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JUNE 24-25 2024

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How I set PEEP at the bedside in 2024?

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GRC CARMAS, IMRB

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Conflicts of interest

Laboratory (Ventilator loan):

- Fisher and Paykel
- Medtronic
- Air Liquide Medical Systems

Lectures:

- Fisher and Paykel
- Medtronic
- Air Liquide Medical Systems
- Dräger
- GE Healthcare

Consulting:

- Air Liquide Medical Systems
- Löwenstein

Lung Recruitment Assessed by Electrical Impedance

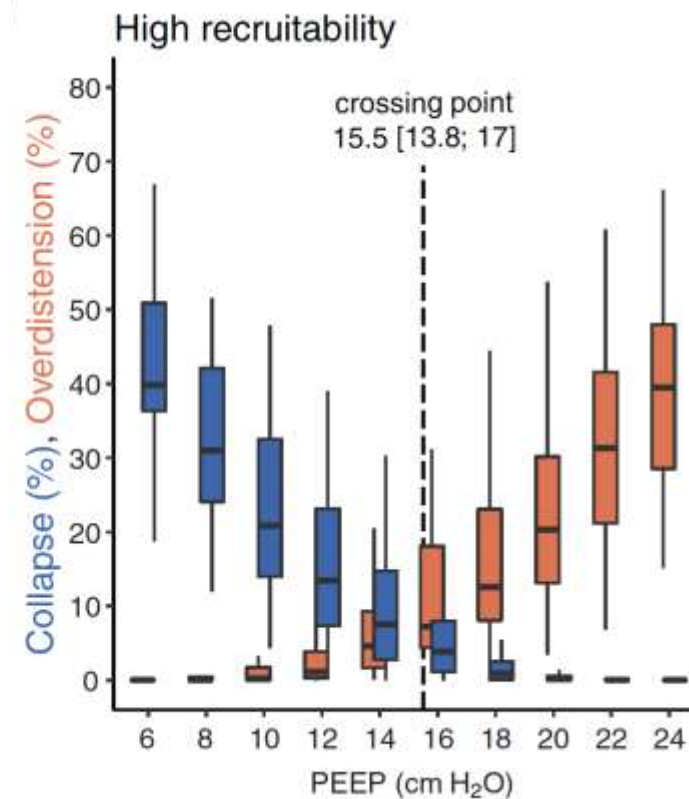
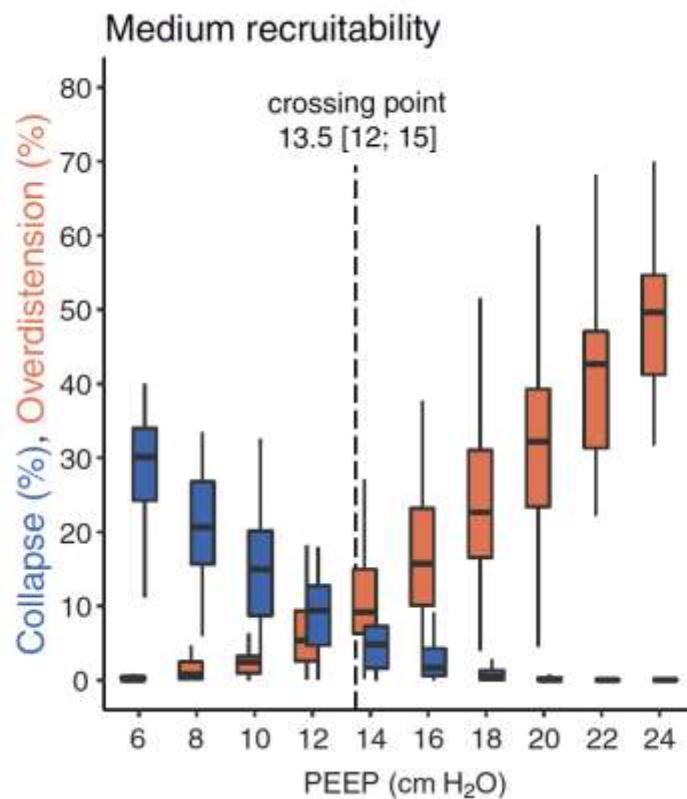
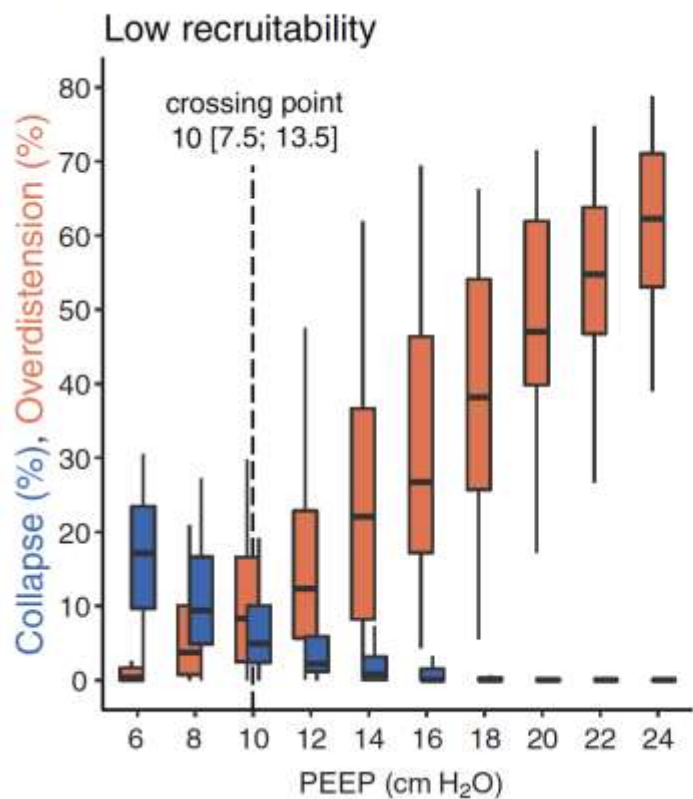
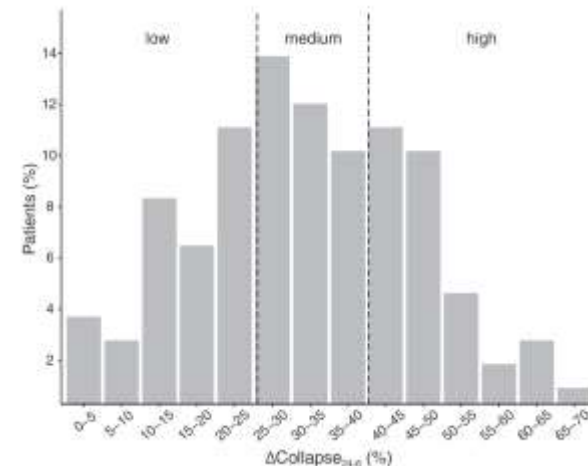
Tomography (RECRUIT)

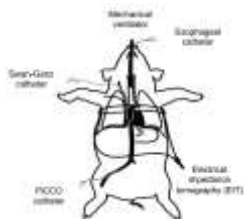
A Multicenter Study of COVID-19 Acute Respiratory Distress Syndrome

Annemijn H. Jonkman^{1,2,3*}, Glasiele C. Alcalá^{4*}, Bertrand Pavlovsky^{5,6}, Oriol Roca^{7,8}, Savino Spadaro^{9,10}, Gaetano Scaramuzza^{9,10}, Lu Chen^{1,2}, Jose Dianti^{2,11}, Mayson L. de A. Sousa^{1,2,4}, Michael C. Sklar^{1,2}, Thomas Piraino^{1,2}, Huiqing Ge¹², Guang-Qiang Chen¹³, Jian-Xin Zhou¹³, Jie Li¹⁴, Ewan C. Goligher^{2,11,15}, Eduardo Costa⁴, Jordi Mancebo^{16†}, Tommaso Mauri^{17‡}, Marcelo Amato^{4‡}, and Laurent J. Brochard^{1,2‡}, for the Pleural Pressure Working Group (PLUG)

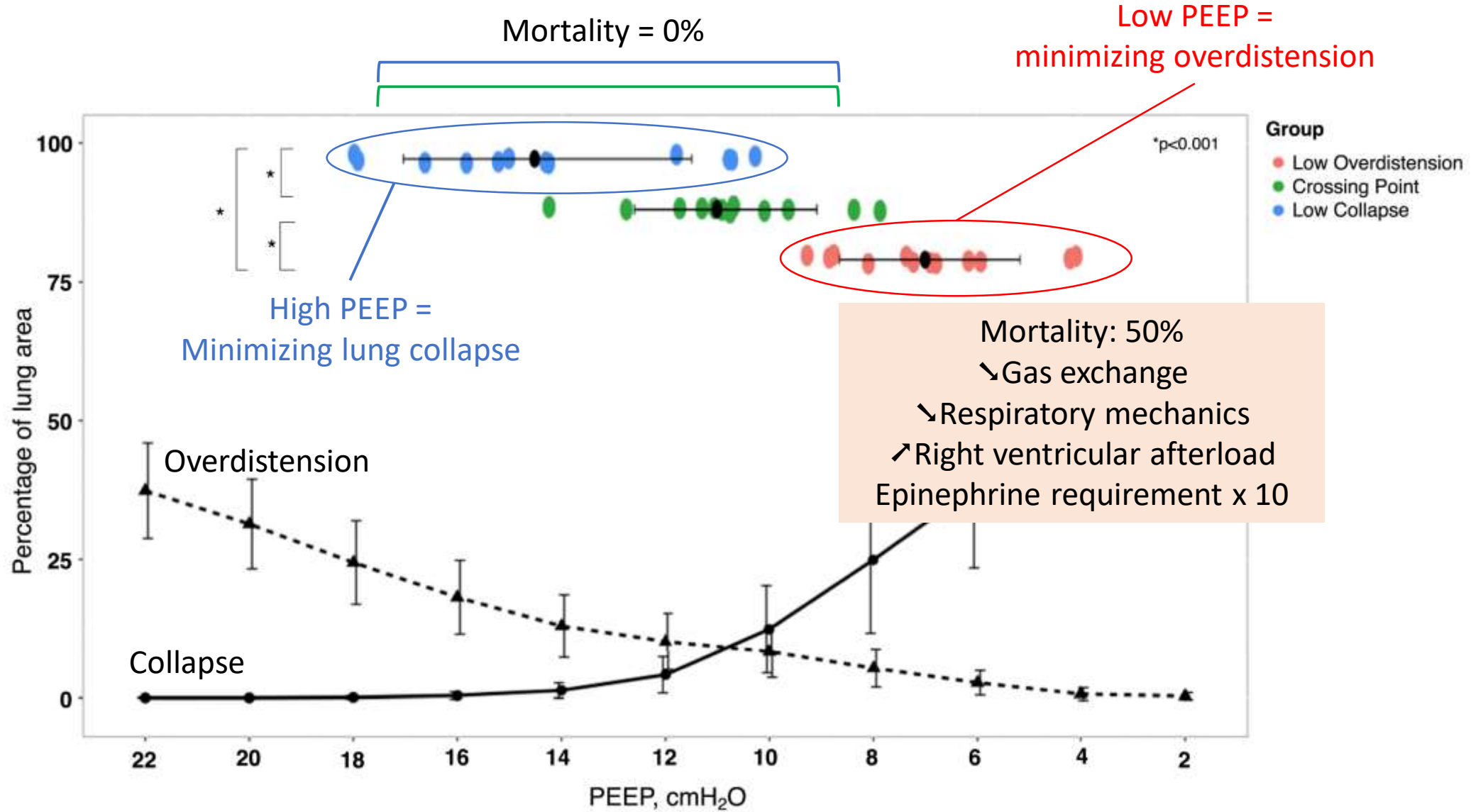
Am J Respir Crit Care Med Vol 208, Iss 1, pp 25–38, Jul 1, 2023

N = 108



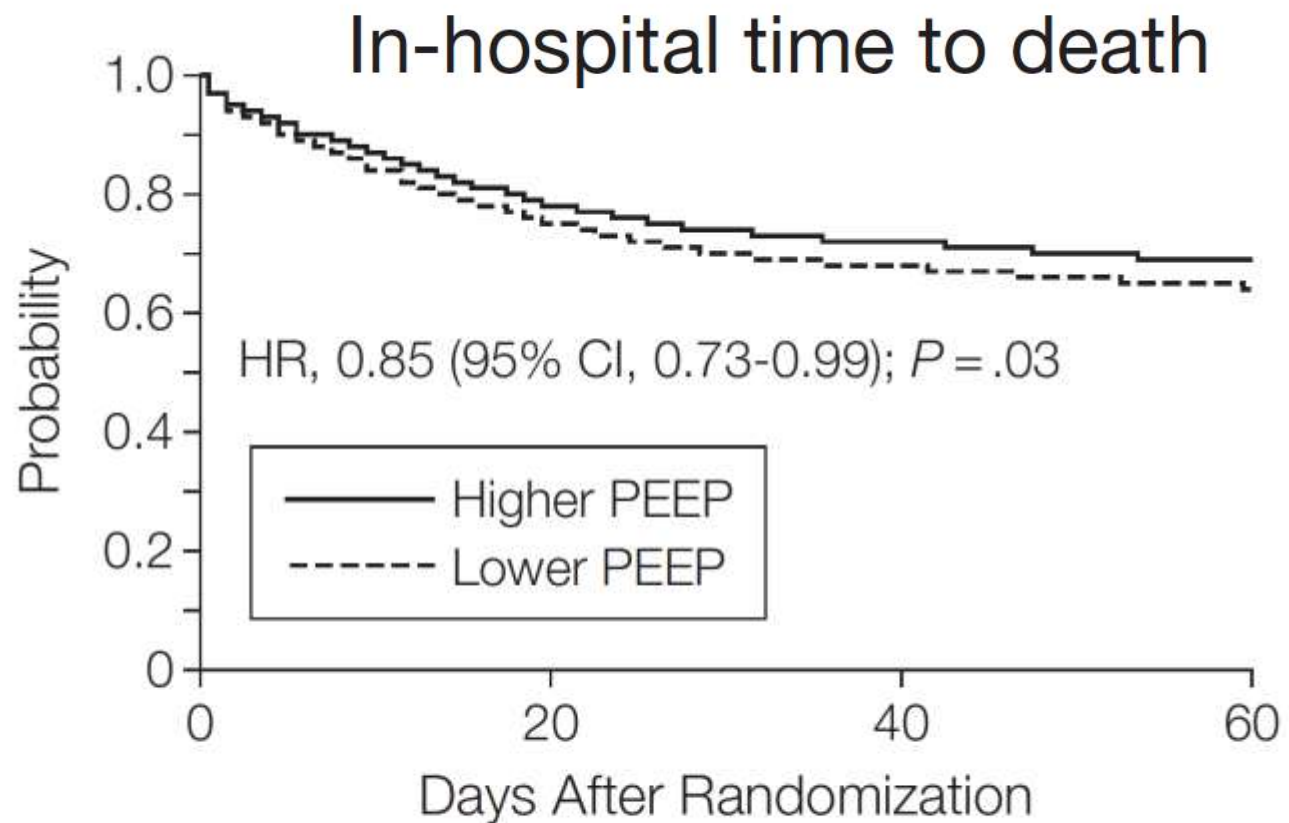


Severe and recruitable animal model of ARDS



MLA Sousa et al. Am J Respir Crit Care Med 2024

PaO₂/FiO₂ ≤ 200 mm Hg



No. at risk

Higher PEEP	949	760	693	666
Lower PEEP	939	723	649	619

Briel M *et al.* JAMA 2010



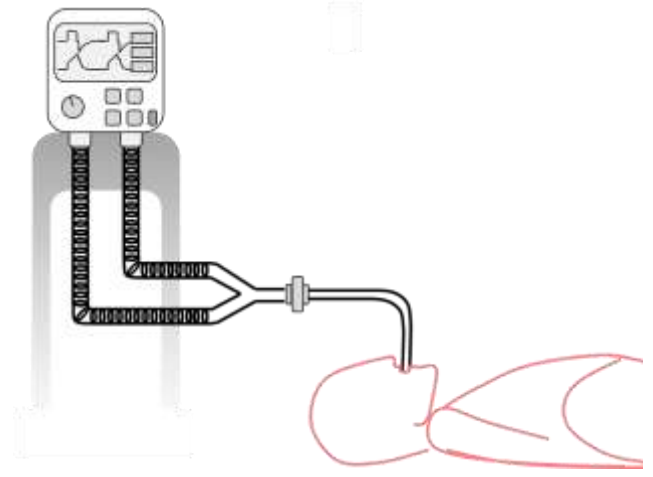
High PEEP



No recommandation

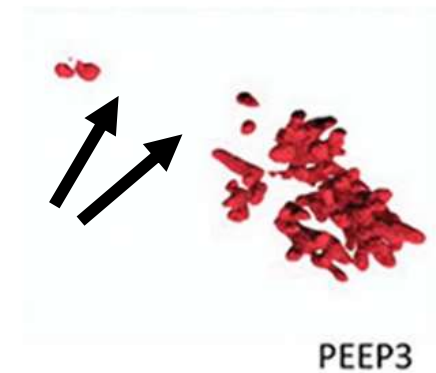
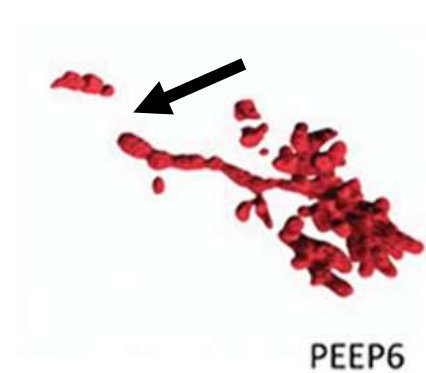
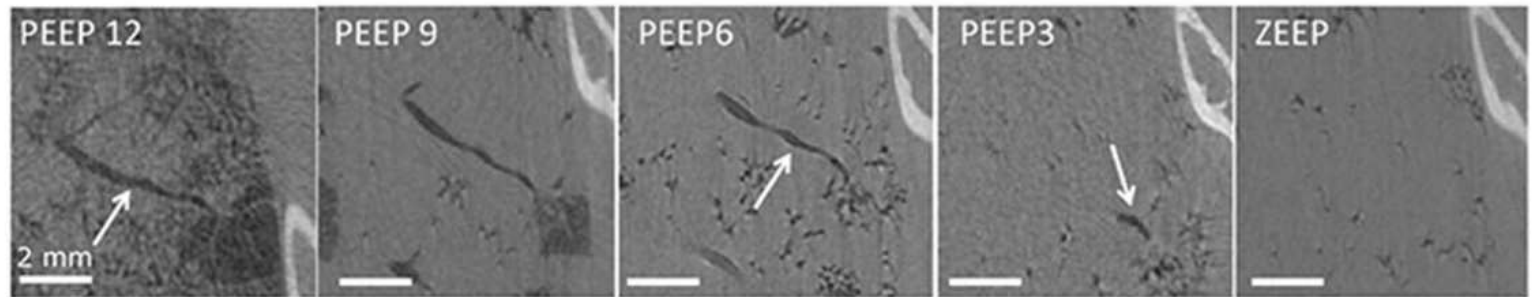
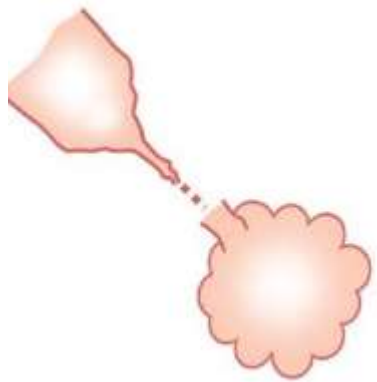


High PEEP



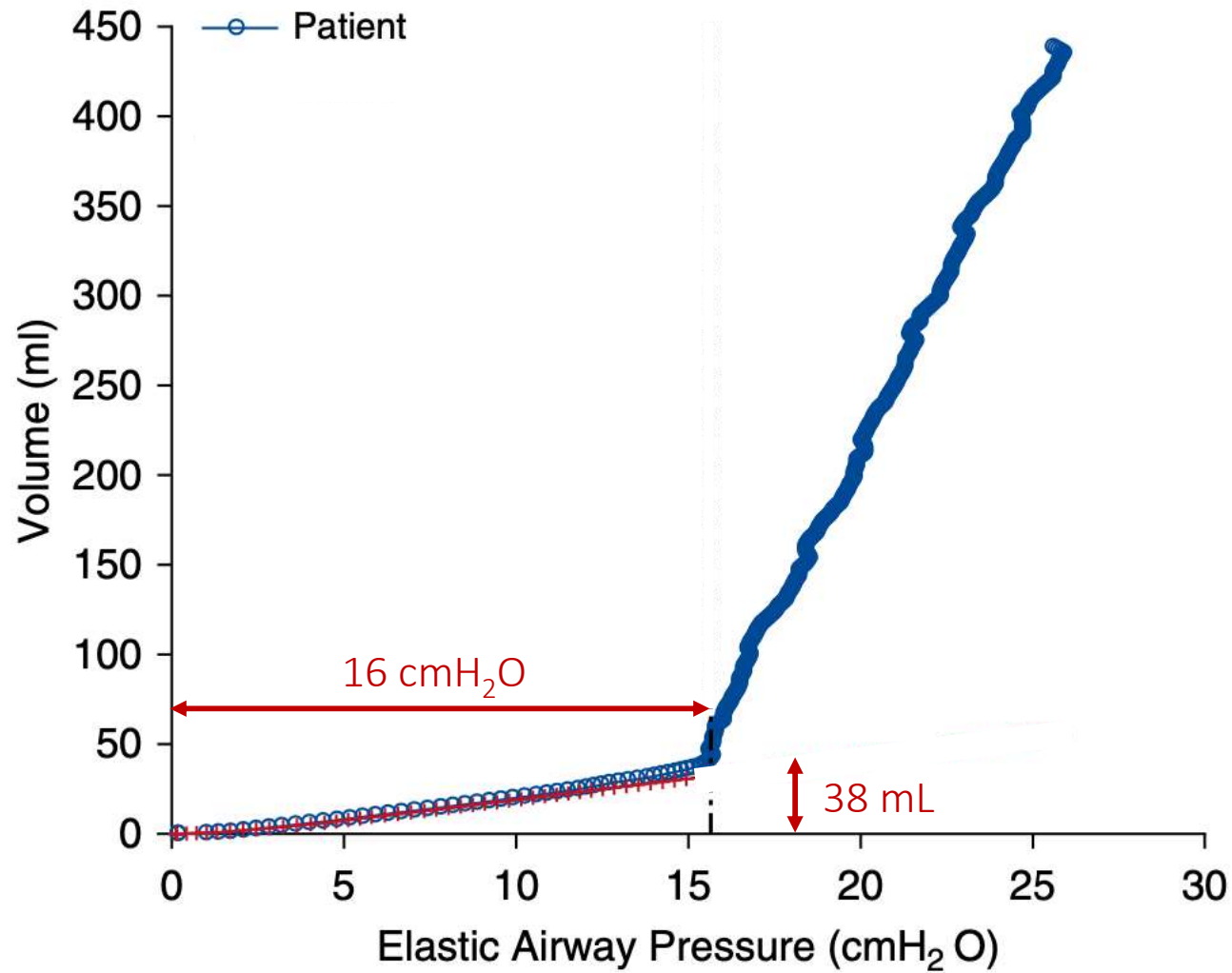
Are the airways open?

*High-resolution
synchrotron phase-
contrast CT*



Broche *et al*, *Crit Care Med*, 2019

PV curve



2.4 mL/cmH₂O

Circuit's compliance

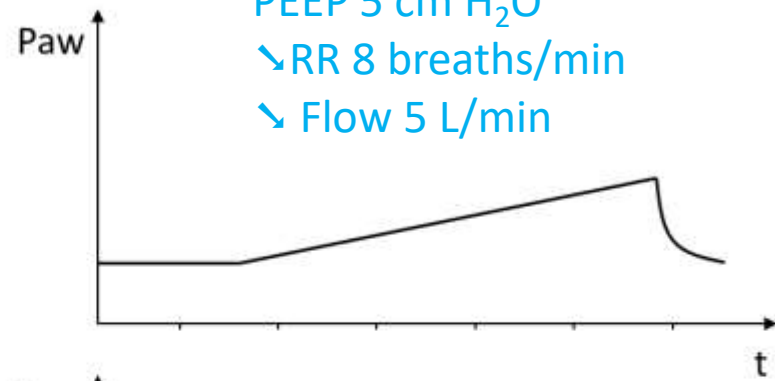
Low flow insufflation

PEEP 5 cm H₂O

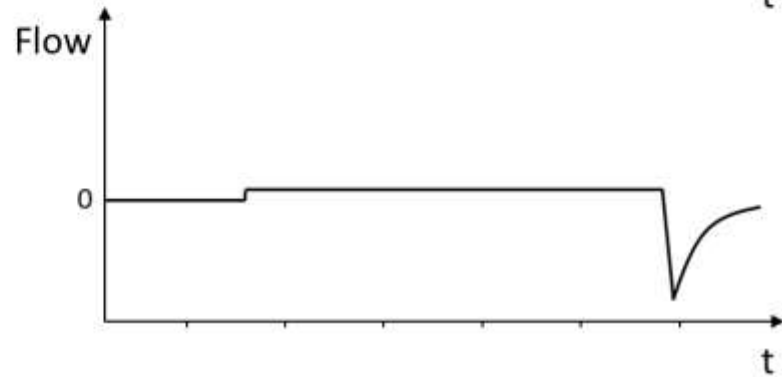
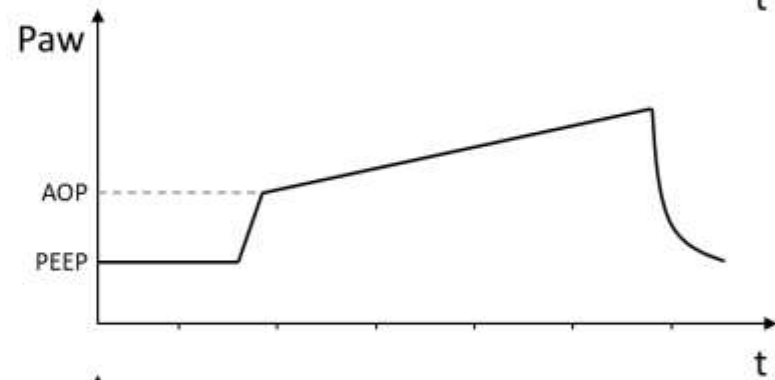
↳ RR 8 breaths/min

↳ Flow 5 L/min

No AOP



AOP

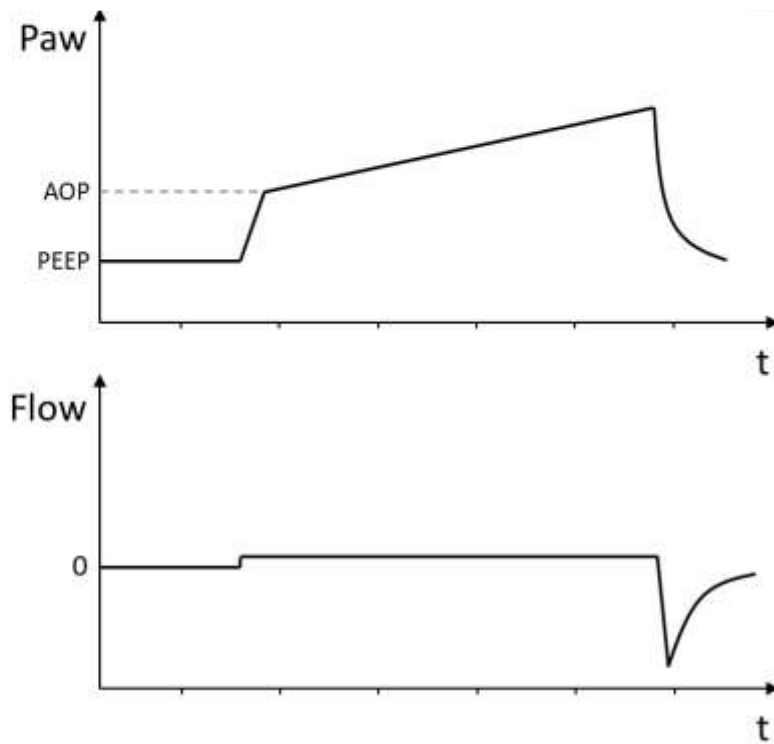


Low flow insufflation

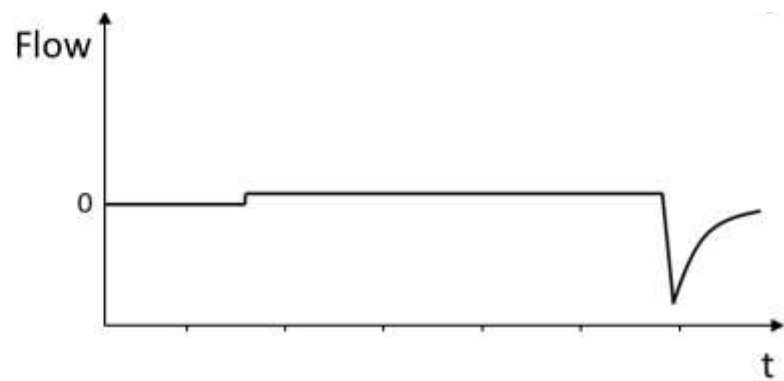
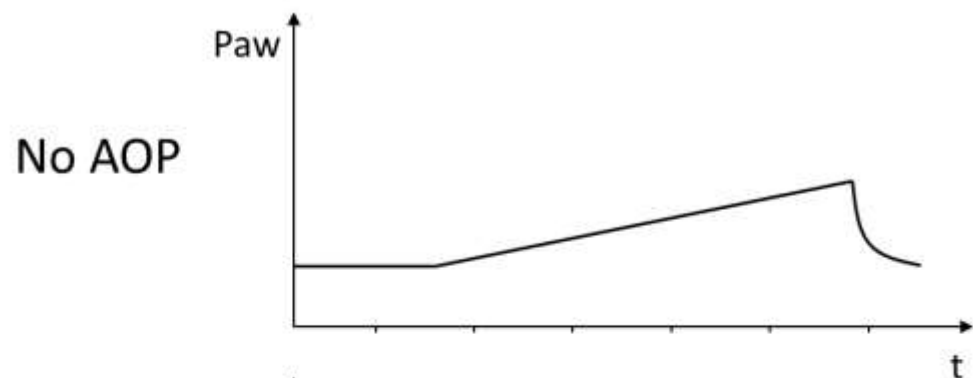
No AOP



AOP



Low flow insufflation

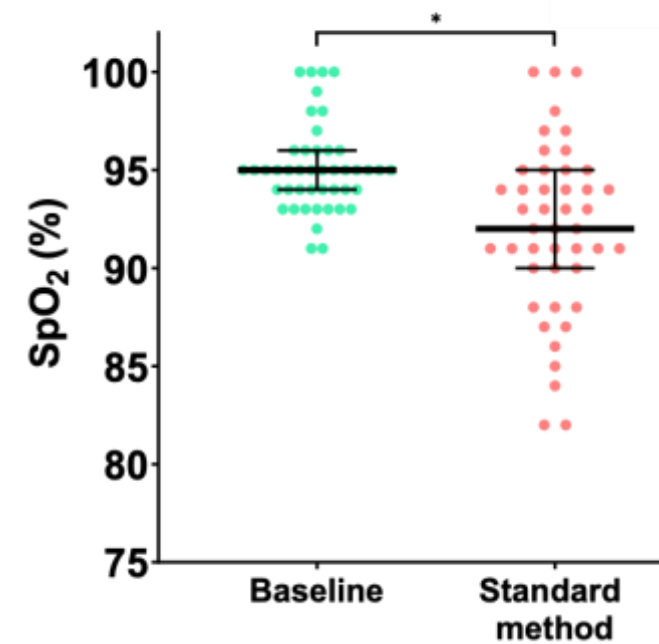
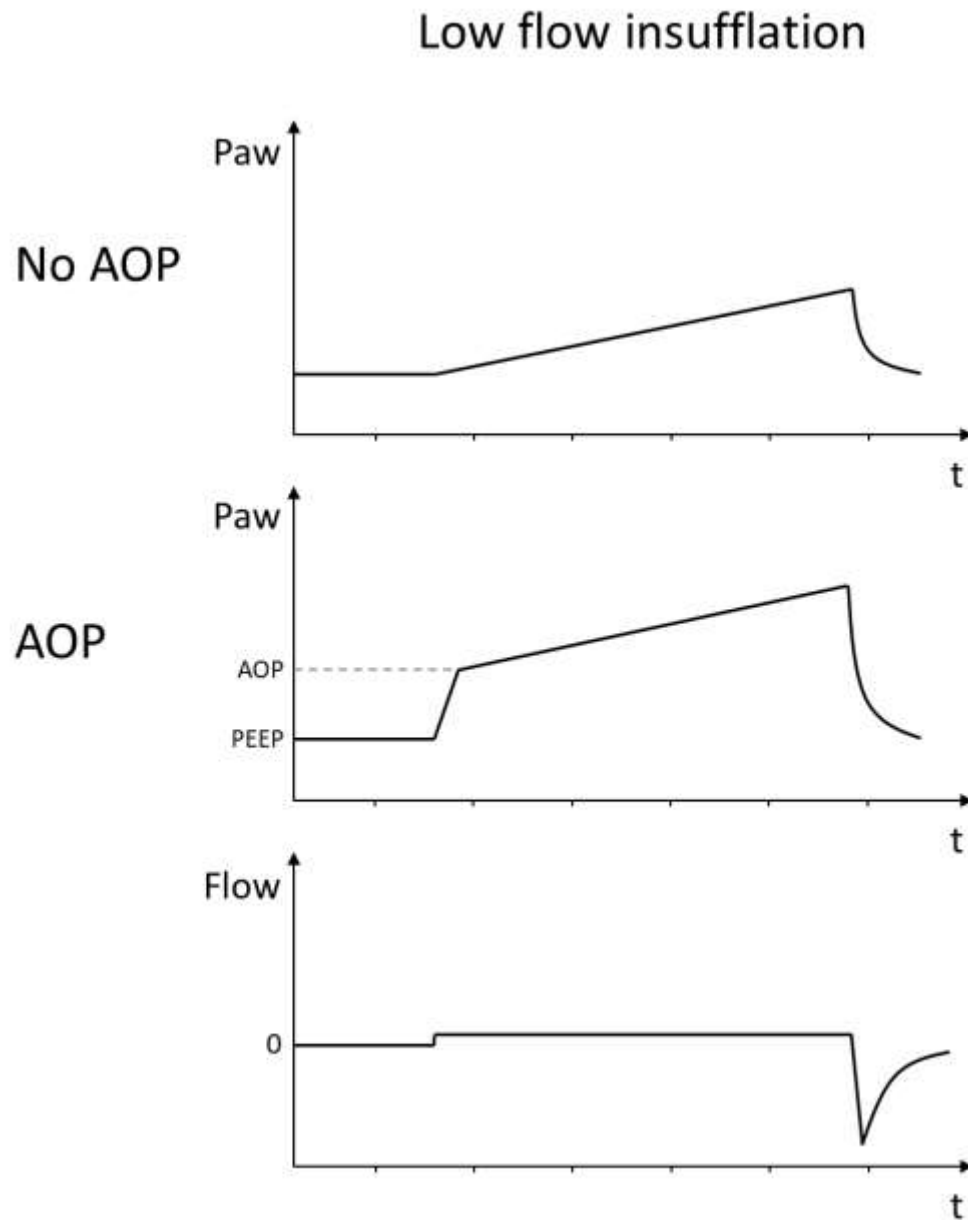




A novel method for assessment of airway opening pressure without the need for low-flow insufflation

Anne-Fleur Haudebourg^{1,2}, Elsa Moncomble^{1,2}, Arnaud Lesimple^{4,5}, Flora Delamaire^{1,2}, Bruno Louis³, Armand Mekontso Dessap^{1,2,3}, Alain Mercat^{4,6}, Jean-Christophe Richard^{6,7}, François Beloncle^{4,6} and Guillaume Carteaux^{1,2,3*}

Critical Care (2023) 27:273



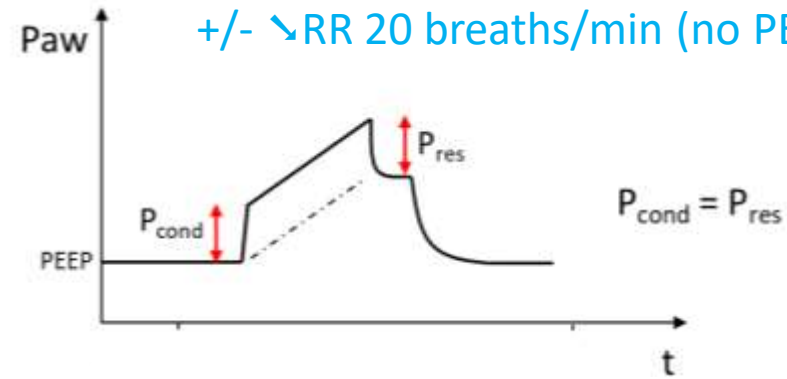
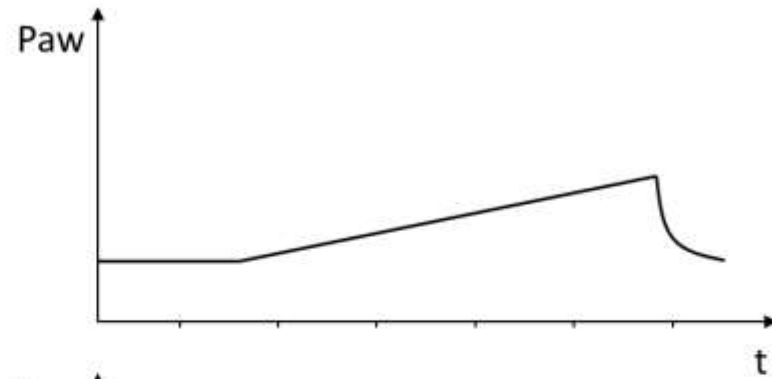
Low flow insufflation

Usual flow insufflation

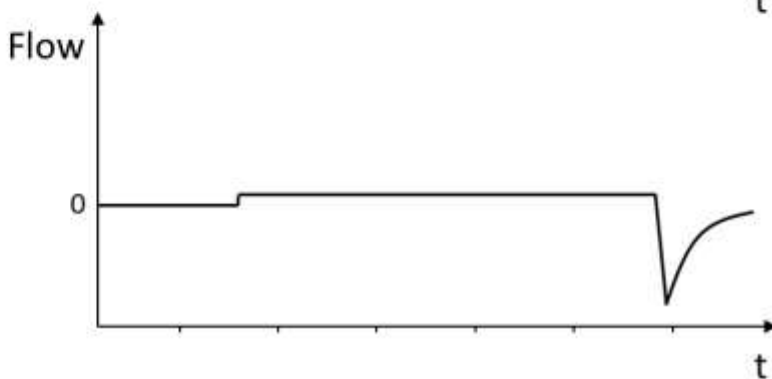
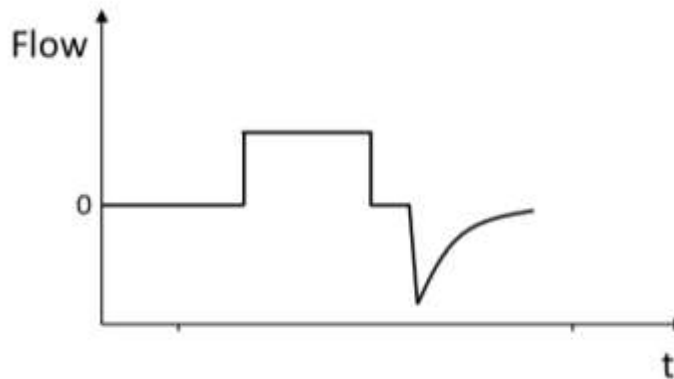
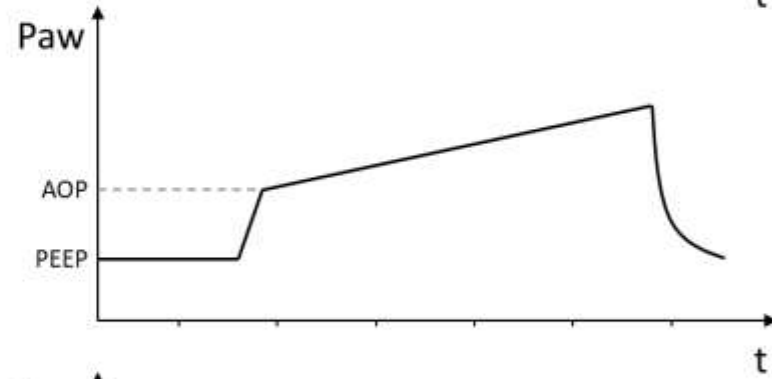
PEEP 5 cm H₂O

+/- RR 20 breaths/min (no PEEPi)

No AOP

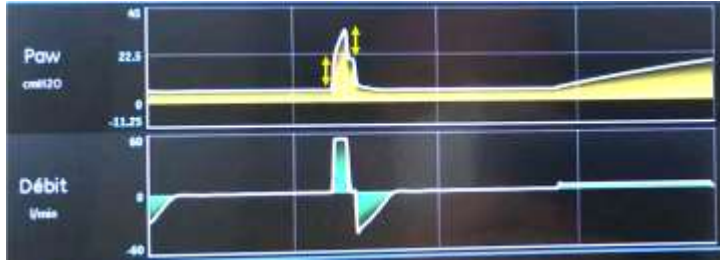


AOP



Low flow insufflation

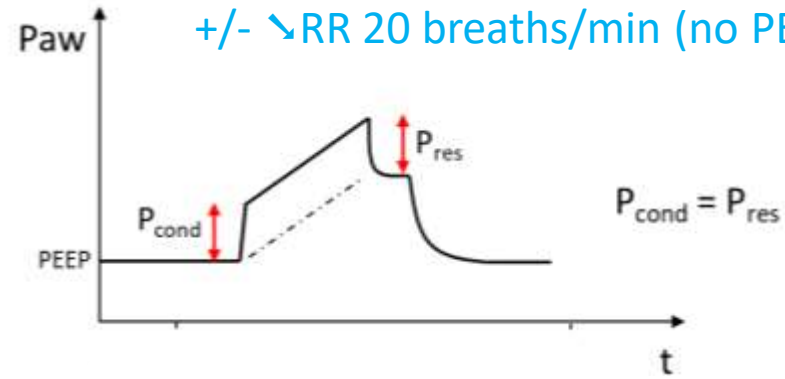
No AOP



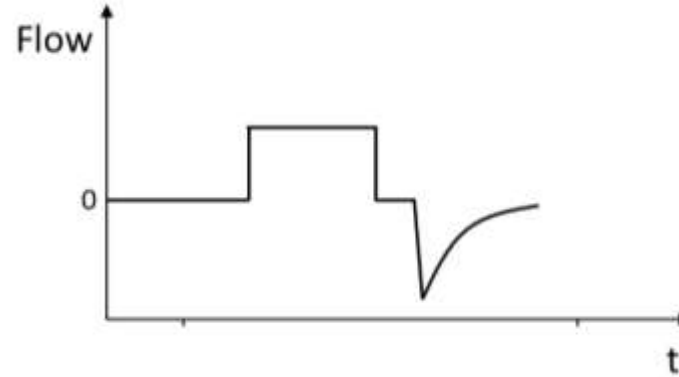
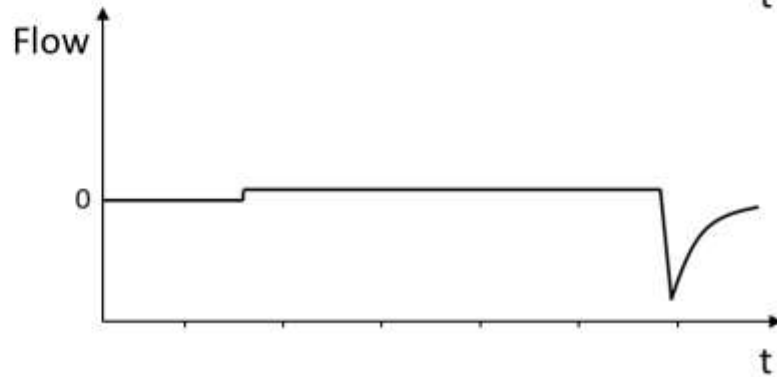
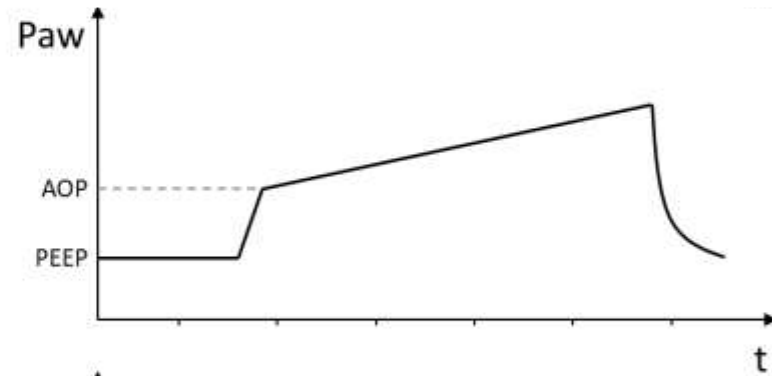
Usual flow insufflation

PEEP 5 cm H₂O

+/- RR 20 breaths/min (no PEEPi)



AOP



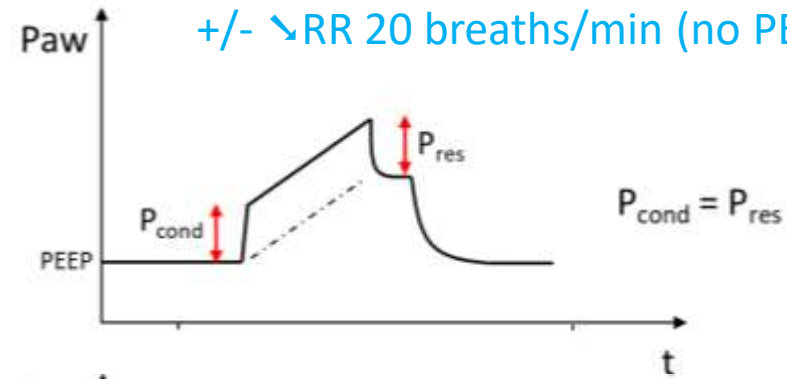
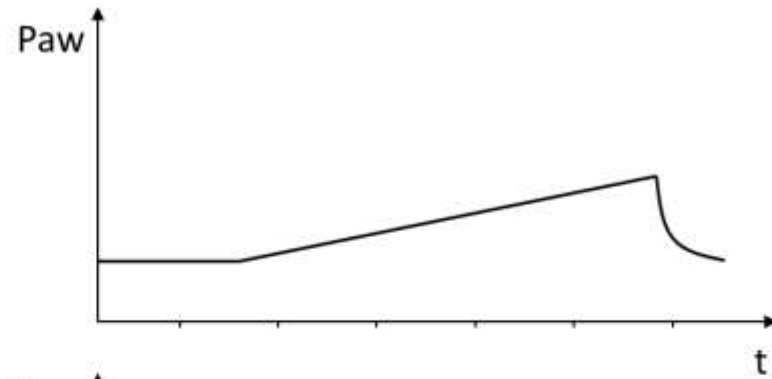
Low flow insufflation

Usual flow insufflation

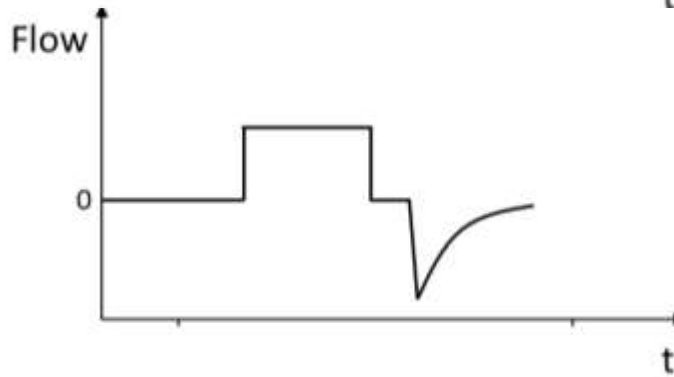
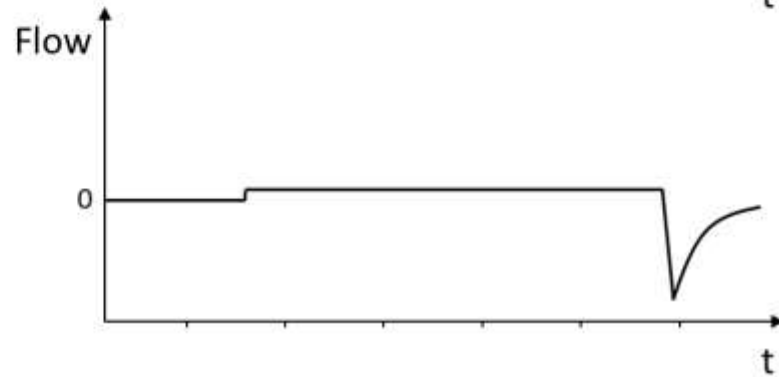
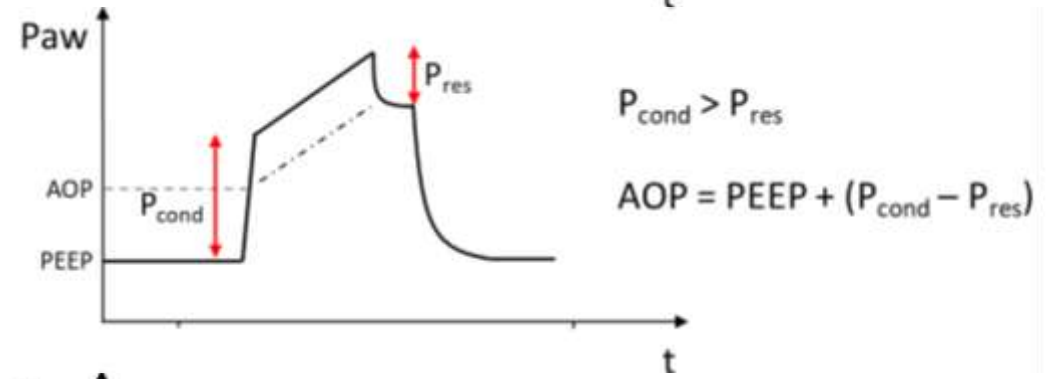
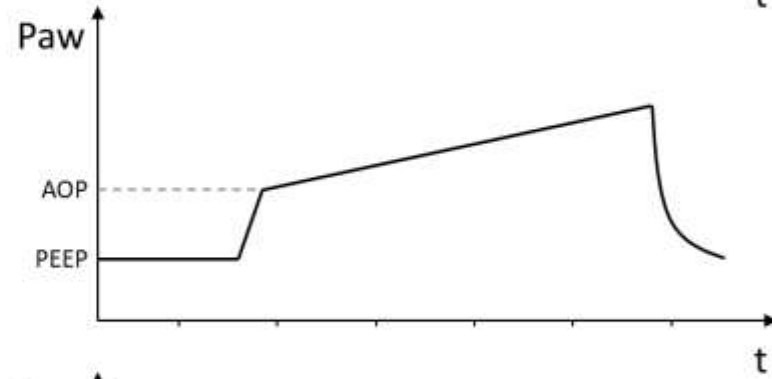
PEEP 5 cm H₂O

+/- RR 20 breaths/min (no PEEPi)

No AOP

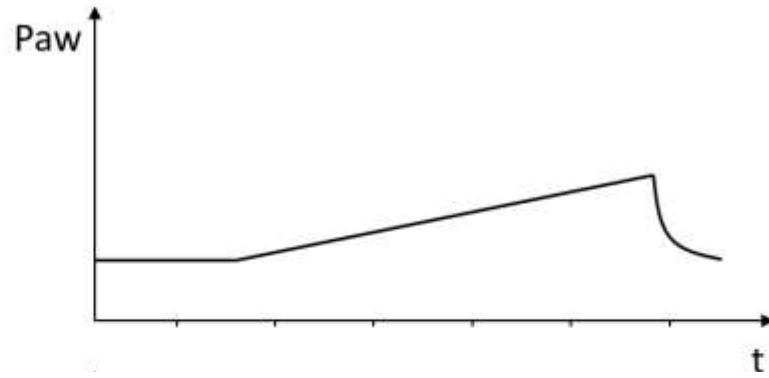


AOP

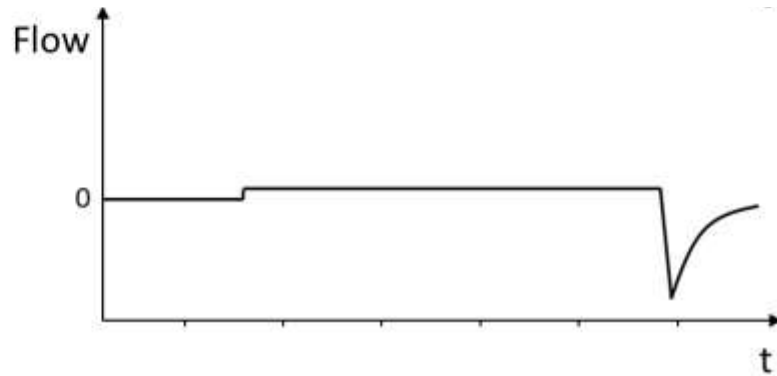
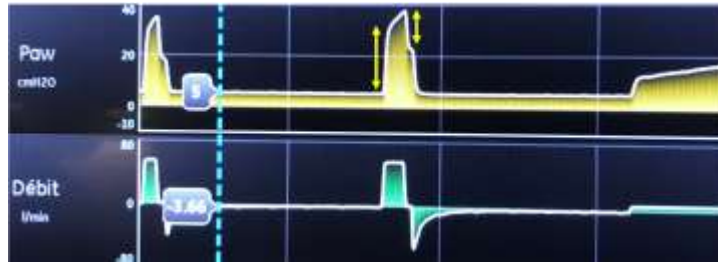


Low flow insufflation

No AOP



AOP

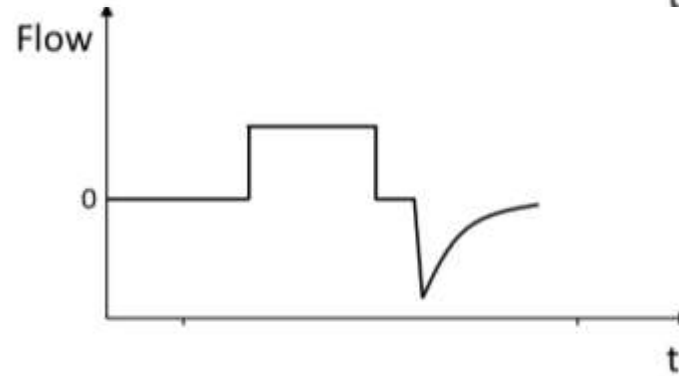
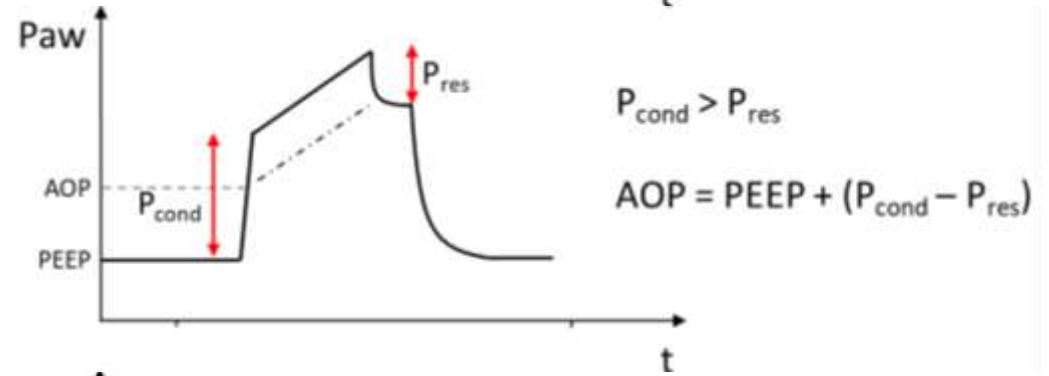
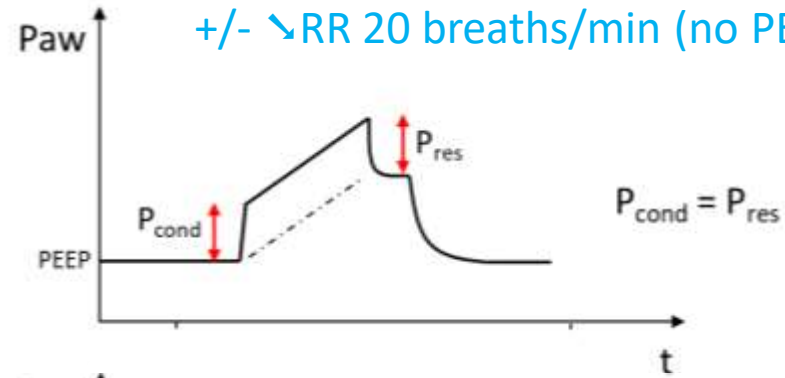


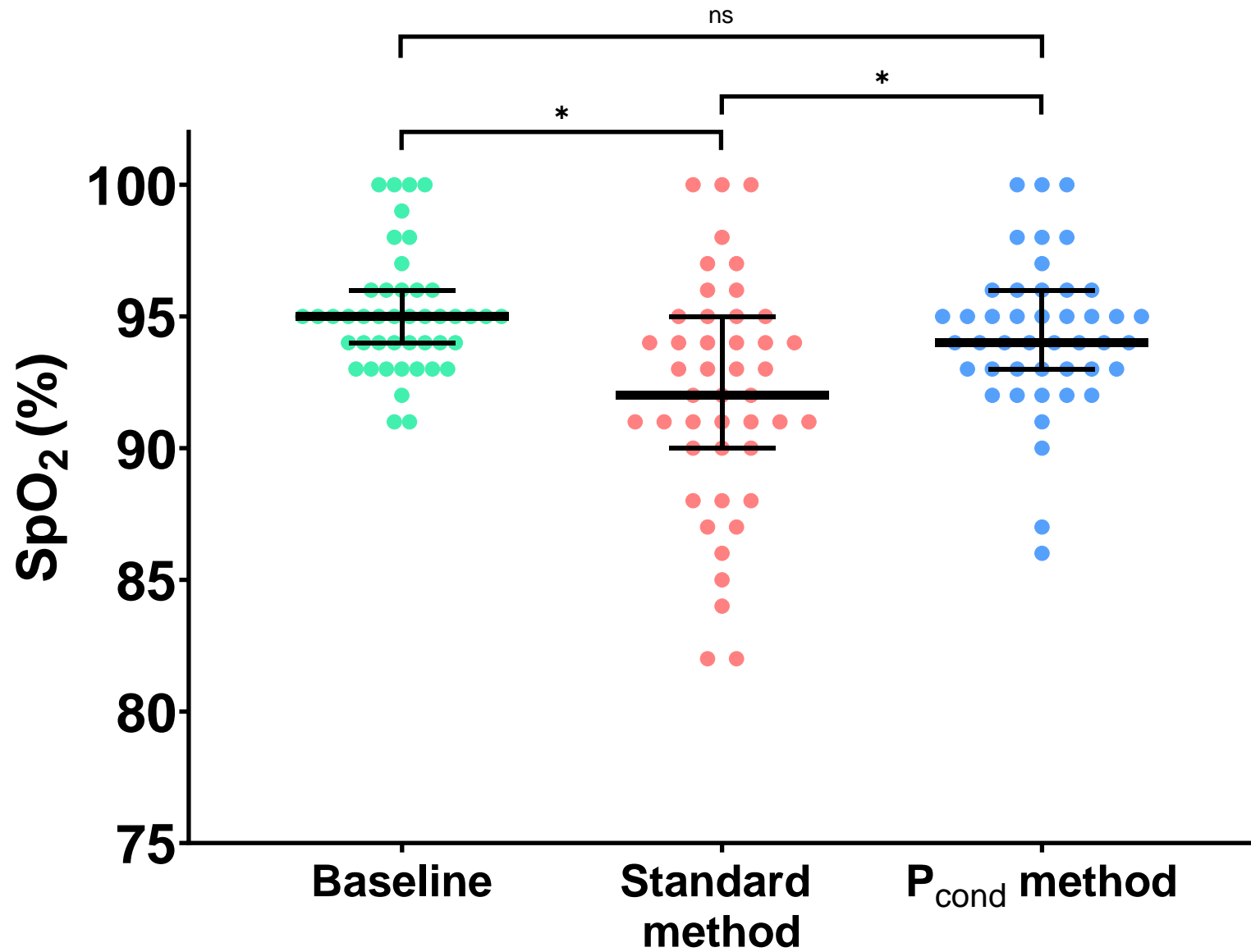
Usual flow insufflation

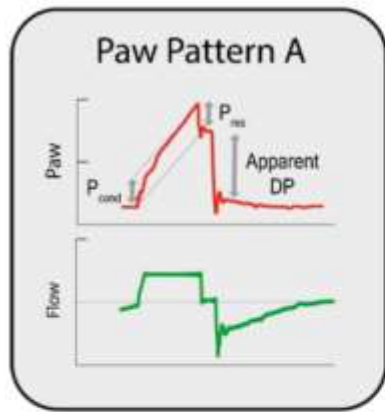
PEEP 5 cm H₂O

+/- RR 20 breaths/min (no PEEPi)

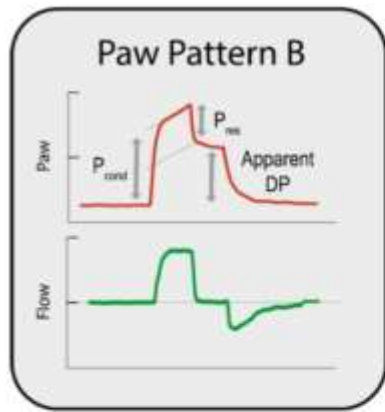
NPV = 97%



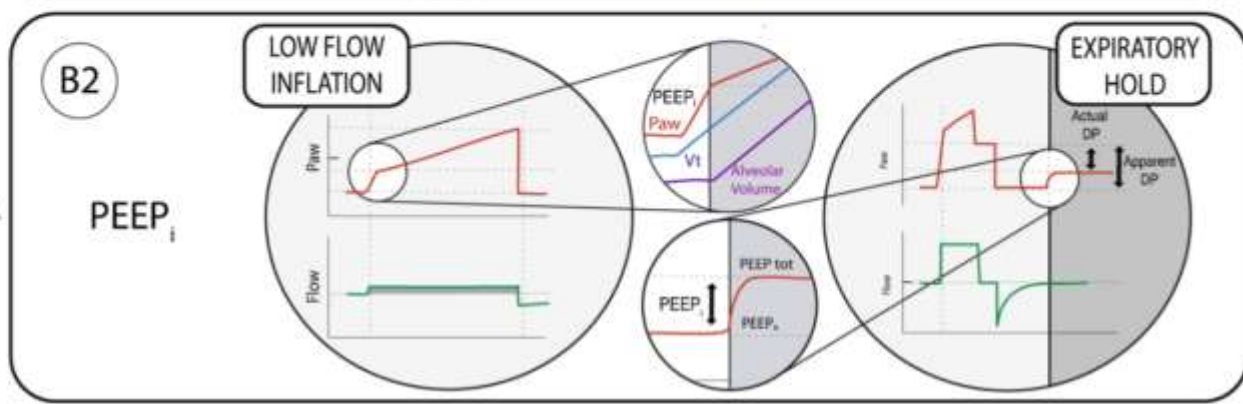
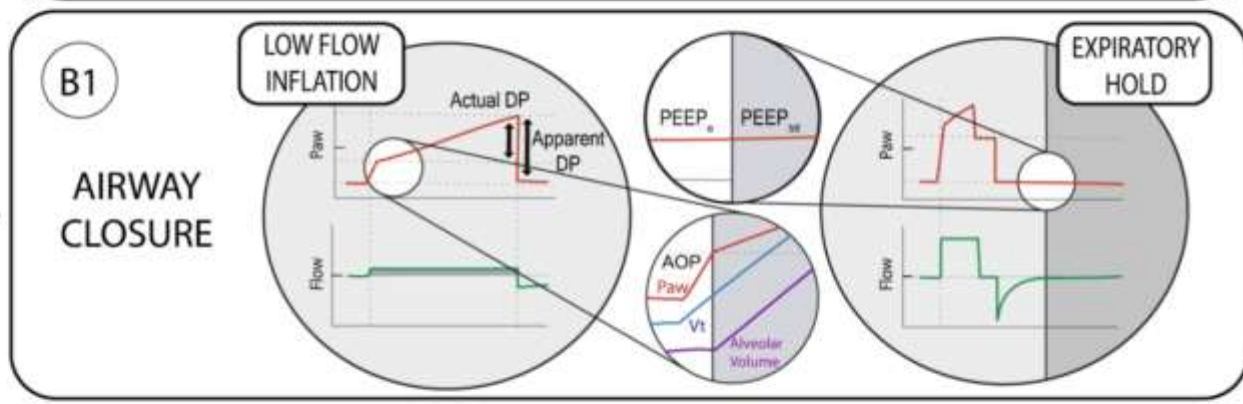
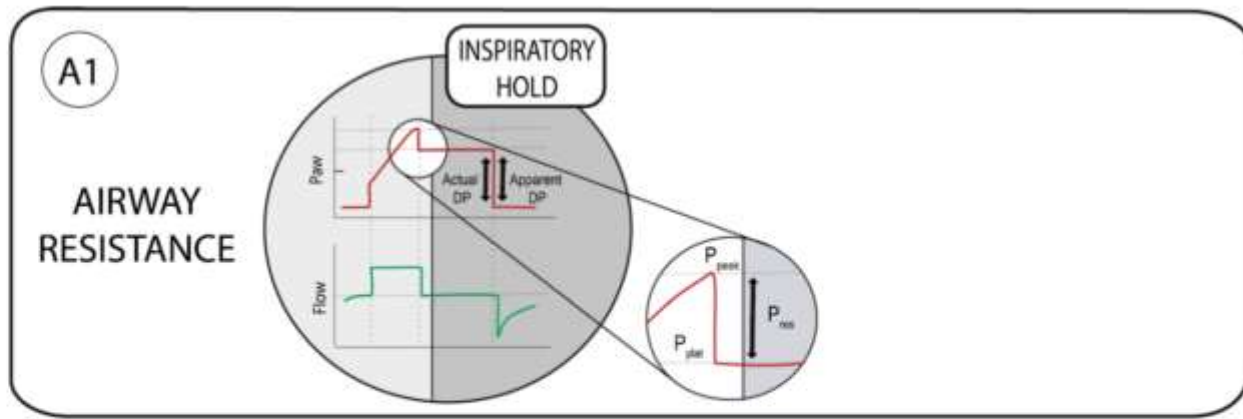




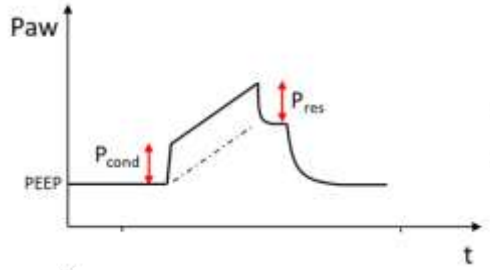
Reliable estimation of Driving Pressure



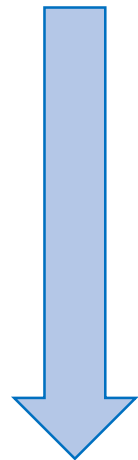
Possible overestimation of Driving Pressure



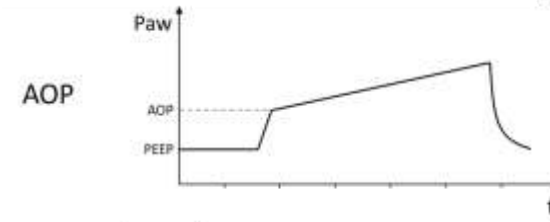
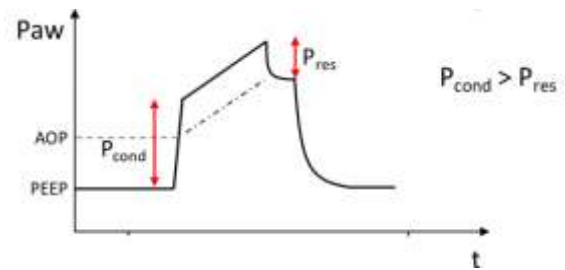
Airway closure?



No airway closure



**Recruitability
assessment**



AOP measurement



AOP \leq 10 cm H₂O



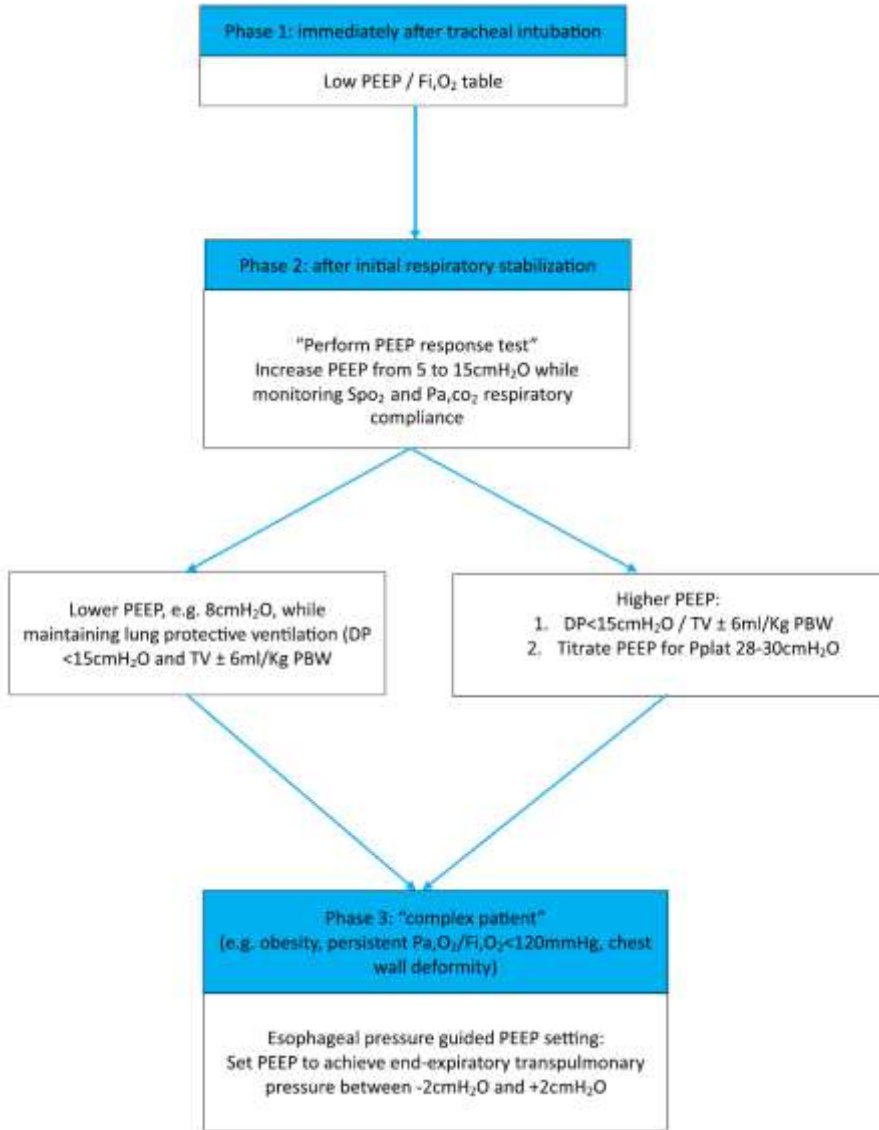
AOP $>$ 10 cm H₂O



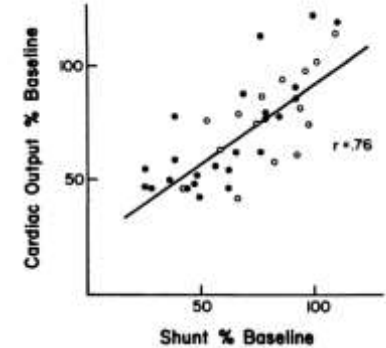
High PEEP

How to assess recruitability?

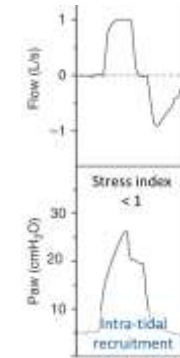
⚠ Caution ⚠



↗ PaO_2 at high PEEP in non-recruiters due to a decrease in cardiac output (cardiac output – shunt relationship)

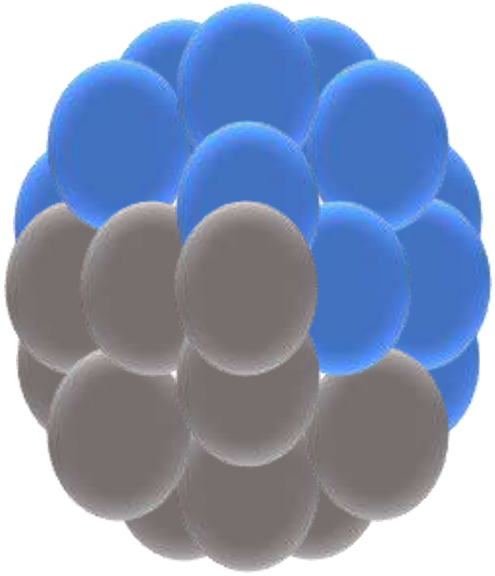


↗ C_{RS} at low PEEP in recruiters due to intra-tidal recruitment



Dantzker DR *et al.* *Chest* 1980

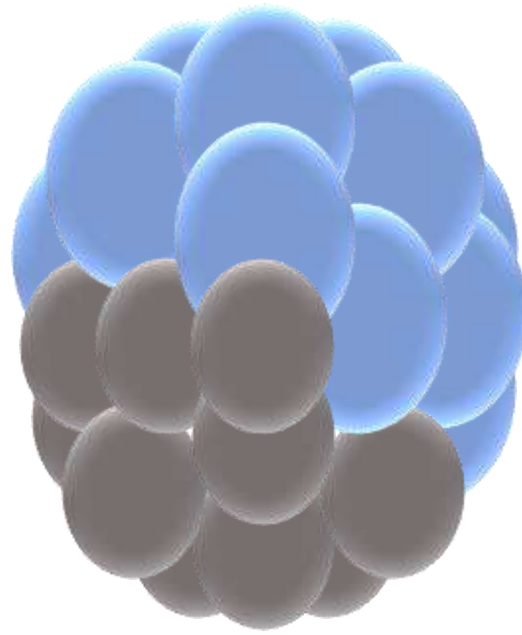
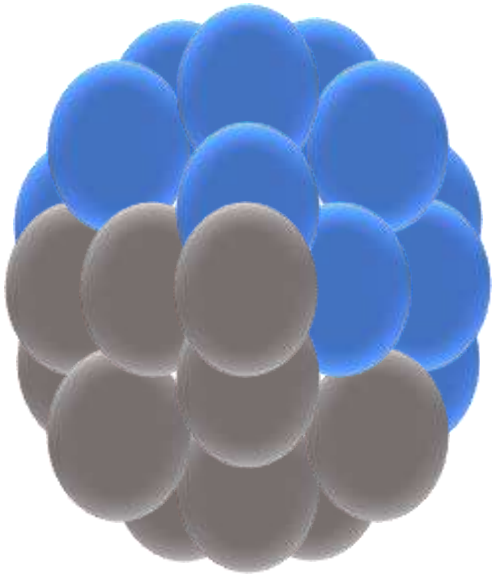
Chen L *et al.* *Am J Respir Crit Care Med* 2020



$C = 30 \text{ ml/cm H}_2\text{O}$

$\text{PEEP} = 5 \text{ cm H}_2\text{O}$

$\text{EELV} = 800 \text{ ml}$

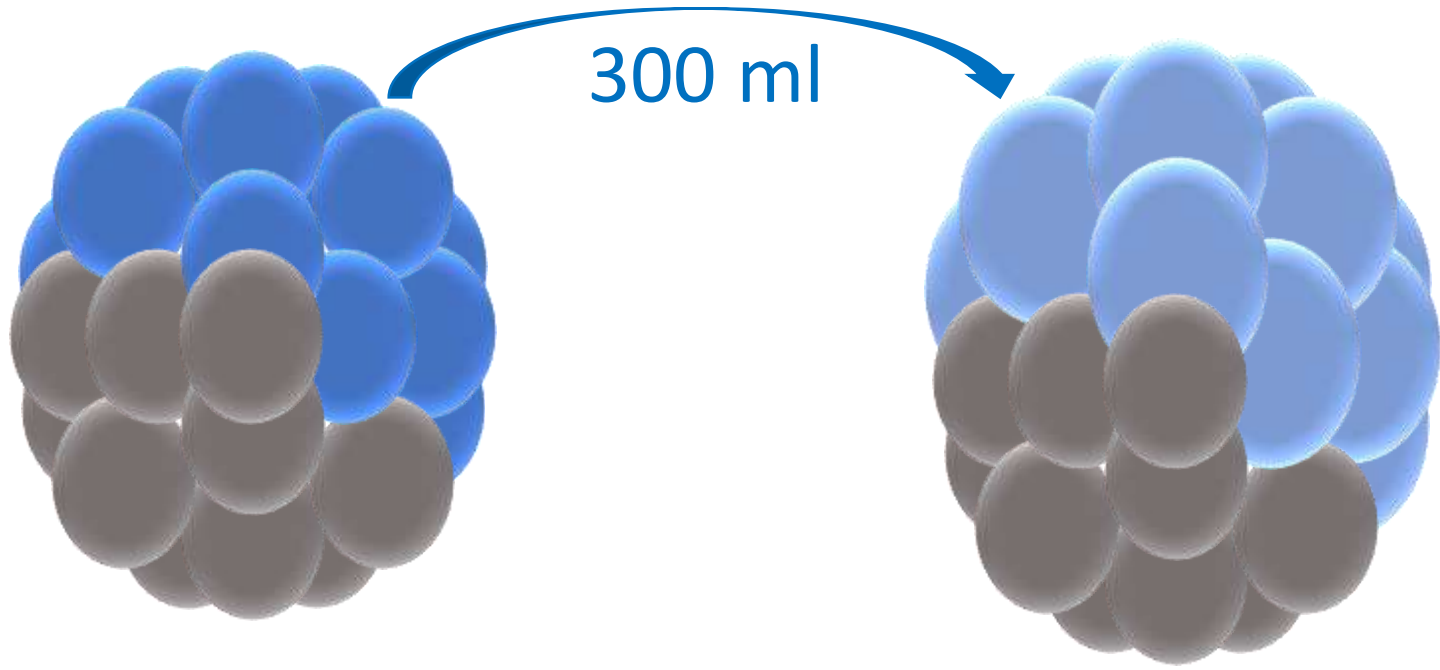


$C = 30 \text{ ml/cm H}_2\text{O}$

$\text{PEEP} = 5 \text{ cm H}_2\text{O} \rightarrow \text{PEEP} = 15 \text{ cm H}_2\text{O}$

$\text{EELV} = 800 \text{ ml}$

$\text{EELV} = ?$

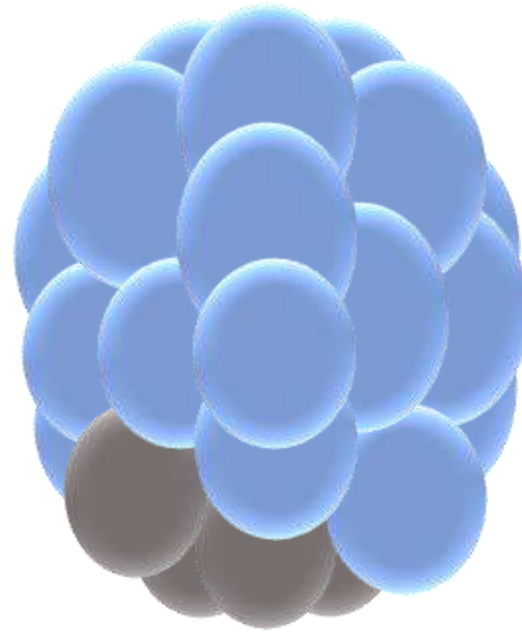
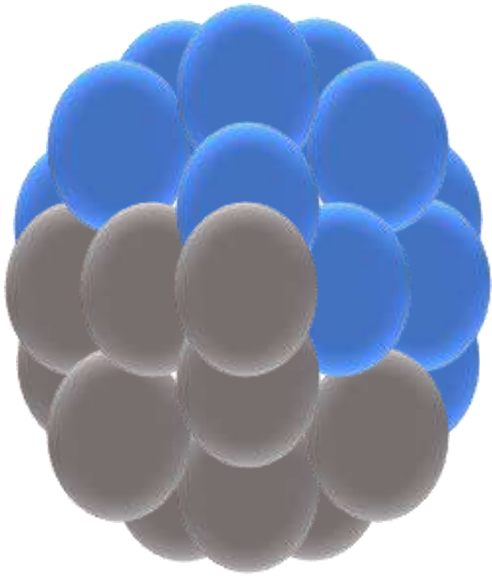


$C = 30 \text{ ml/cm H}_2\text{O}$

$\text{PEEP} = 5 \text{ cm H}_2\text{O} \rightarrow \text{PEEP} = 15 \text{ cm H}_2\text{O}$

$\text{EELV} = 800 \text{ ml}$

$\text{EELV} = 1100 \text{ ml}$

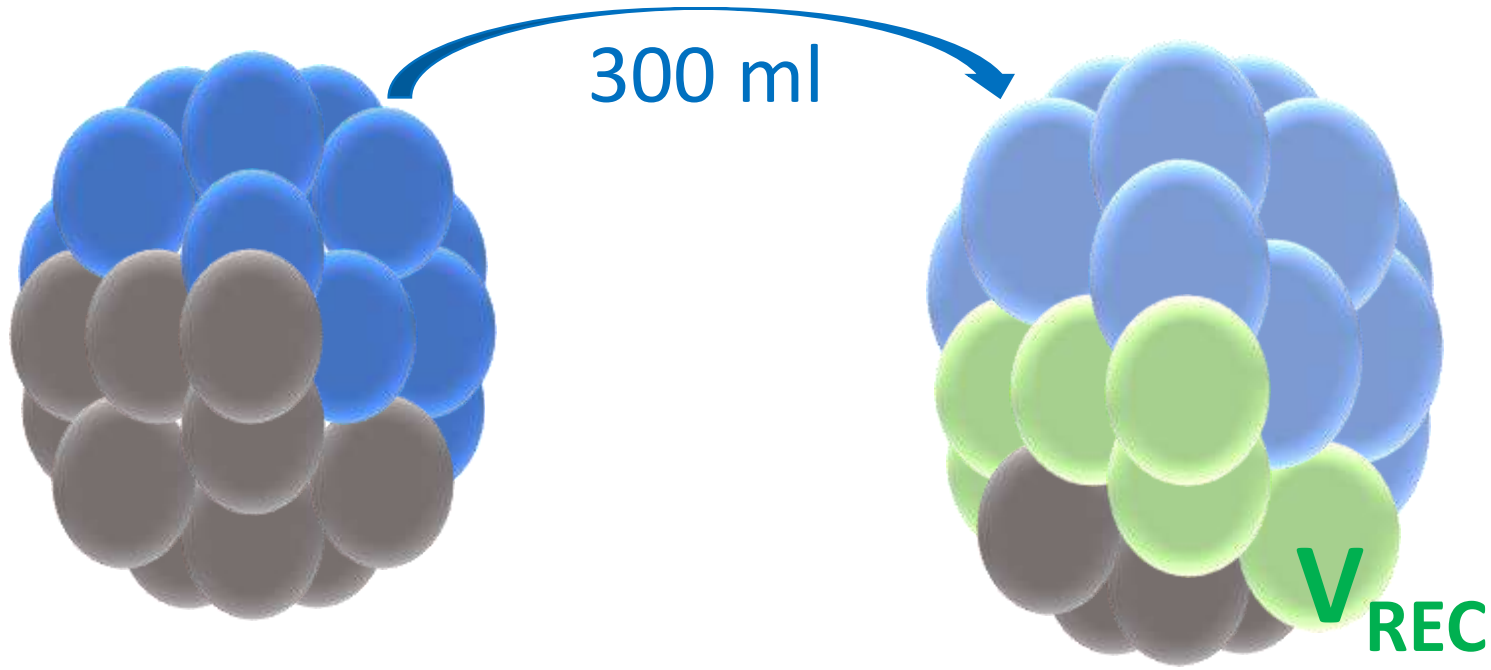


$C = 30 \text{ ml/cm H}_2\text{O}$

$\text{PEEP} = 5 \text{ cm H}_2\text{O} \rightarrow \text{PEEP} = 15 \text{ cm H}_2\text{O}$

$\text{EELV} = 800 \text{ ml}$

$\text{EELV} = ?$

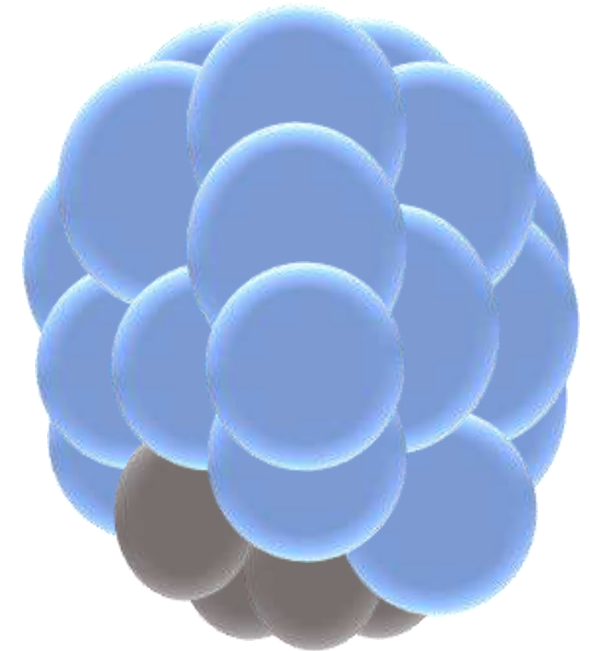
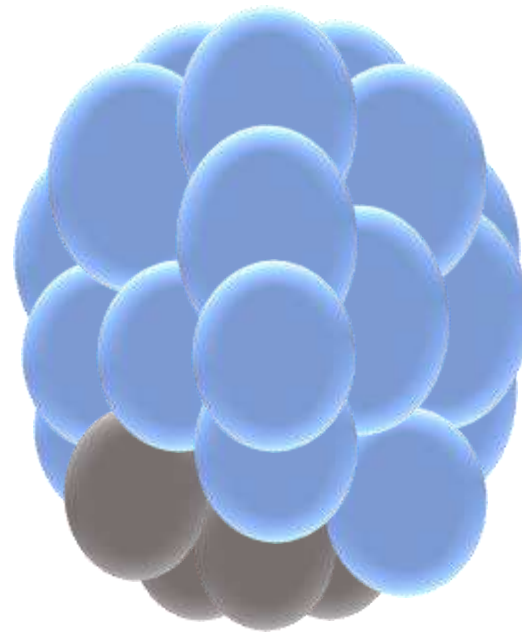
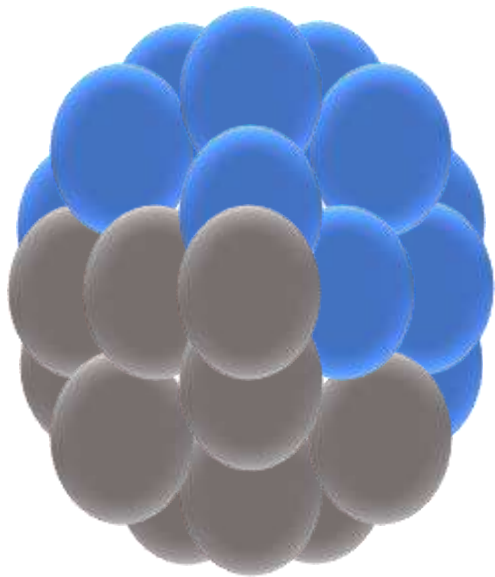


$$C = 30 \text{ ml/cm H}_2\text{O}$$

$$\text{PEEP} = 5 \text{ cm H}_2\text{O} \rightarrow \text{PEEP} = 15 \text{ cm H}_2\text{O}$$

$$\text{EELV} = 800 \text{ ml}$$

$$\text{EELV} = 1100 \text{ ml} + V_{\text{rec}}$$

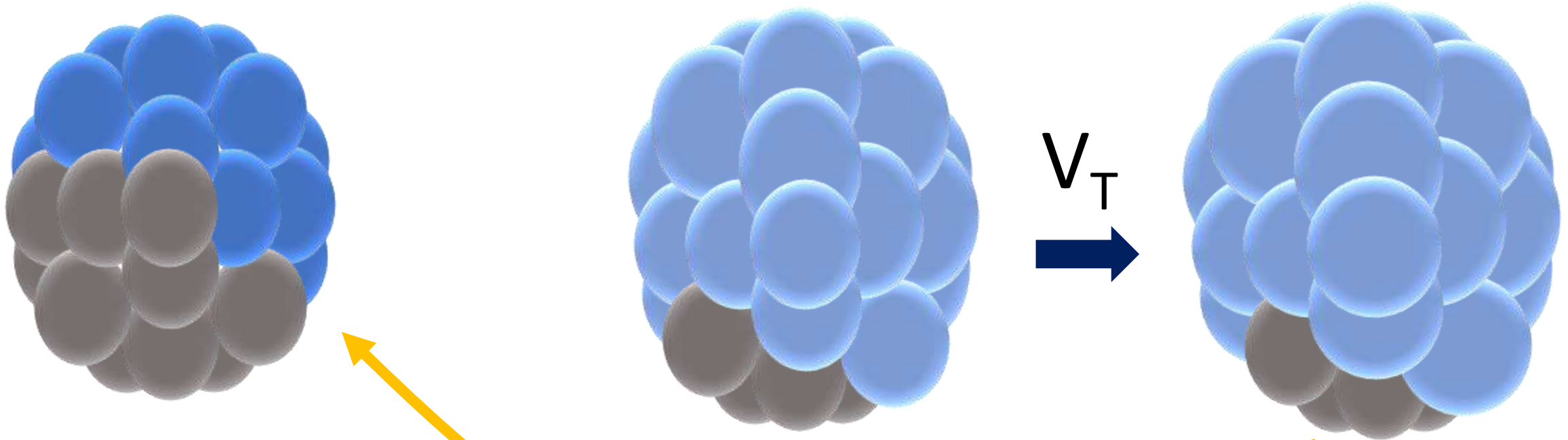


$C = 30 \text{ ml/cm H}_2\text{O}$

$\text{PEEP} = 5 \text{ cm H}_2\text{O} \rightarrow \text{PEEP} = 15 \text{ cm H}_2\text{O}$

$\text{EELV} = 800 \text{ ml}$

$\text{EELV} = 1100 \text{ ml} + V_{\text{rec}}$

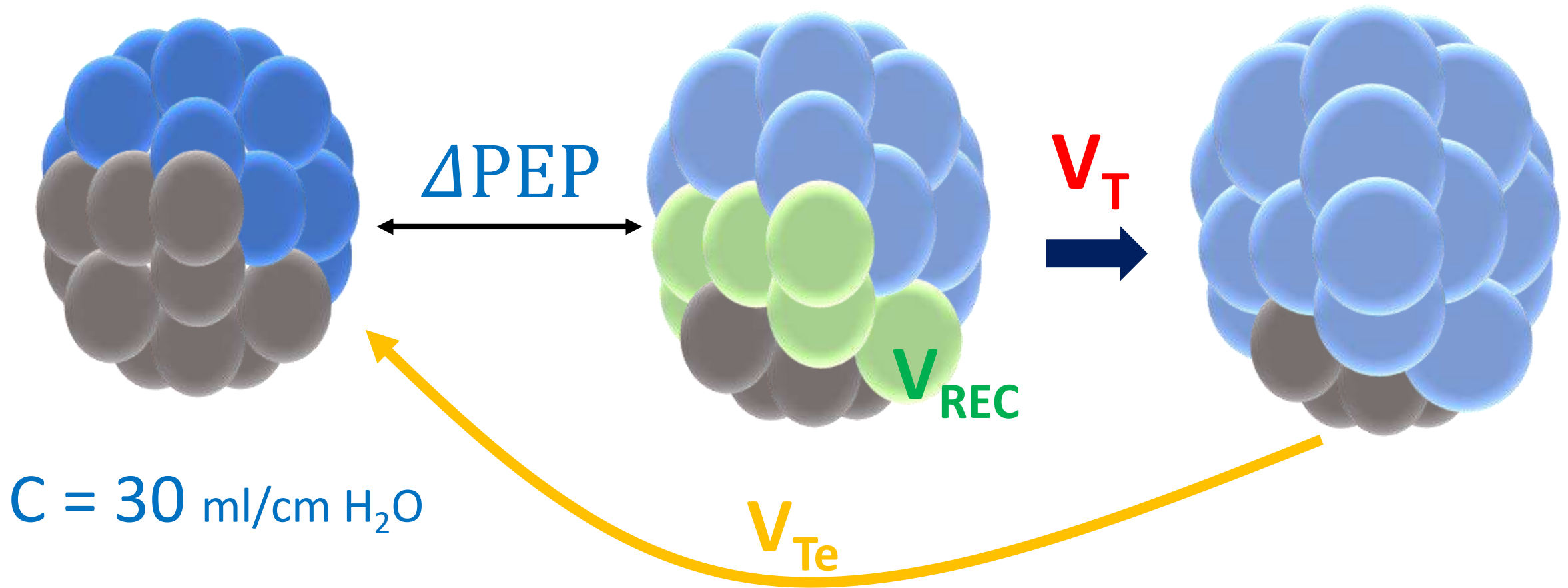


$C = 30 \text{ ml/cm H}_2\text{O}$

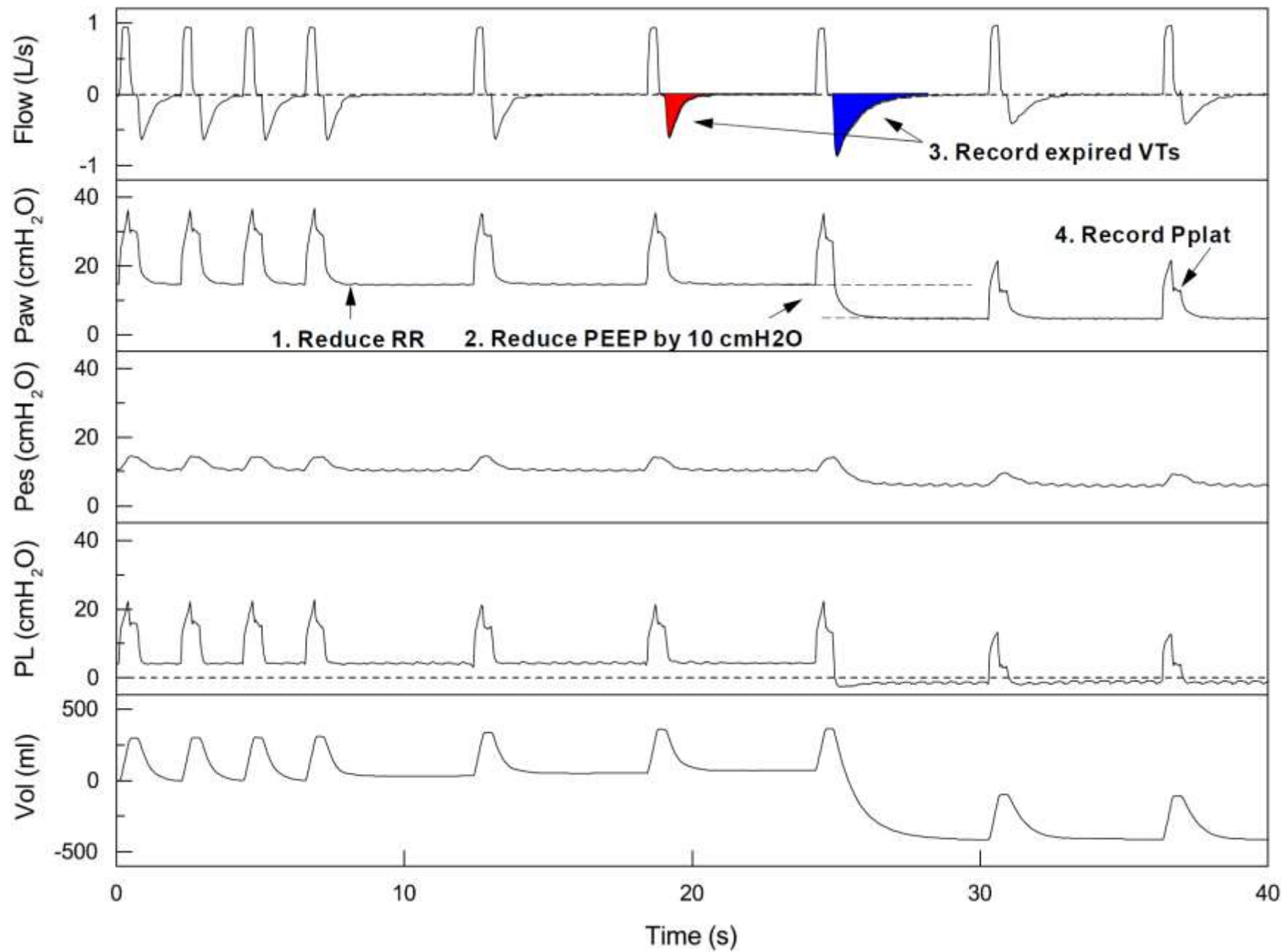
$\text{PEEP} = 5 \text{ cm H}_2\text{O} \rightarrow \text{PEEP} = 15 \text{ cm H}_2\text{O}$

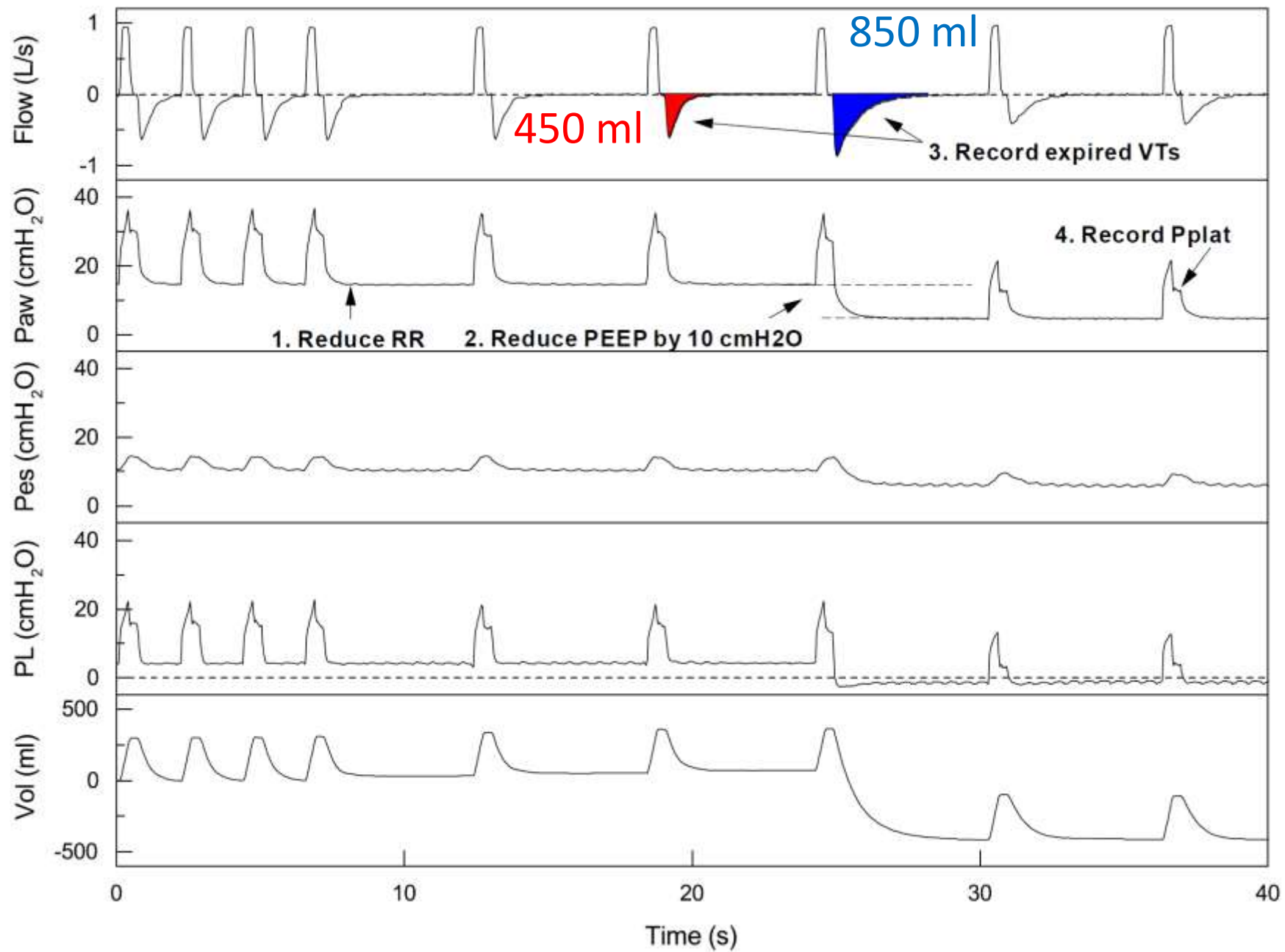
$\text{EELV} = 800 \text{ ml}$

$\text{EELV} = 1100 \text{ ml} + V_{\text{rec}}$



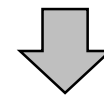
$$V_{\text{REC}} = V_{\text{Te}} - V_{\text{T}} - (C_{\text{low PEEP}} \times \Delta\text{PEEP})$$



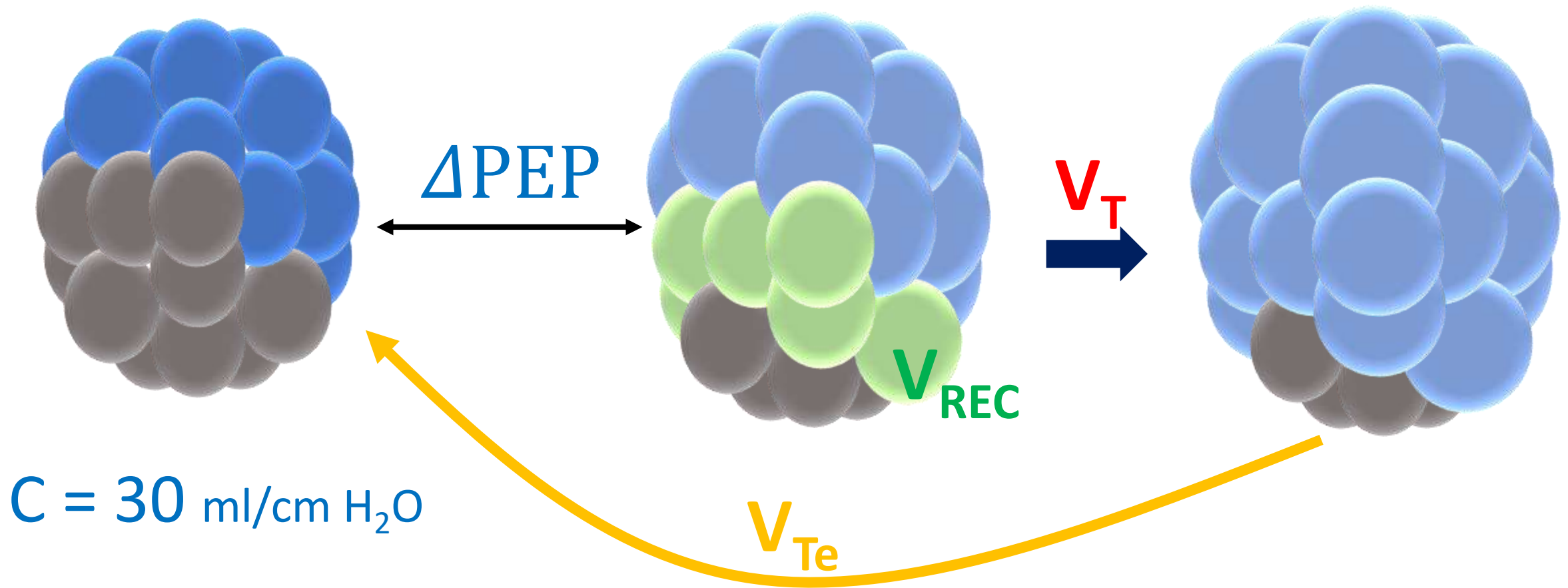


$P_{plat} = 20 \text{ cmH}_2\text{O}$

$PEEP = 5 \text{ cmH}_2\text{O}$

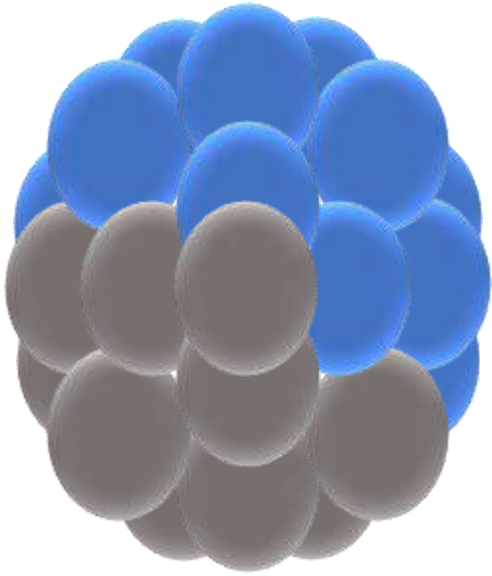


$C_{low-PEEP} = 30 \text{ ml/cmH}_2\text{O}$



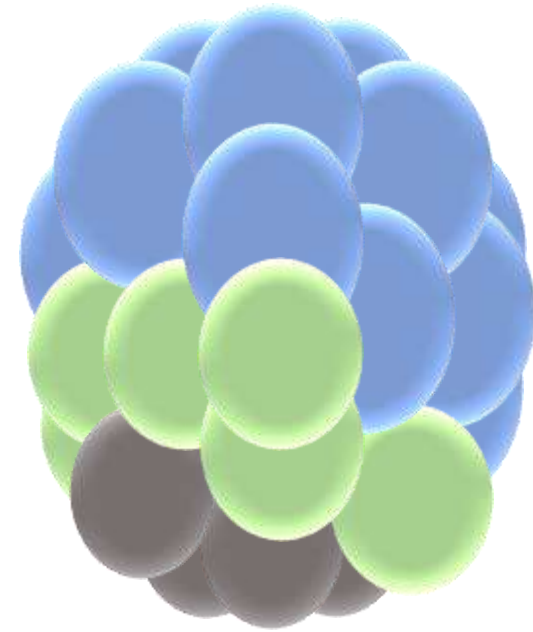
$$V_{\text{REC}} = V_{\text{Te}} - V_T - (C_{\text{basse-PEEP}} \times \Delta\text{PEEP})$$

$$V_{\text{REC}} = 850 - 450 - (30 \times 10) = 100 \text{ mL}$$



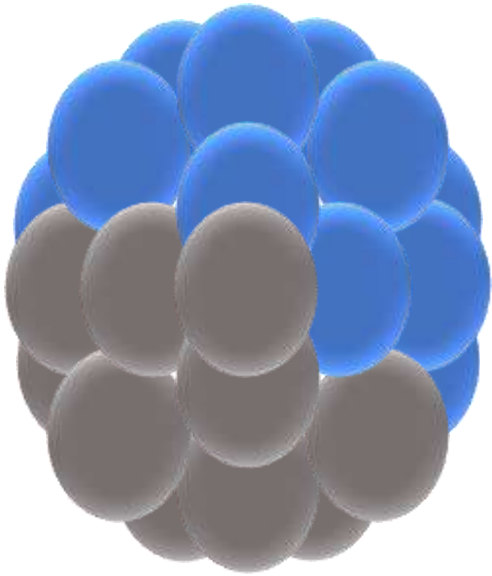
PEP = 5 cm H₂O

$$C_{\text{low PEEP}} = 30 \text{ ml/cm H}_2\text{O}$$



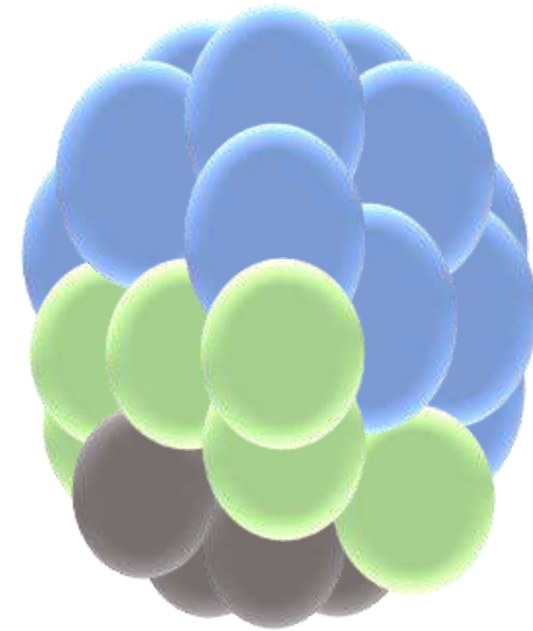
PEP = 15 cm H₂O

$$\begin{aligned} C_{\text{REC}} &= 100 \text{ ml} / 10 \text{ cm H}_2\text{O} \\ &= 10 \text{ ml/cm H}_2\text{O} \end{aligned}$$



PEEP = 5 cm H₂O

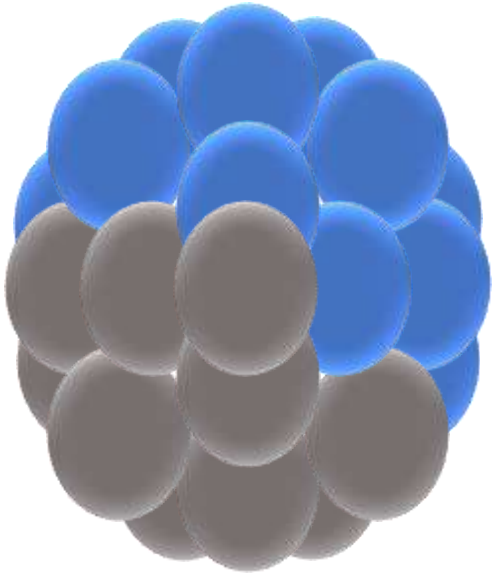
$$C_{\text{low PEEP}} = 30 \text{ ml/cm H}_2\text{O}$$



PEEP = 15 cm H₂O

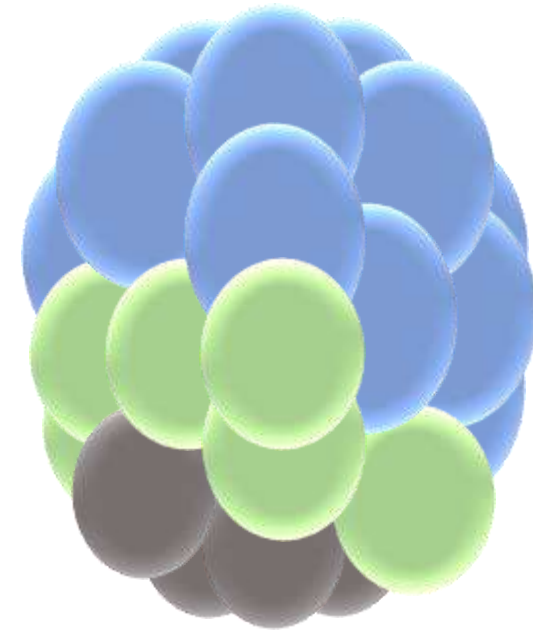
$$C_{\text{REC}} = 100 \text{ ml} / 10 \text{ cm H}_2\text{O} \\ = 10 \text{ ml/cm H}_2\text{O}$$

$$\frac{\textit{Recruitment}}{\textit{Inflation}} = \frac{R}{I} = \frac{C_{\text{REC}}}{C_{\text{low PEEP}}}$$



PEP = 5 cm H₂O

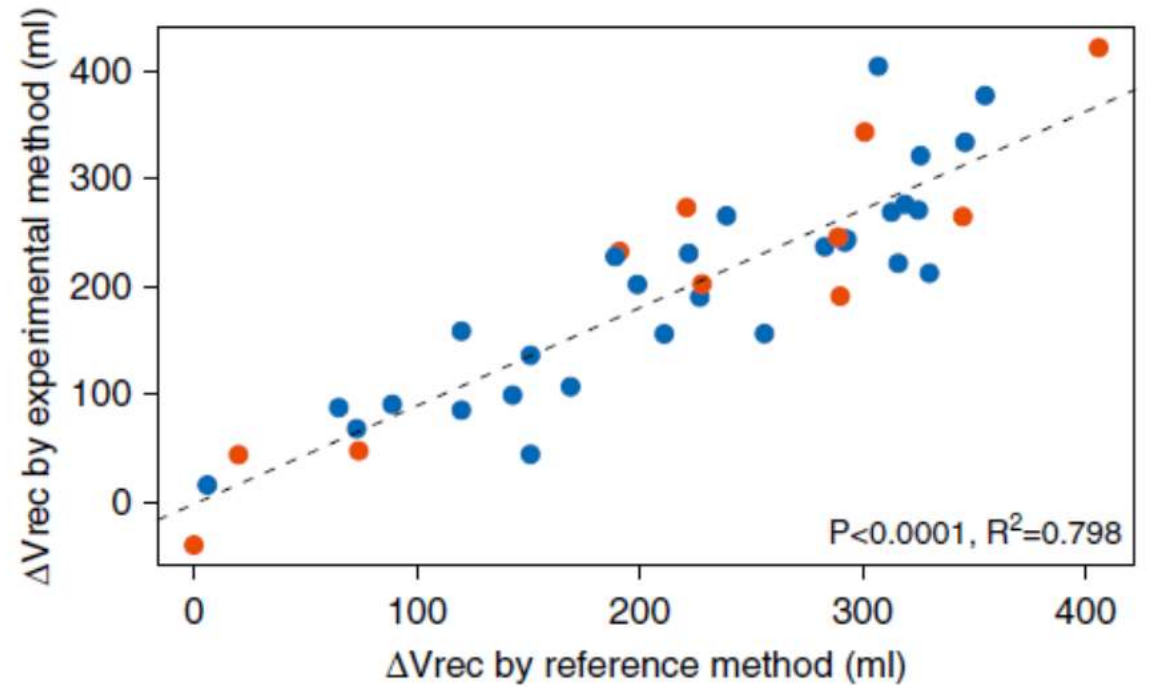
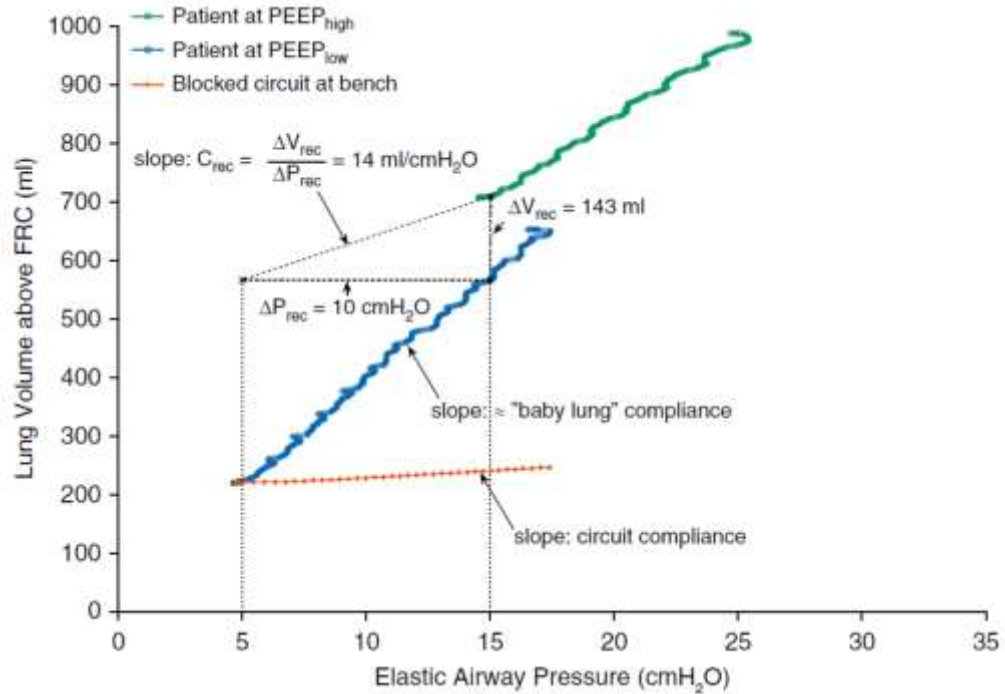
$$C_{\text{low PEEP}} = 30 \text{ ml/cm H}_2\text{O}$$



PEP = 15 cm H₂O

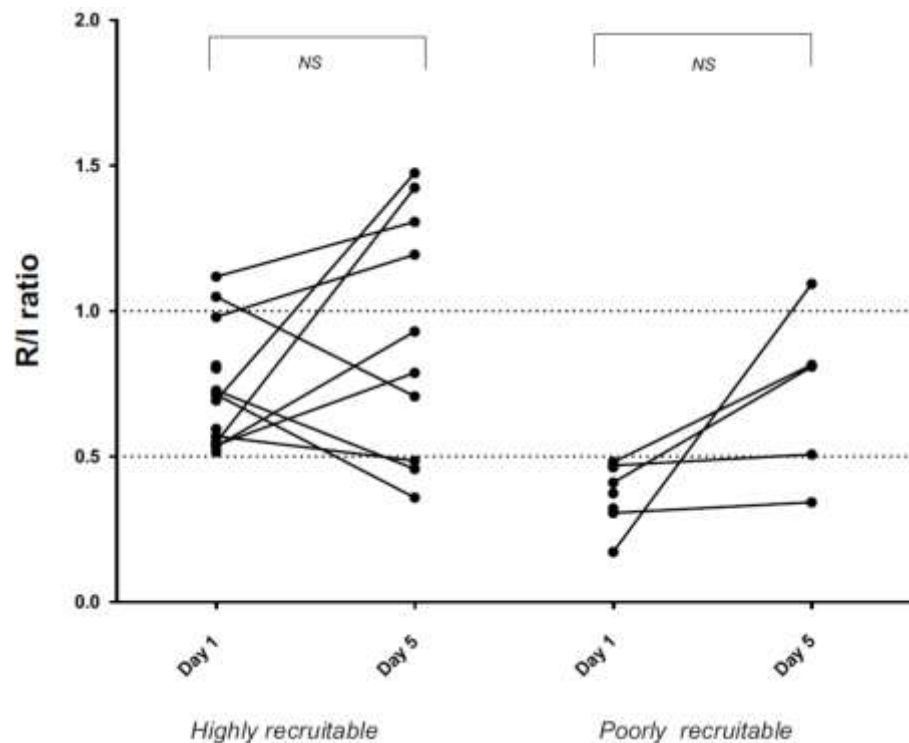
$$C_{\text{REC}} = 100 \text{ ml} / 10 \text{ cm H}_2\text{O} \\ = 10 \text{ ml/cm H}_2\text{O}$$

$$\frac{R}{I} = 0,3$$



Recruitability and effect of PEEP in SARS-Cov-2-associated acute respiratory distress syndrome

François M. Beloncle^{1*}, Bertrand Pavlovsky¹, Christophe Desprez¹, Nicolas Fage¹, Pierre-Yves Olivier¹, Pierre Asfar¹, Jean-Christophe Richard^{1,2} and Alain Mercat¹ *Ann. Intensive Care* (2020) 10:55



Recruitment-to-inflation ratio measured with modern intensive care unit ventilators: How accurate is it?

Martin Cour^{1,2*}, Charlotte Biscarrat^{1†}, Neven Stevic^{1,2}, Florian Degivry¹, Laurent Argaud^{1,2} and Claude Guérin^{1,2}

Critical Care (2022) 26:85



Bench study:

Simulated R/I = 0; 0,5; 1
5 ventilators



⚠ Error: -0,27 à + 0,17

R/I ratio



$$R/I \leq 0.2$$



No potential for lung
recruitment



« Low » PEEP

PEEP = 8 cm H₂O

$$R/I > 0.2$$



Potential for lung
recruitment



« High » PEEP

PEEP = ?

What is High PEEP?

Increasing PEEP to the maximum without signs of overdistension

↗ PEEP until

By default



« Express » PEEP

$P_{plat} = 28 \text{ cm H}_2\text{O}$



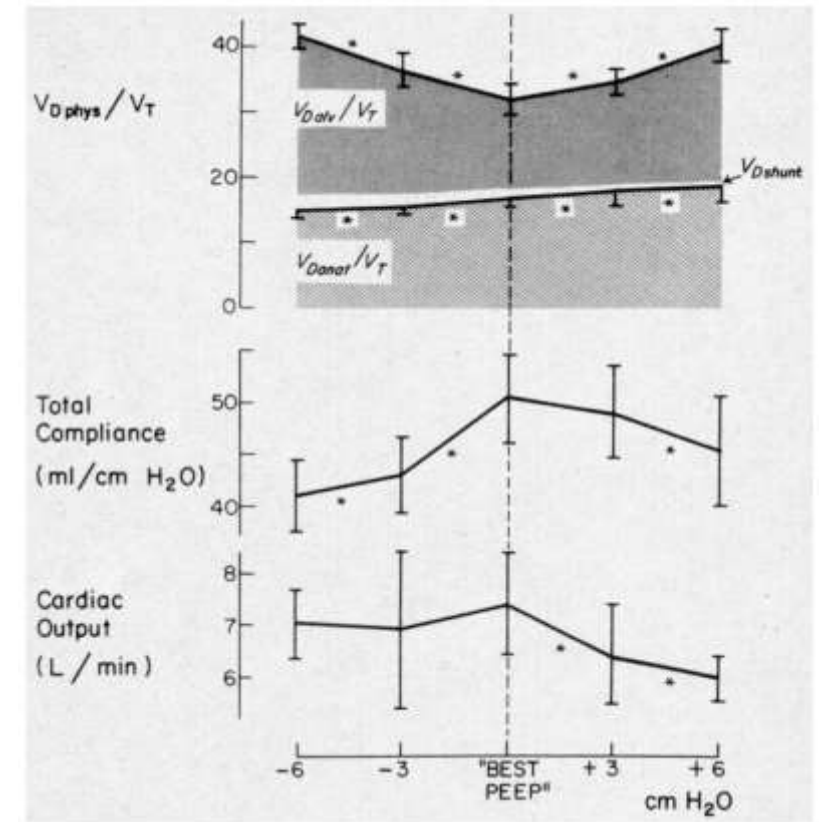
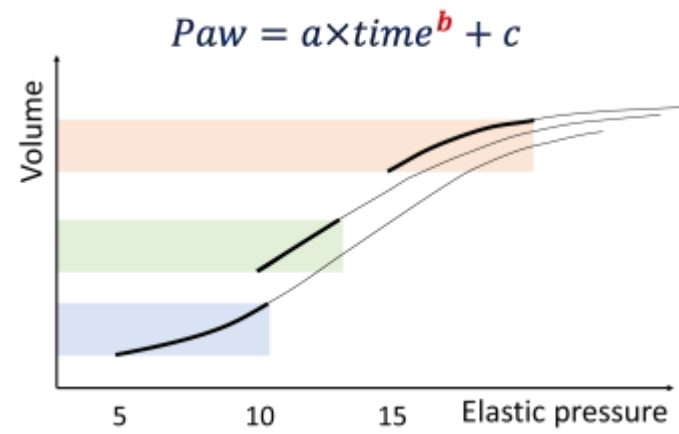
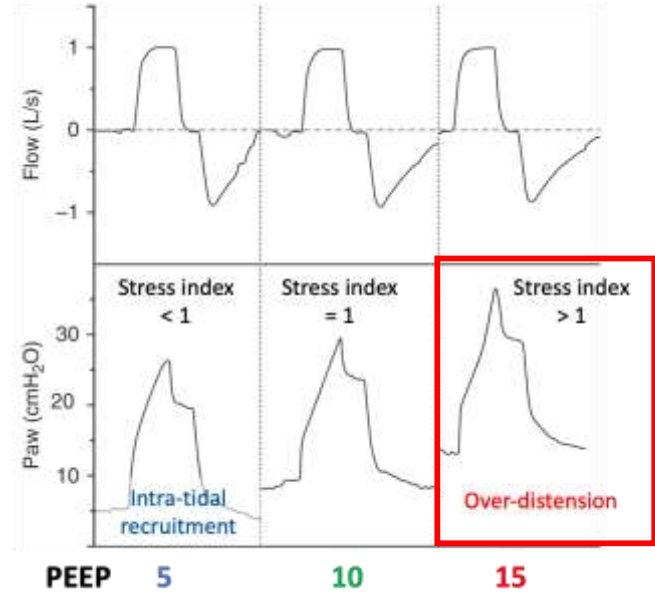
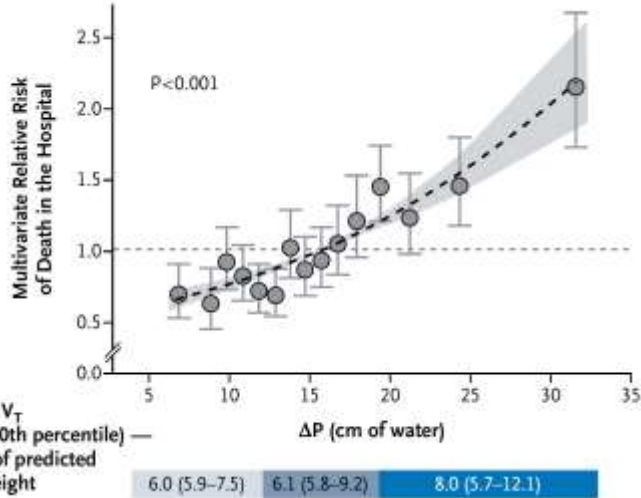
Stop earlier if signs of overdistension occur

$\Delta P \geq 15 \text{ cm H}_2\text{O}$

Stress index > 1

↗ PaCO₂

Poor hemodynamic tolerance

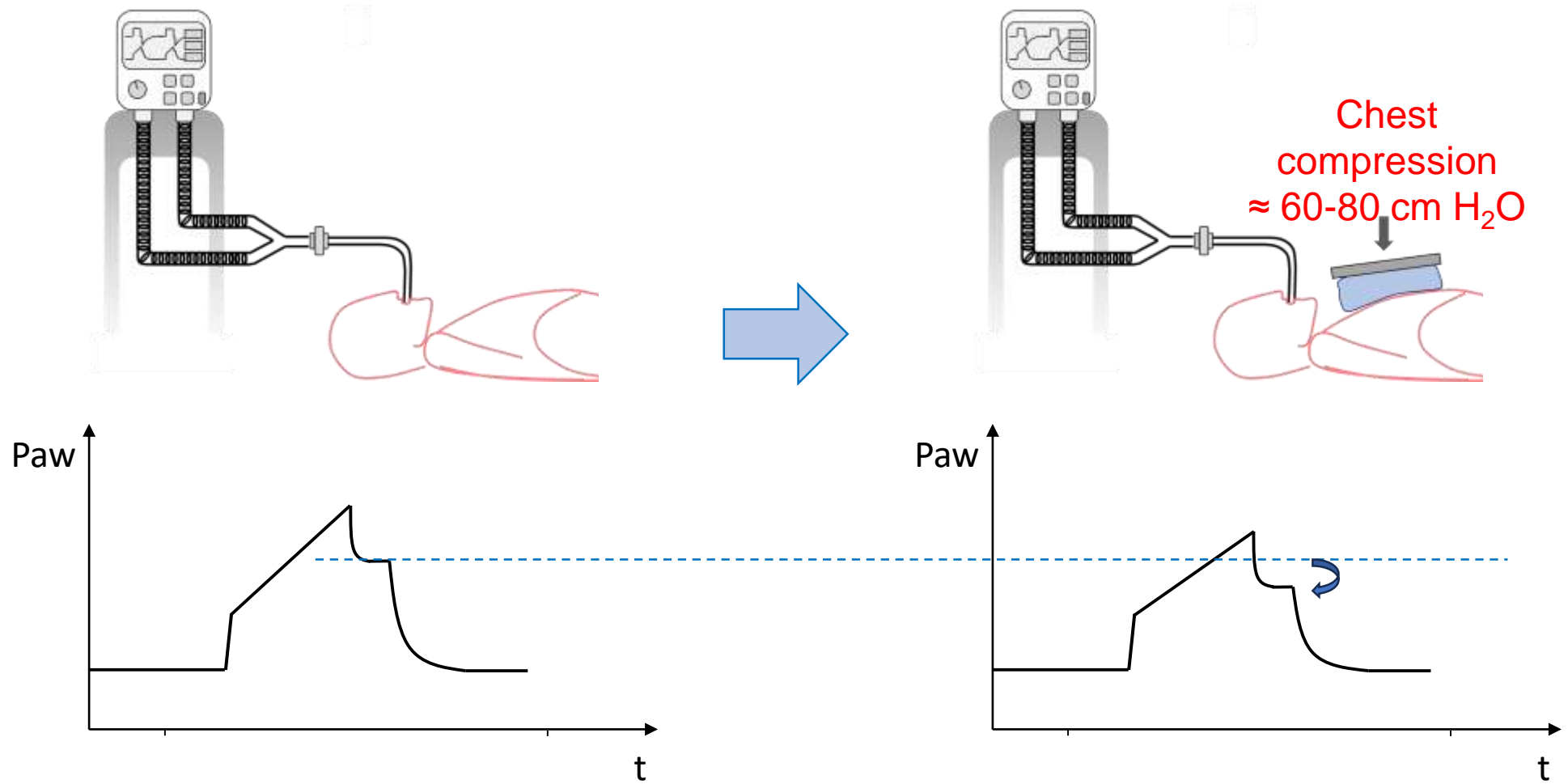


Grasso S et al. Crit Care Med 2004

Henderson W.R. et al. Am J Respir Crit Care Med 2017

Suter PM et al. NEJM 1975

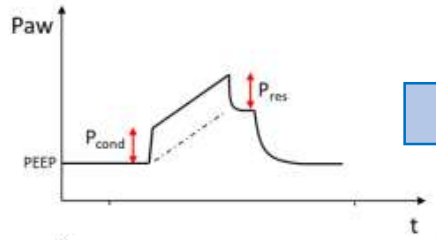
Paradoxical response to continuous anterior chest compression?



E Moncomble *et al.* *Am J Respir Crit Care Med* 2024
Carteaux G *et al.* *Crit Care Med* 2021

Take home message

Airway closure?



No airway closure

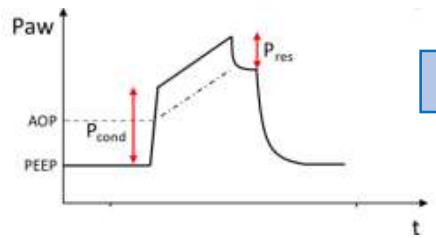
R/I ratio

R/I ratio ≤ 0.2

Low PEEP
= 8 cm H₂O

R/I ratio > 0.2

AOP ≤ 10 cm H₂O

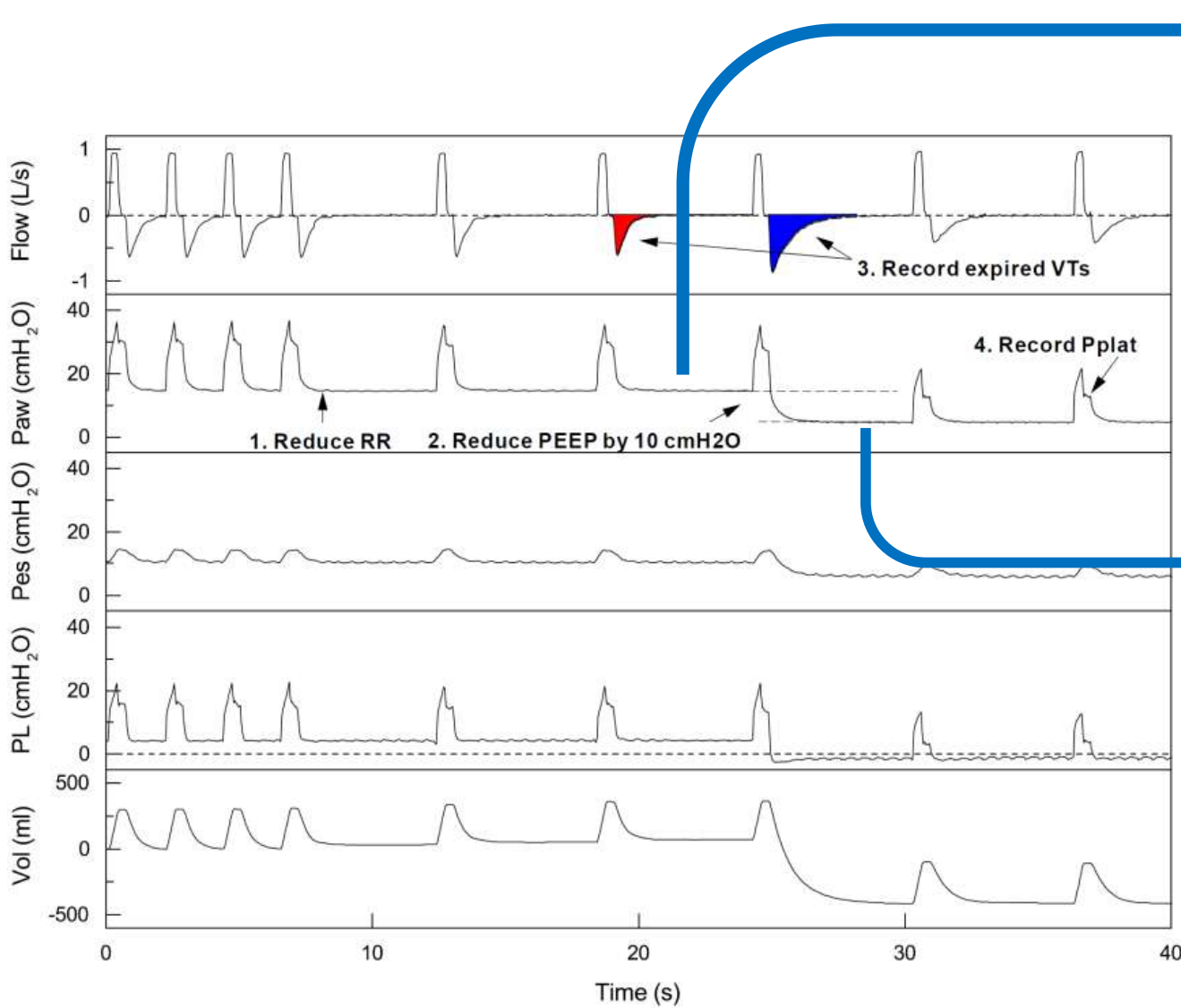


AOP measurement

AOP > 10 cm H₂O

High PEEP

↗ PEEP
↳ Pplat = 28 cm H₂O
without
Stress index > 1
Resp mechanics deterioration
↗ PaCO₂
Poor hemodynamic tolerance



PEEP = 15 cm H₂O

PEEP = 5 cm H₂O

Or

PEEP = AOP
if $5 < AOP \leq 10 \text{ cm H}_2\text{O}$