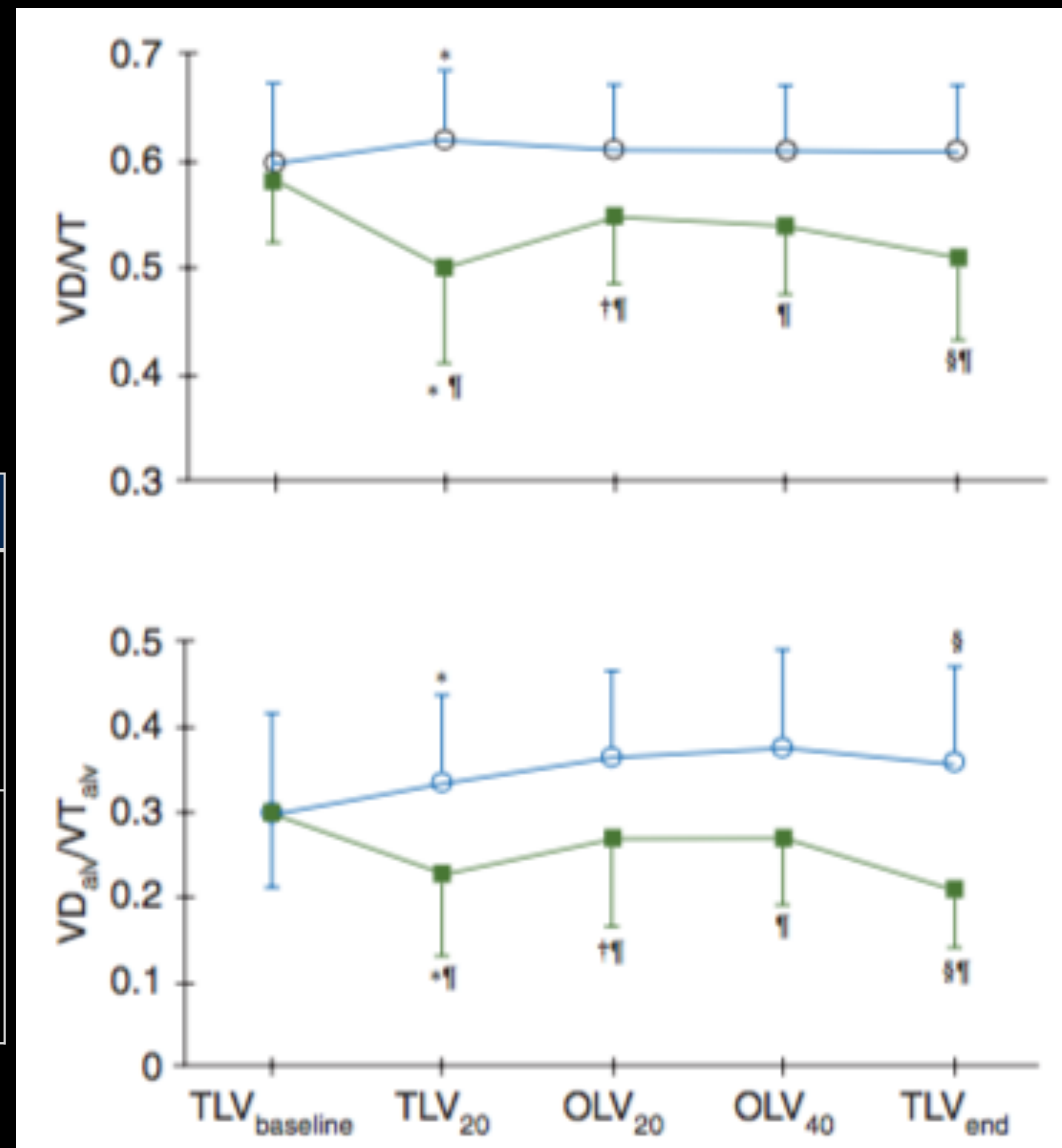
[Park EJA 2011]

Alveolar recruitment improves ventilation during thoracic surgery: a randomized controlled trial

C. Unzueta[1*], G. Tusman[2], F. Suarez-Sipmann[3], S. Böhm[4] and V. Moral[1]

40 pts
RCT
"Tusman" RM

	Control	RM
VD/VT	↑	↓
P/F	=	↑



[Unzueta BJA 2012]

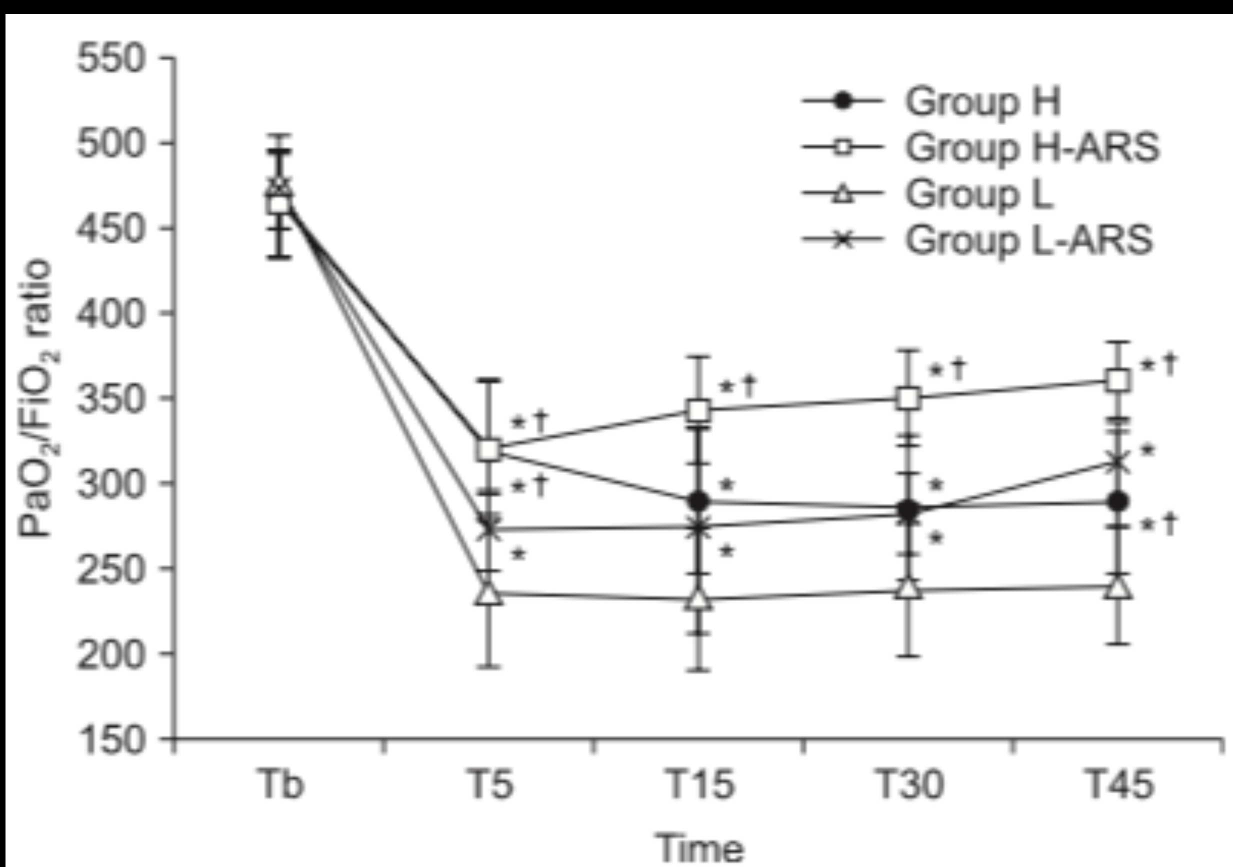
Effects of a preemptive alveolar recruitment strategy on arterial oxygenation during one-lung ventilation with different tidal volumes in patients with normal pulmonary function test

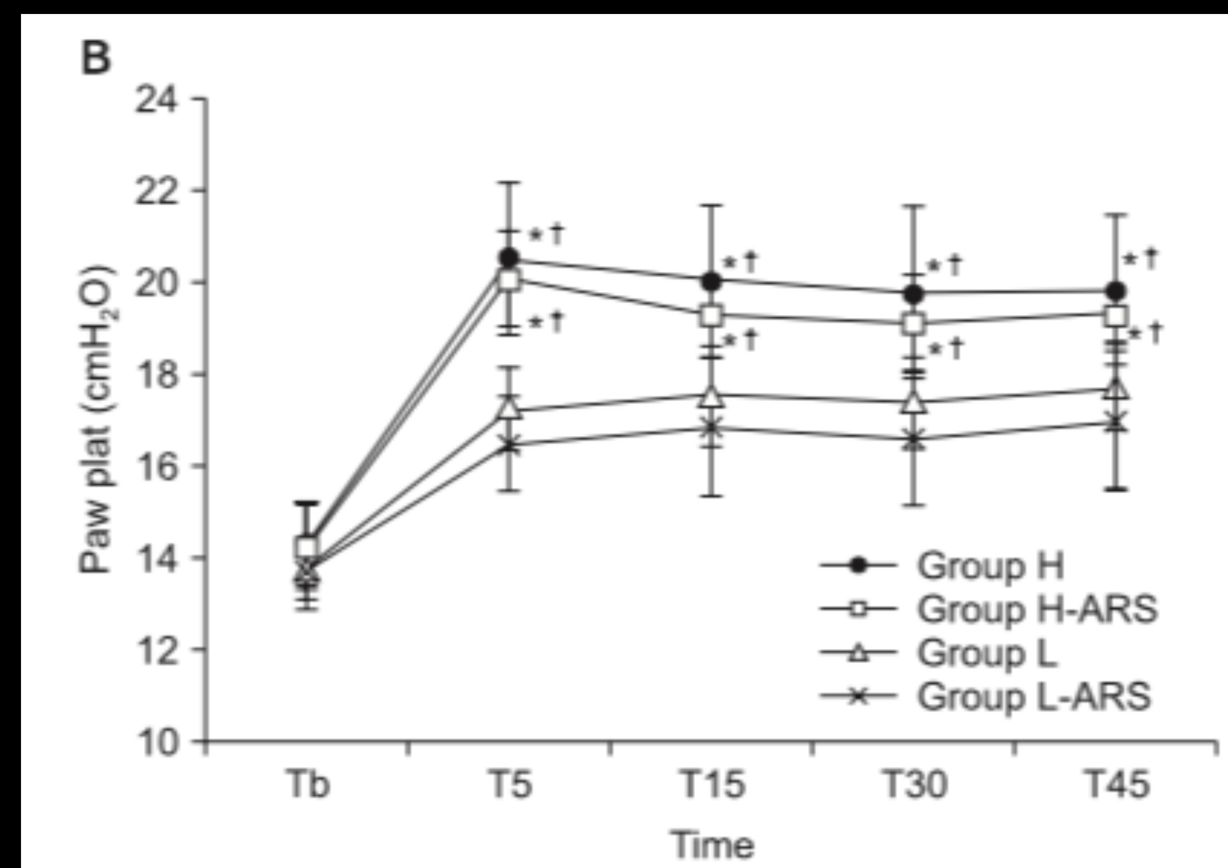
Jong Dal Jung[1,2], Sang Hun Kim[1,2], Byung Sik Yu[1,2], and Hye Ji Kim[2]

120 pts

RCT

“Tusman” RM





[Jung Kor J Anesth 2017]

Table 2 Clinical studies related to the use of RM during OLV

Author, year	Kind of study (number of patients)	Kind of surgery	Kind of RM	Main effects
Tusman et al. 2002 [19]	Prospective, case-series ($n = 10$)	Open lobectomies	Cycling RM in the dependent lung: 40/20 cm H_2O of Ppl/PEEP for 10 breaths	RM increased PaO_2 and lowered airway pressure during OLV
Tusman et al. 2004 [66]	Prospective, case-series ($n = 12$)	Open lobectomies, thoracoscopies, minimal-invasive CABG	Cycling RM in the dependent lung: 40/20 cm H_2O of Ppl/PEEP for 10 breaths	RM increased PaO_2 and decreased dead space variables during OLV
Cinella et al. 2008 [67]	Prospective, case-series ($n = 13$)	Open lobectomies, lung resections	Cycling RM in the dependent lung: 40/20 cm H_2O of Ppl/PEEP for 6 breaths	RM increased PaO_2 and decreased respiratory elastance during OLV Transient decrease in cardiac output during RM
Garutti et al. 2009 [68]	Prospective, case-series ($n = 40$)	Open thoracotomy	Cycling RM in the dependent lung: 40/20 cm H_2O of Ppl/PEEP for 5 breaths	RM improved arterial and venous oxygenation. Slight and transient effects on hemodynamics during RM
Park et al. 2011 [69]	Prospective, randomized, controlled study ($n = 40$)	Open lobectomies, pneumonectomies, wedge resections	Cycling RM in the dependent lung of treated patients: 40/20 cm H_2O of Ppl/PEEP for 12 min	RM increased PaO_2 and compliance during OLV in the treated group compared to control group
Unzueta et al. 2011 [70••]	Prospective, randomized, controlled study ($n = 40$)	Open lobectomies	Cycling RM during two lung ventilation in treated patients: 40/20 cm H_2O of Ppl/PEEP for 10 breaths	RM increased PaO_2 and compliance and decreased dead space during OLV in the treated group compared to control group

n = 155 pts + **Jung n = 120 pts** = **n = 275 pts**

[Tusman Curr Anesthesiol Rep 2014]

RE.MA.TO Study

[Ceraolo to be submitted]

RE.MA.TO Study
REcruitment MAneuver in Torino

- Prospective Observational Study
- Local Ethical Committee Approval
- Informed Consent from each patient
- Setting: Tertiary Care Hospital
- Population: patients scheduled for thoracic surgery
- Aim: evaluate non inferiority of CPAP RM vs Cycling RM

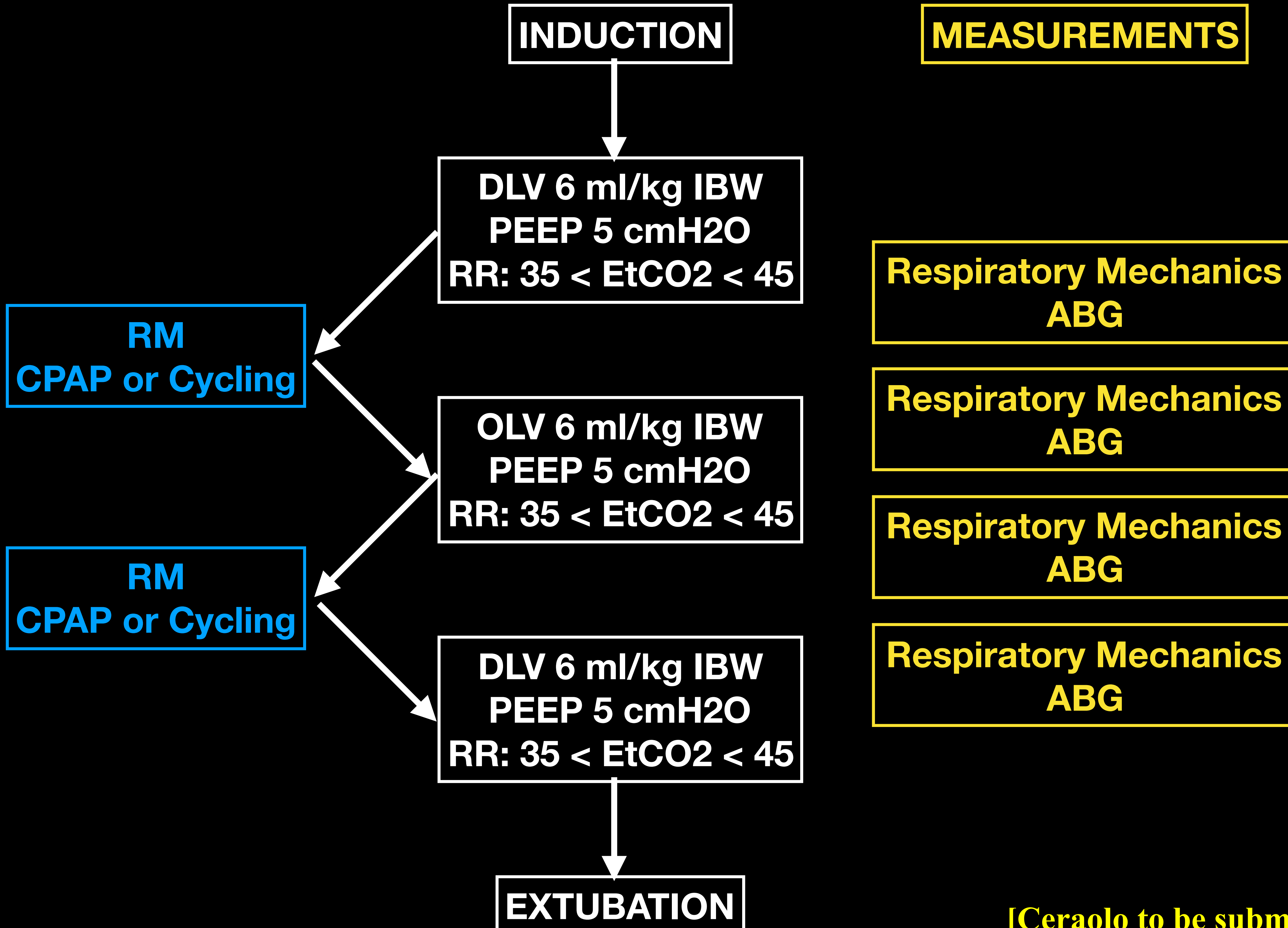
[Ceraolo to be submitted]

RE.MA.TO Study
REcruitment MAneuver in Torino

- **Inclusion criteria: patients scheduled for thoracic procedure & OLV in lateral decubitus position**
- **Exclusion criteria:**
  - **BMI > 30**
  - **Age < 18 years**
  - **Emphysema**
  - **Previous PNX**
  - **Previous thoracic procedures**
  - **Emodynamic impairment**
  - **Pregnancy**

[Ceraolo to be submitted]

RE.MA.TO Study
REcruitment MAneuver in Torino



[Ceraolo to be submitted]

RE.MA.TO Study
REcruitment MAneuver in Torino

	53 patients
Age (years)	61.6 ± 13.8 (65; 52-71)
Weight (kg)	72.5 ± 19.6 (71; 62-80)
Height (cm)	166.6 ± 9.3
BMI kg/m^2	26.0 ± 5.71 (25.3; 22.7-28)
ASA n (%)	I = 1 (1.9) II = 19 (36.5) III = 31 (59.6) IV = 1 (1.9)
FEV1 %	94.7 ± 25.5 (94; 83-109)
FVC %	101.4 ± 23.9 (101, 89-118)
DLCO %	80.8 ± 17.5 (78.5; 70.5-91)

[Ceraolo to be submitted]

RE.MA.TO Study
REcruitment MAneuver in Torino

	CPAP 27 pts	CYCLING 26 pts	
Age (years)	63.19 ± 13.20	59.96 ± 14.73	NS
Weight (kg)	73.9 ± 11.7	71.19 ± 25.56	NS
Height (cm)	165.6 ± 9.3	167.73 ± 9.4	NS
BMI kg/m^2	26.9 ± 3.7	25.02 ± 7.1	NS
ASA n (%)	I = 0 II = 8 (30.7) III = 17 (65.3) IV = 1 (3.8)	I = 1 (3.8) II = 11 (42.3) III = 14 (53.8) IV = 0	NS
FEV1 %	92.1 ± 30.3	97.1 ± 20.6	NS
FVC %	92.3 ± 25.7	108.9 ± 20	NS
DLCO %	81 ± 20.4	80.5 ± 15	NS

[Ceraolo to be submitted]

RE.MA.TO Study
REcruitment MAneuver in Torino

DLV	CPAP	Cycling	p value
Driving Pressure PreRM	10,3 ± 3,8	8,7 ± 2,1	NS
Driving Pressure PostRM	8.8 ± 3,6	7,3 ± 2,1	NS
p value	0,003	<0,001	

[Ceraolo to be submitted]

RE.MA.TO Study
REcruitment MAneuver in Torino

OLV	CPAP	Cycling	p value
Driving Pressure PreRM	13,4 ± 3,3	12,5 ± 3,6	NS
Driving Pressure PostRM	12,3 ± 3,6	10,3 ± 3,3	**0,048**
p value	<0,001	<0,001	

[Ceraolo to be submitted]

RE.MA.TO Study
REcruitment MAneuver in Torino

OLV	CPAP	Cycling	p value
pCO_2-$EtCO_2$ preRM mmHg	8,9 ± 3,7	9,1 ± 3,4	NS
pCO_2-$EtCO_2$ postRM mmHg	7,7 ± 4	6,6 ± 3	NS
p value	NS	**<0,001**	

[Ceraolo to be submitted]

RE.MA.TO Study
REcruitment MAneuver in Torino

Conclusions of RE.MA.TO Study:

- CPAP and Cycling RM equally effective in improving respiratory system mechanics in DLV and OLV
- Cycling RM is slightly more effective than CPAP RM in reducing Driving Pressure - OLV only
- Only Cycling RM effective in reducing Dead Space Ventilation (pCO_2-$EtCO_2$) - OLV only
- No significant SAE in both groups

[Ceraolo to be submitted]

CONCLUSION

- No strong evidence
- RM may be an option in OR
- RM must be applied to the right patient, at the right moment, for a right period of time, at the right pressure
- RM recommended for hypoxemia and atelectasis prevention/treatment
- RM CPAP & RM Cycling probably equally effective and safe
- Further research is needed