CRITCARE BITES

SETTING PEEP IN ARDS

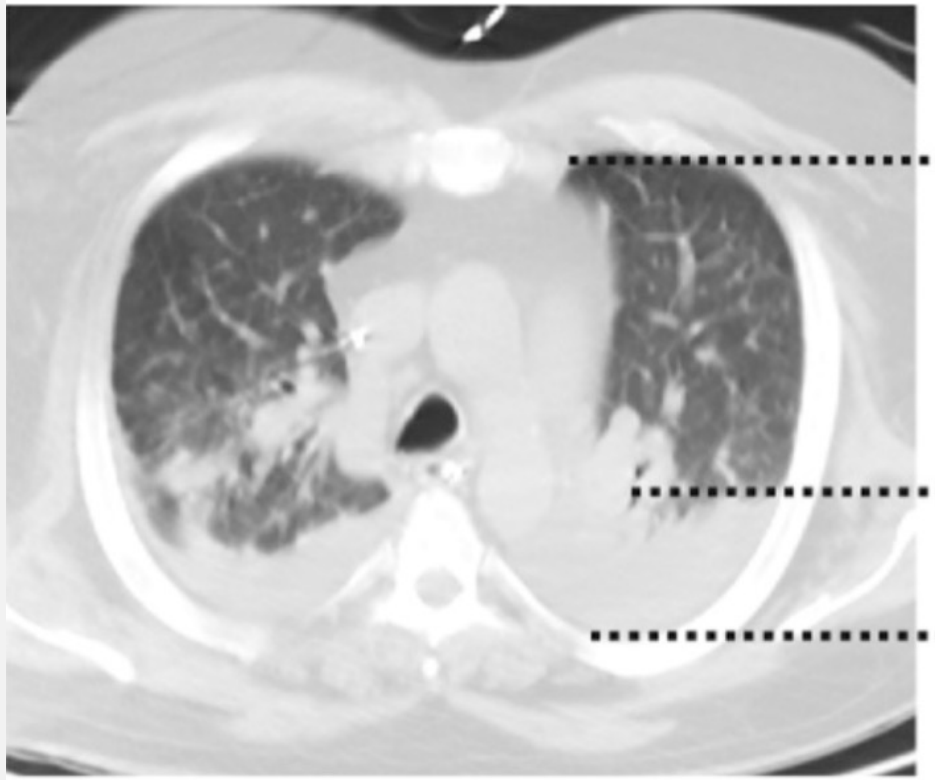
Wang Zhemin

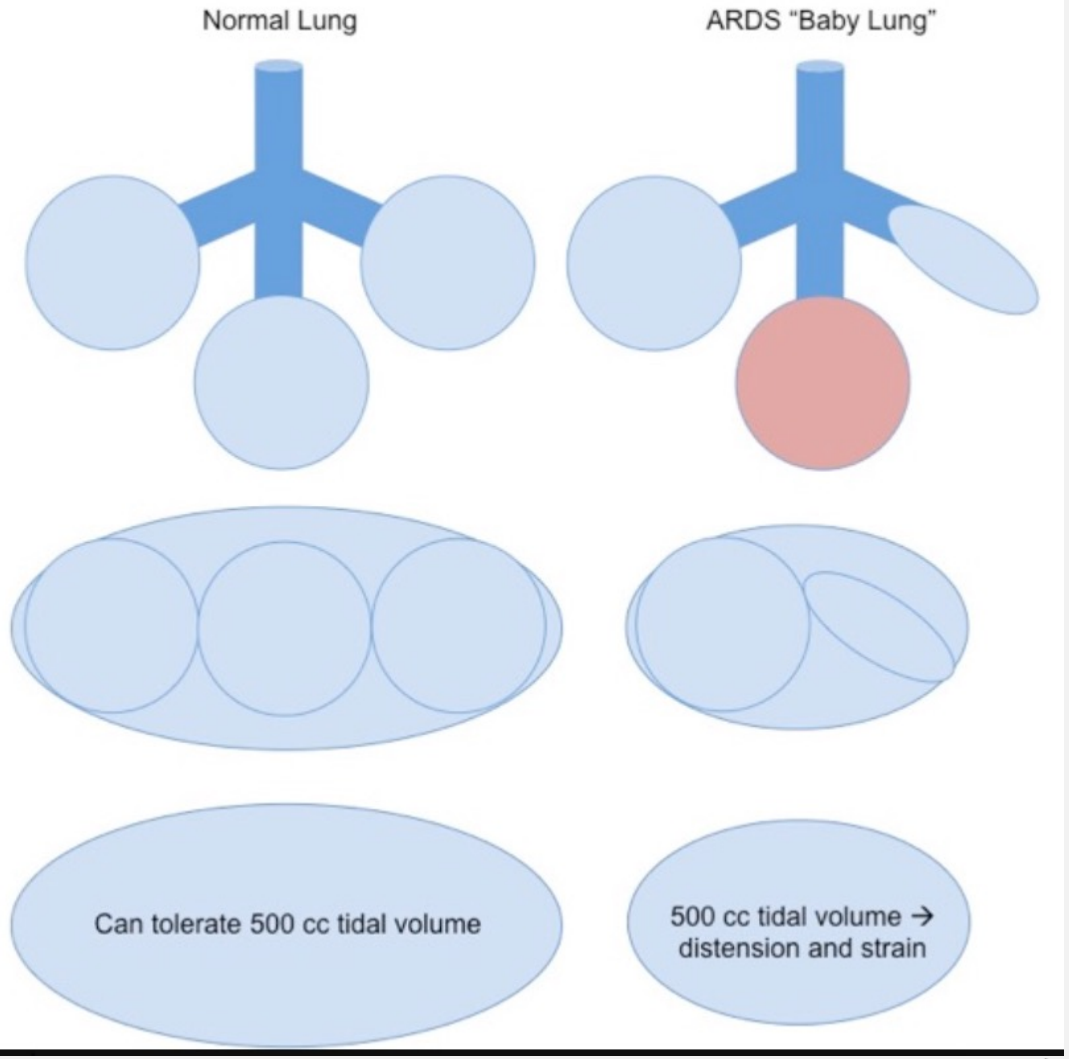
SICM
Society of Intensive Care Medicine
SINGAPORE

MAD FOR MEDICINE

OVERVIEW

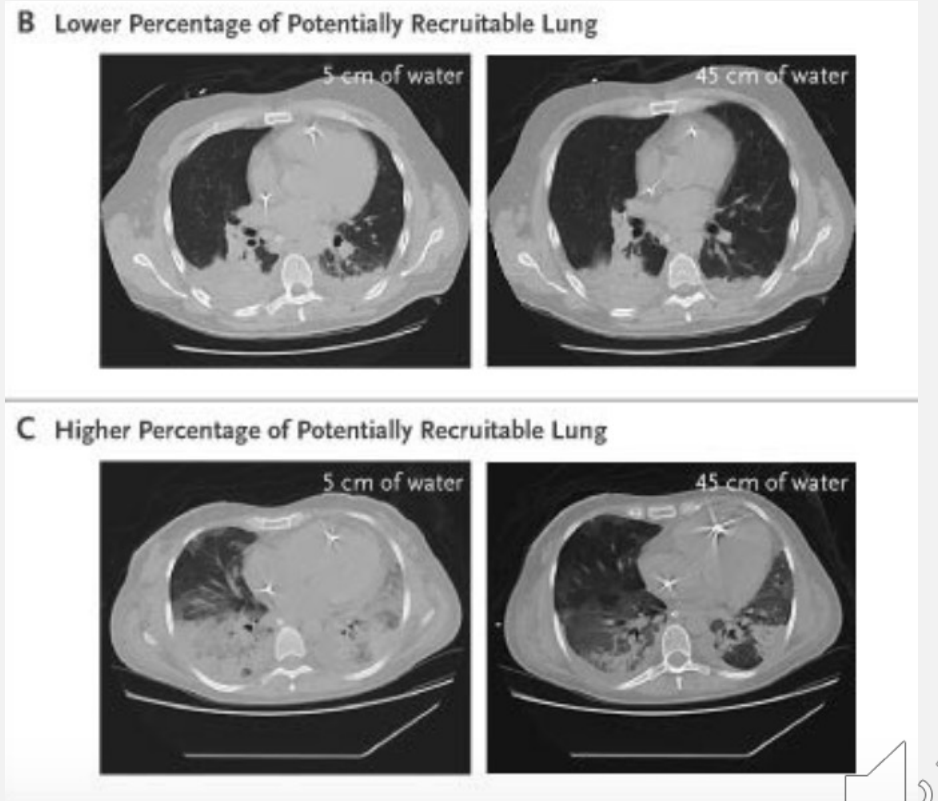
- Physiology of PEEP
- Methods of setting PEEP
- Review of 2023 ESICM ARDS guidelines on PEEP
- Practical approach

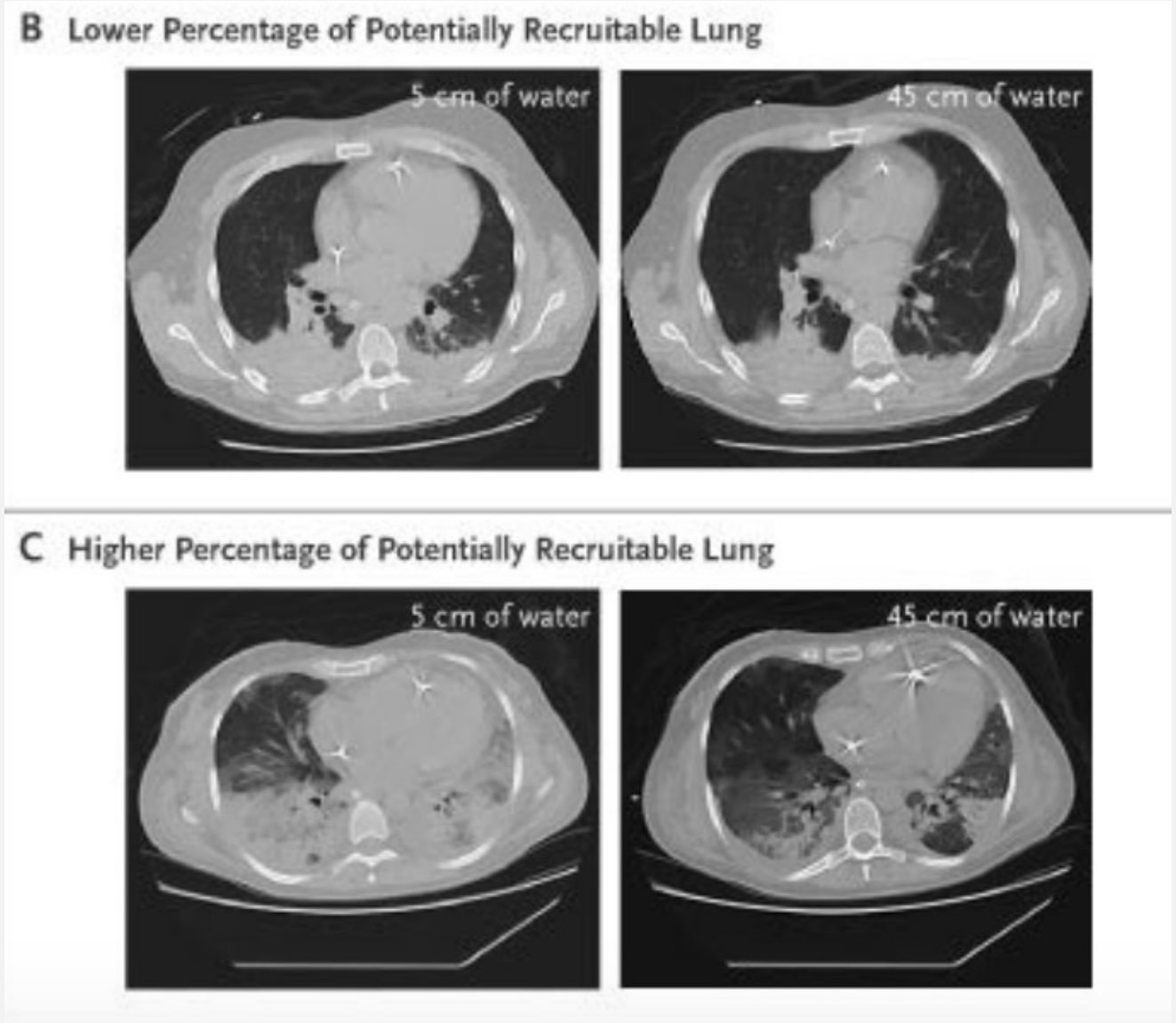

ARDS "baby lung" volume
Atelectatic lung


Normal Lung
ARDS "Baby Lung"
Can tolerate 500 cc tidal volume
500 cc tidal volume → distension and strain

ROLE OF PEEP

- Lung protection
  - Lung recruitment → Increased distribution of strain
  - Prevention of atelectrauma
- Oxygenation

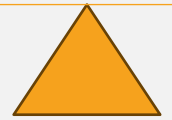




Methods to assess recruitability

- Oxygenation
- Lung mechanics
  - Compliance
  - Driving pressure
  - Pressure volume loops
  - Stress index
  - Transpulmonary pressure
- Volumetric measurements
  - Recruitment inflation ratio
  - Imaging: CT scan, electrical impedence tomography, ultrasound

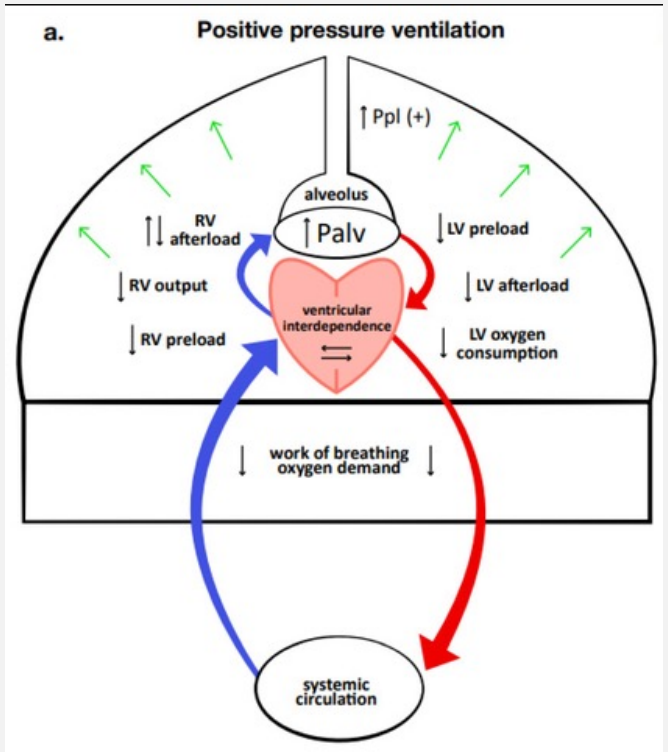
Recruitment Overdistension



Gattinoni L, Caironi P, Cressoni M, et al. Lung recruitment in patients with the acute respiratory distress syndrome. *N Engl J Med*. 2006;354(17):1775-1786. doi:10.1056/NEJMoa052052

OTHER CONSIDERATIONS

Haemodynamics



Pulmonary Vascular Resistance

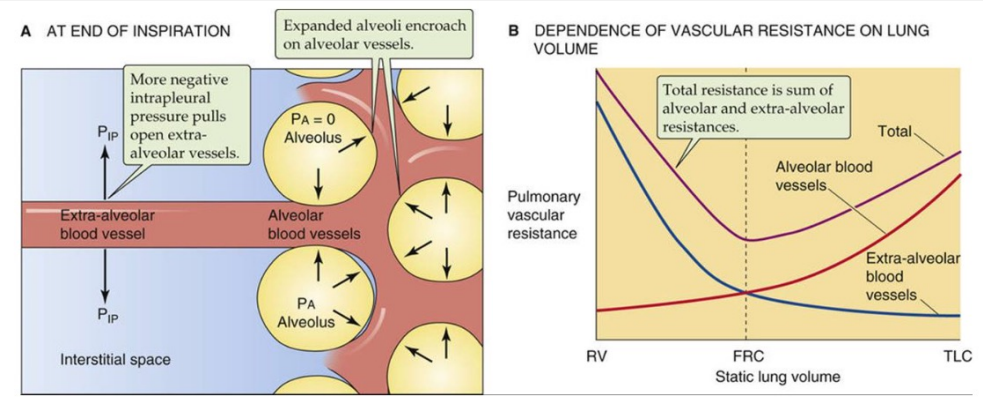
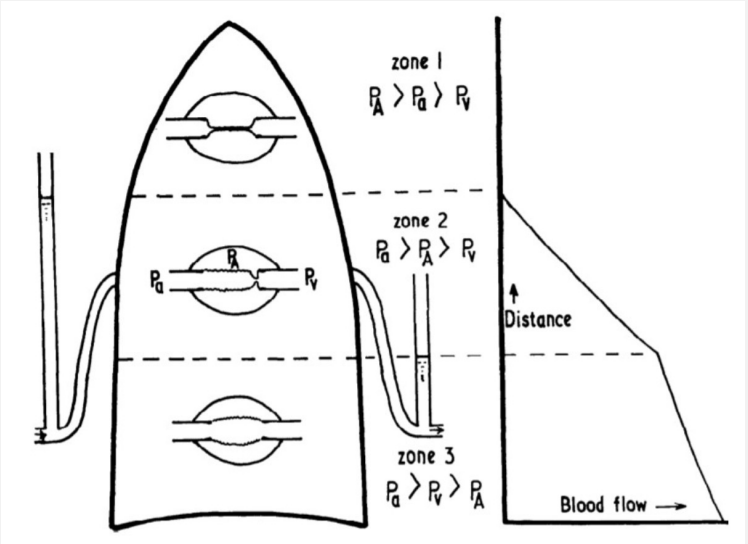
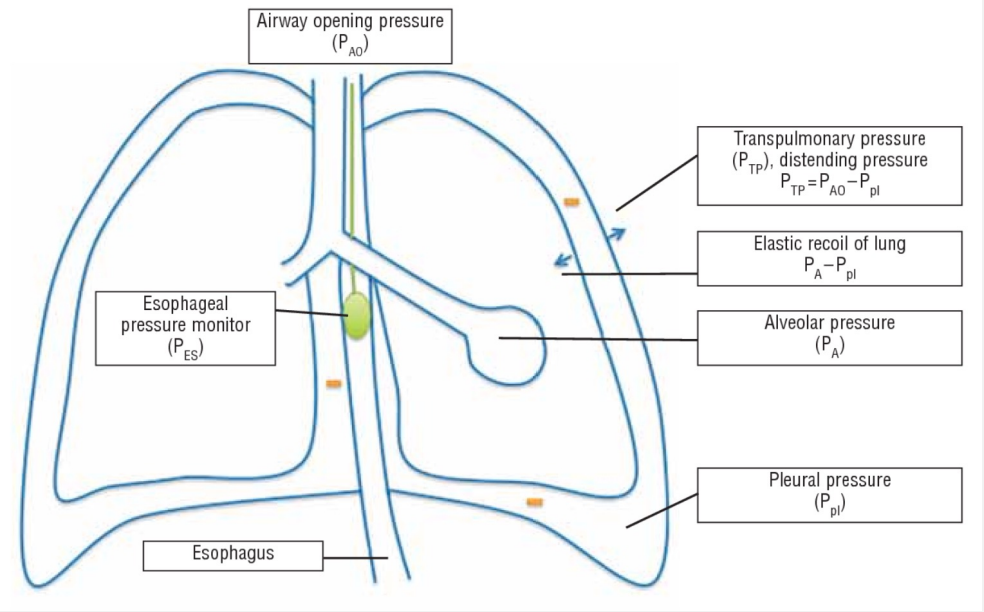
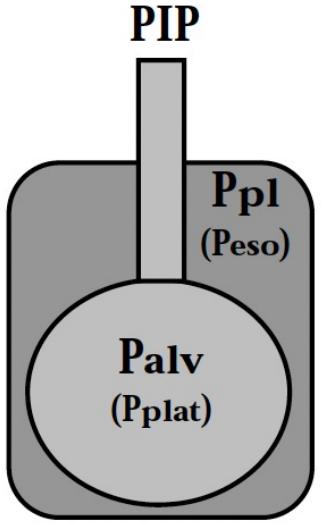


FIGURE 31-7 Pulmonary vascular resistance. (**B,** Data from Murray JF: The Normal Lung, 2nd ed. Philadelphia, WB Saunders, 1986.)

Dead Space





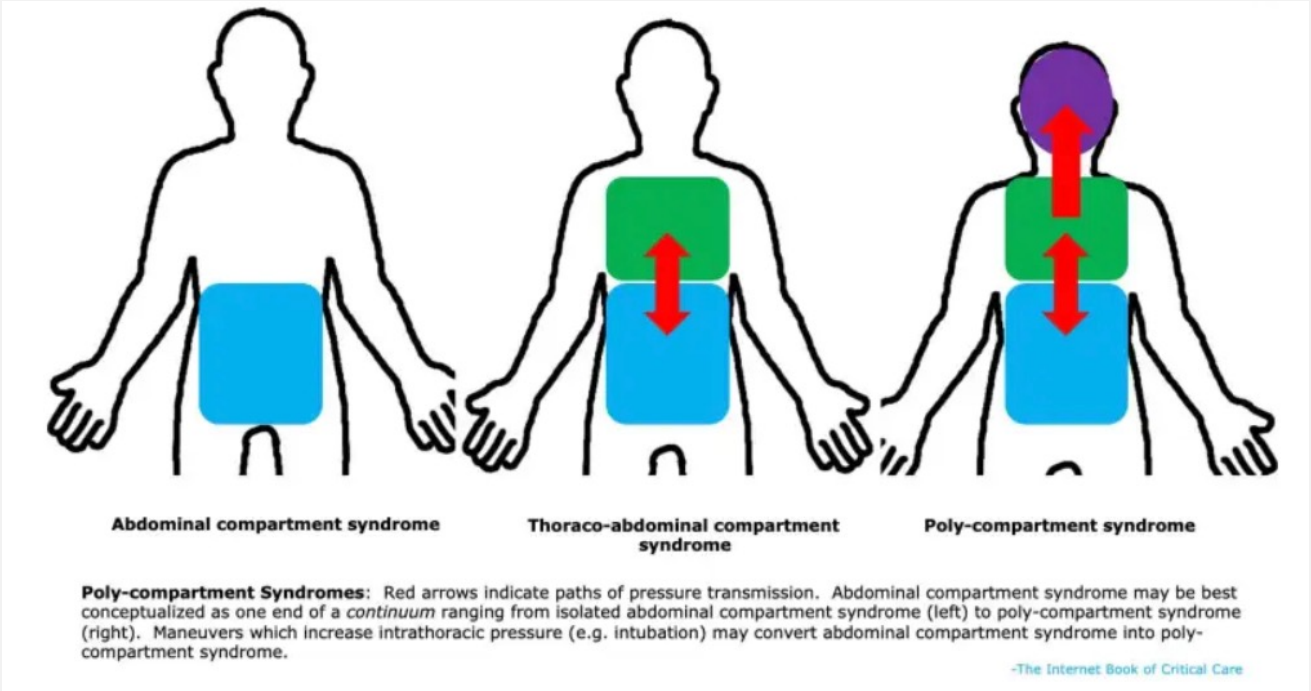


$$Crs = \frac{\text{tidal volume}}{\text{Pplat - PEEP}}$$

$$Ccw = \frac{\text{tidal volume}}{\Delta\text{Peso}}$$

$$C_L = \frac{\text{tidal volume}}{(\text{Pplat} - \text{PEEP}) - \Delta\text{Peso}}$$

$$R_i = \frac{\text{PIP - Pplat}}{\text{flow}}$$



Poly-compartment Syndromes: Red arrows indicate paths of pressure transmission. Abdominal compartment syndrome may be best conceptualized as one end of a *continuum* ranging from isolated abdominal compartment syndrome (left) to poly-compartment syndrome (right). Maneuvers which increase intrathoracic pressure (e.g. intubation) may convert abdominal compartment syndrome into poly-compartment syndrome.

-The Internet Book of Critical Care

IDEAL PEEP?

- Lung protection: Balancing lung recruitment and overdistension, prevent atelectrauma
- Oxygen delivery
  - Cardiac function – RV and LV
  - Oxygenation
- Other considerations: Obesity, abdominal compartment syndrome, acute brain injury, dynamic hyperinflation

METHODS TO SET PEEP

- PEEP/FiO2 table
- Recruitment maneuvers
- Compliance and driving pressure
- Pressure volume curve
- Stress index
- Esophageal pressure and transpulmonary pressure
- Recruitment inflation ratio
- Volume assessment by imaging: CT, electric impedence tomography

PEEP FIO2 TABLE

Lower PEEP/F_{IO_2} Combination*													
F_{IO_2}	0.3	0.4	0.4	0.5	0.5	0.6	0.7	0.7	0.7	0.8	0.9	0.9	0.9	1.0
PEEP, cm H_2O	5	5	8	8	10	10	10	12	14	14	14	16	18	18–24

Higher PEEP/F_{IO_2} Combination†													
F_{IO_2}	0.3	0.3	0.4	0.4	0.5	0.5	0.5	0.6	0.7	0.8	0.8	0.9	1.0
PEEP, cm H_2O	12	14	14	16	16	18	20	20	20	20	22	22	22–24

HIGH PEEP VS LOW PEEP

- ALVEOLI (NEJM, 2004): High vs low PEEP using PEEP/FiO2 table – No difference in mortality or ventilator free days
- LOVS (JAMA, 2008): Low TV strategy vs low TV + lung recruitment maneuvers + high PEEP – no improvement in mortality with latter strategy, but improvement in hypoxemia
- EXPRESS (JAMA, 2008): Moderate PEEP (5-9) vs PEEP to reach plateau pressure of 28-30 cmH2O – No difference in mortality, but increased recruitment strategy improved secondary outcomes of lung function, duration on mechanical ventilation and duration of organ failure

HIGH PEEP VS LOW PEEP

Caring for the Critically Ill Patient

March 3, 2010

Higher vs Lower Positive End-Expiratory Pressure in Patients With Acute Lung Injury and Acute Respiratory Distress Syndrome

Systematic Review and Meta-analysis

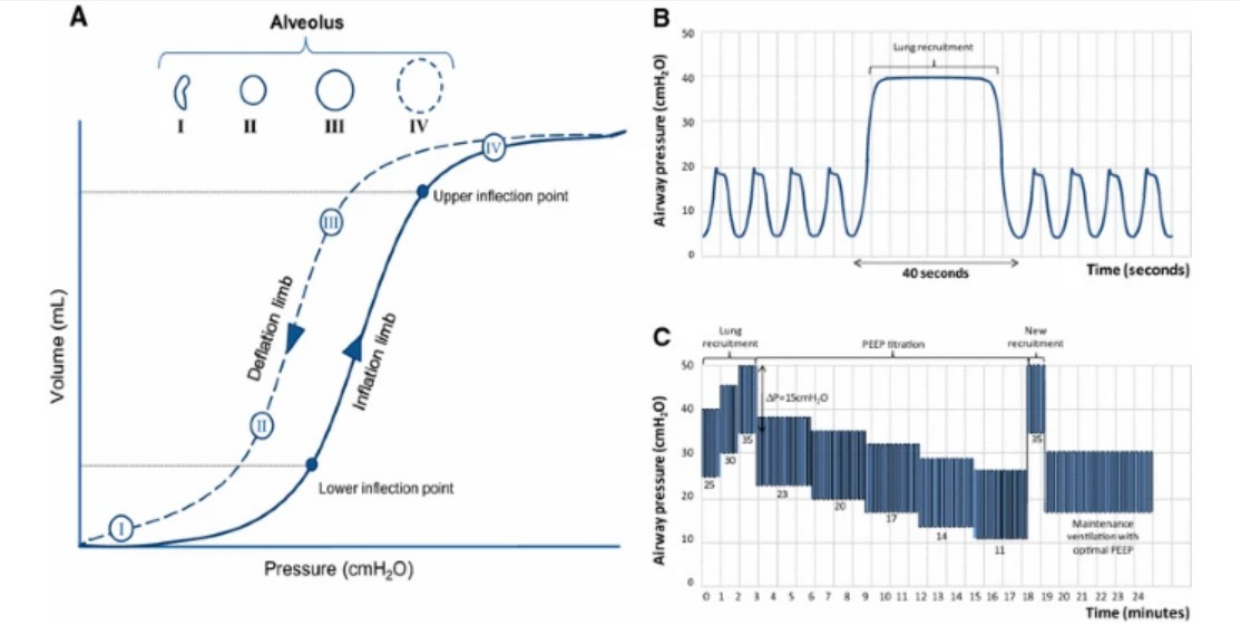
Matthias Briel, MD, MSc; Maureen Meade, MD, MSc; Alain Mercat, MD; et al

» Author Affiliations | Article Information

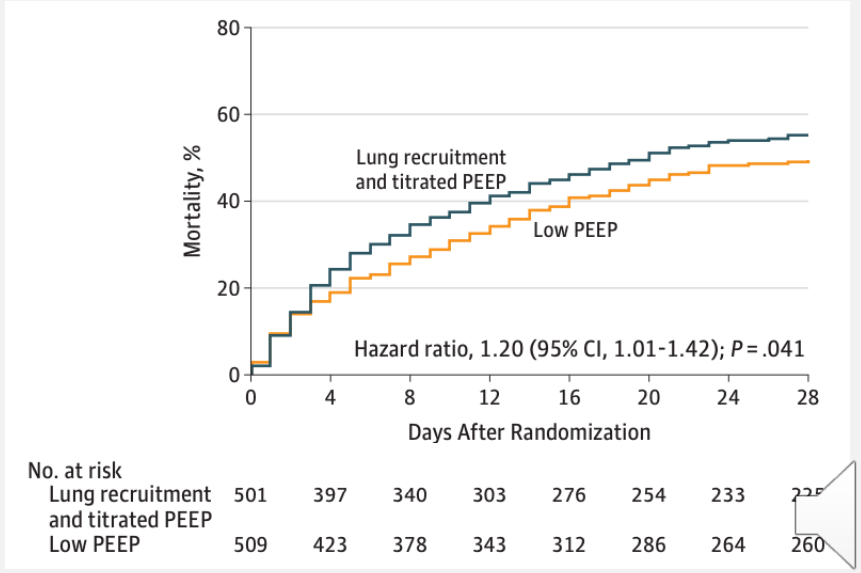
JAMA. 2010;303(9):865-873. doi:10.1001/jama.2010.218

- Treatment with higher vs lower levels of PEEP was not associated with improved hospital survival. However, higher levels were associated with improved survival among the subgroup of patients with ARDS
- Suggesting need for PEEP individualisation

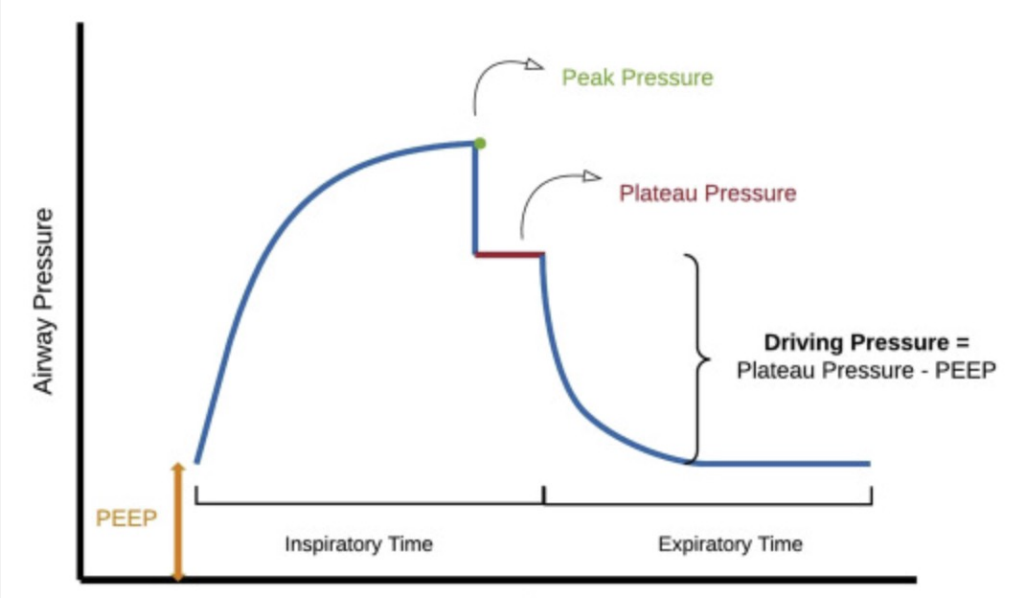
RECRUITMENT MANEUVERS



Effect of Lung Recruitment and Titrated Positive End-Expiratory Pressure (PEEP) vs Low PEEP on Mortality in Patients With Acute Respiratory Distress Syndrome
A Randomized Clinical Trial



COMPLIANCE AND DRIVING PRESSURE

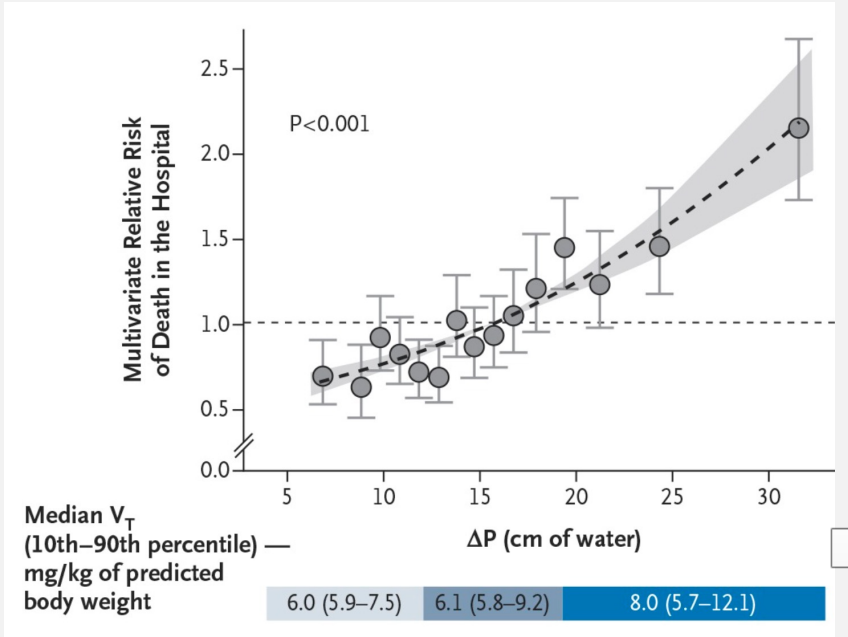


- Compliance = Δ Volume / Δ Pressure (i.e. driving pressure)
- Driving pressure: Pplat – PEEP *or* Vt / Crs
- Crs proportional to 'baby lung' – as recruitment increases, Crs increases (and driving pressure falls), and as overdistension occurs Crs decreases (and driving pressure rises)
- Driving pressure target of ~ 15cmH2O

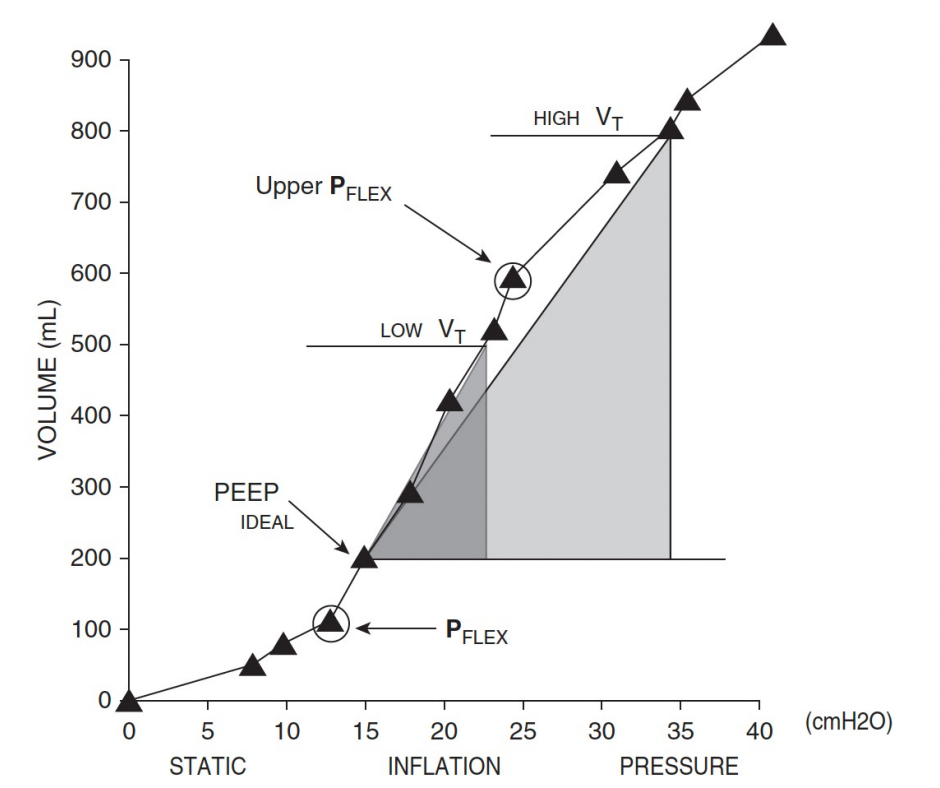
SPECIAL ARTICLE

Driving Pressure and Survival in the Acute Respiratory Distress Syndrome

Marcelo B.P. Amato, M.D., Maureen O. Meade, M.D., Arthur S. Slutsky, M.D., Laurent Brochard, M.D., Eduardo L.V. Costa, M.D., David A. Schoenfeld, Ph.D., Thomas E. Stewart, M.D., Matthias Briel, M.D., Daniel Talmor, M.D., M.P.H., Alain Mercat, M.D., Jean-Christophe M. Richard, M.D., Carlos R.R. Carvalho, M.D., et al.



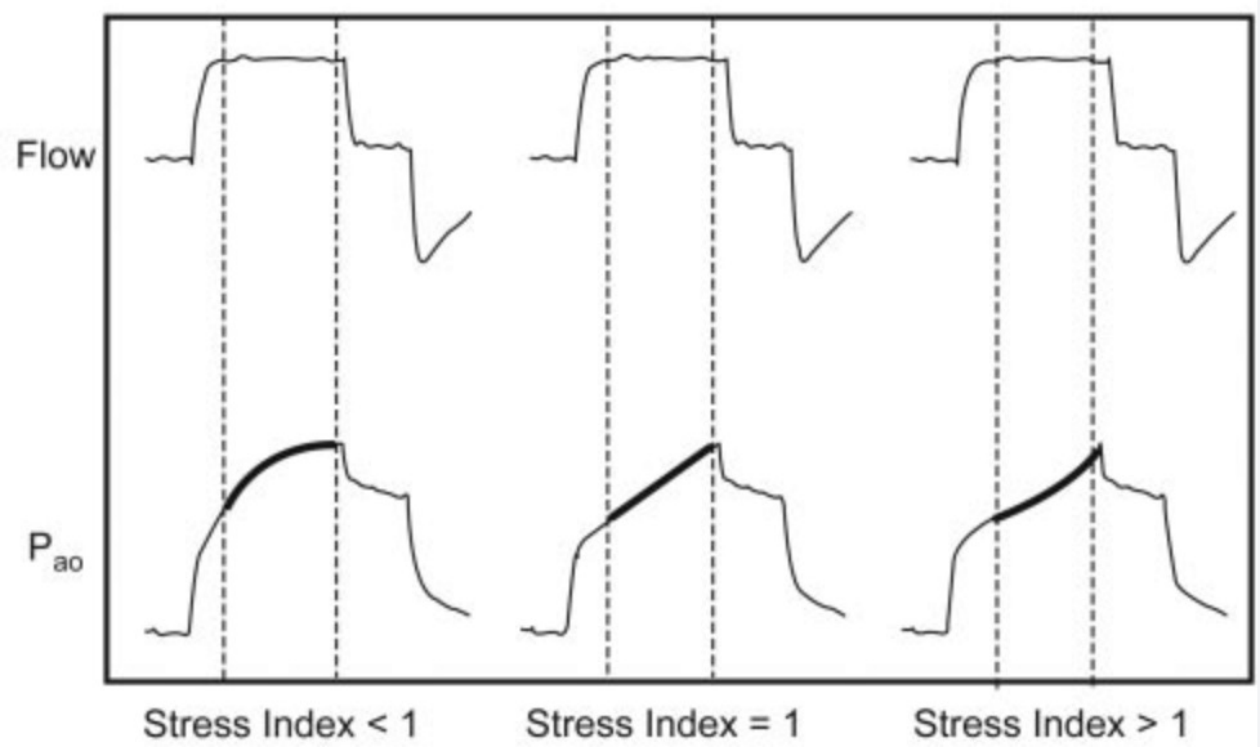
PRESSURE VOLUME CURVES



- PEEP set above the lower inflection point to ensure adequate alveolar recruitment and prevention of collapse
- Limitations
  - Requirement for deep sedation and even paralysis
  - Difficulty in identifying lower inflection point
  - Recruitment still occurs above lower inflection point

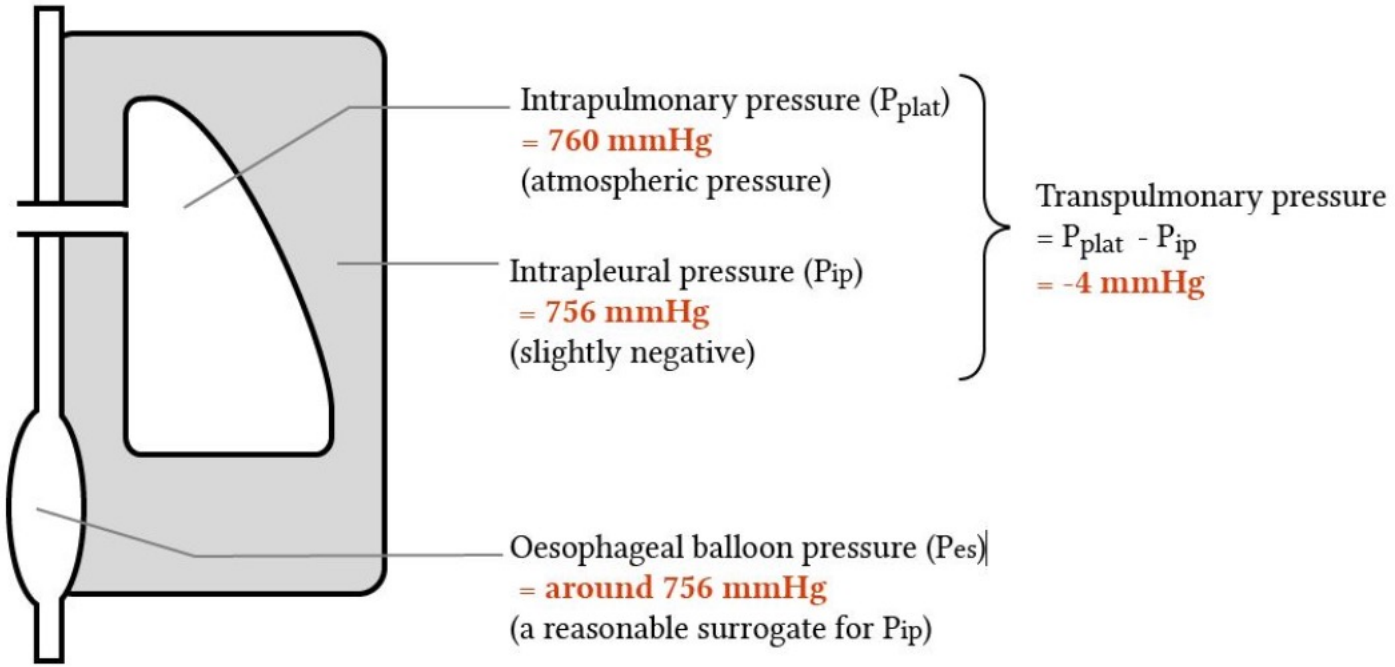
Sahetya SK, Goligher EC, Brower RG. Fifty Years of Research in ARDS. Setting Positive End-Expiratory Pressure in Acute Respiratory Distress Syndrome [published correction appears in Am J Respir Crit Care Med. 2018 Mar 1;197(5):684-685]. *Am J Respir Crit Care Med*. 2017;195(11):1429-1438. doi:10.1164/rccm.201610-2035CI

STRESS INDEX



Grasso S, Stripoli T, De Michele M, et al. ARDSnet ventilatory protocol and alveolar hyperinflation: role of positive end-expiratory pressure. *Am J Respir Crit Care Med*. 2007;176(8):761-767. doi:10.1164/rccm.200702-193OC

ESOPHAGEAL MANOMETRY & TRANSPULMONARY PRESSURE



- Transpulmonary pressure = Pplat – Pip (surrogated by Pes)
- Rationale: Excludes effect of chest wall compliance on respiratory mechanics
- Use: Morbid obesity, kyphoscoliosis, abdominal compartment syndrome
- Method
  - Inspiratory TPP < 25 cmH2O
  - Expiratory TPP 0-10 cmH2O
- Limitations: Measurements affected by various factors (positional, patient posture), assumption of equivalence of esophageal and pleural pressure, and homogeneity of pleural pressure

ORIGINAL ARTICLE

Mechanical Ventilation Guided by Esophageal Pressure in Acute Lung Injury

Daniel Talmor, M.D., M.P.H., Todd Sarge, M.D., Atul Malhotra, M.D., Carl R. O'Donnell, Sc.D., M.P.H., Ray Ritz, R.R.T., Alan Lisbon, M.D., Victor Novack, M.D., Ph.D., and Stephen H. Loring, M.D.

Table 2. Measurements of Ventilatory Function at Baseline and 72 Hours.*

Measurement	Baseline			72 Hr†		
	Esophageal-Pressure–Guided (N=30)	Conventional Treatment (N=31)	P Value	Esophageal-Pressure–Guided (N=29)	Conventional Treatment (N=29)	P Value
PaO_2:FiO_2	147±56	145±57	0.89	280±126	191±71	0.002
Respiratory-system compliance (ml/cm of water)	36±12	36±10	0.94	45±14	35±9	0.005

Table 4. Clinical Outcomes.*

Outcome	Esophageal-Pressure–Guided (N=30)	Conventional Treatment (N=31)	P Value
28-Day mortality — no. (%)	5 (17)	12 (39)	0.055
180-Day mortality — no. (%)	8 (27)	14 (45)	0.13
Length of ICU stay — days			0.16
Median	15.5	13.0	
Interquartile range	10.8–28.5	7.0–22.0	
No. of ICU-free days at 28 days			0.96
Median	5.0	4.0	
Interquartile range	0.0–14.0	0.0–16.0	
No. of ventilator-free days at 28 days			0.50
Median	11.5	7.0	
Interquartile range	0.0–20.3	0.0–17.0	
No. of days of ventilation among survivors			0.71
Median	12.0	16.0	
Interquartile range	7.0–27.5	7.0-20.0	

Effect of Titrating Positive End-Expiratory Pressure (PEEP) With an Esophageal Pressure–Guided Strategy vs an Empirical High PEEP-FiO_2 Strategy on Death and Days Free From Mechanical Ventilation Among Patients With Acute Respiratory Distress Syndrome

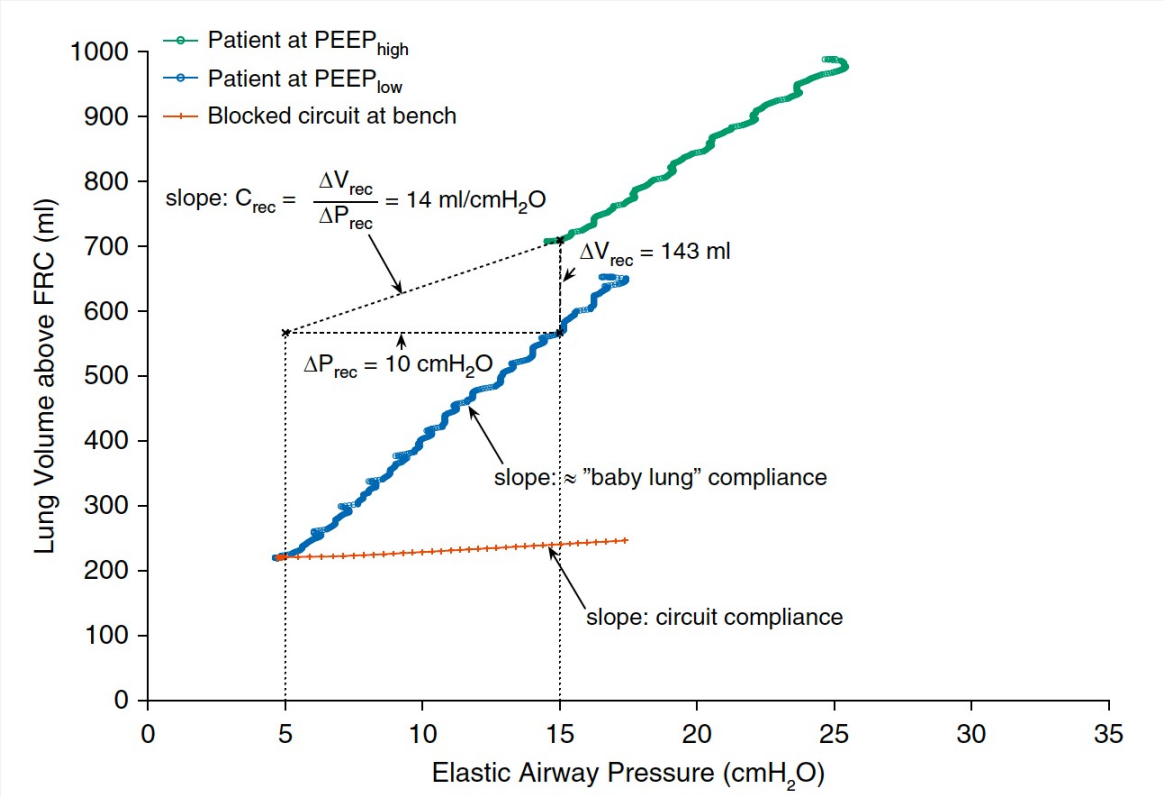
A Randomized Clinical Trial

Jeremy R. Beitler, MD, MPH[1]; Todd Sarge, MD[2]; Valerie M. Banner-Goodspeed, MPH[2]; et al

Table 3. Patient Outcomes[a]

Variable	P_{ES}-Guided PEEP (n = 102)	Empirical PEEP-FiO_2 (n = 98)	Absolute Difference, % (95% CI)[b]	*P* Value[c]
Primary End Point				
Probability of more favorable outcome, a ranked composite incorporating death and days free from mechanical ventilation among survivors, % (95% CI)[d]	49.6 (41.7 to 57.5)	50.4 (42.5 to 58.3)	NR[e]	.92
Secondary Clinical End Points				
Mortality through day 28, No. (%)	33 (32.4)	30 (30.6)	1.7 (−11.1 to 14.6)	.88
Days free from mechanical ventilation among survivors through day 28, median (IQR)	22 (15 to 24)	21 (16.5 to 24)	0 (−1 to 2)	.85
Mortality through day 60, No./total No. (%)	38/101 (37.6)	37/98 (37.8)	−0.1 (−13.6 to 13.3)	>.99
Mortality through 1 y, No./total No. (%)	44/100 (44.0)	44/96 (45.8)	−1.8 (−15.8 to 12.1)	.89
Ventilator-free days through day 28, median (IQR)[f]	15.5 (0 to 23)	17.5 (0 to 23)	0 (0 to 0)	.93
ICU length of stay through day 28, median (IQR), d	10 (6 to 17)	9.5 (5 to 14)	1 (−1 to 3)	.24
Hospital length of stay through day 28, median (IQR), d	16 (9 to 26)	15 (8 to 24)	0 (−1 to 3)	.58
Hospital length of stay through day 60, median (IQR), d	16 (9 to 26)	15 (8 to 24)	1 (−2 to 4)	.47
Rescue therapy administered, No. (%)[g]	4 (3.9)	12 (12.2)	−8.3 (−15.8 to -0.8)	.04
Prone positioning, No. (%)	1 (1.0)	3 (3.1)	−2.1 (−6.0 to 1.8)	.36
Inhaled pulmonary vasodilator, No. (%)	3 (2.9)	10 (10.2)	−7.3 (−14.1 to −0.4)	.046
Extracorporeal membrane oxygenation, No. (%)	1 (1.0)	3 (3.1)	−2.1 (−6.0 to 1.8)	.36
Recruitment maneuvers, No. (%)	1 (1.0)	1 (1.0)	0.0 (−2.8 to 2.7)	>.99
Safety End Points				
Shock-free days, median (IQR)[f]	14 (0 to 21)	17 (0 to 21)	0 (−2 to 0)	.47
Acute kidney injury requiring renal replacement therapy in the first 28 d, No./total, No. (%)[h]	21/100 (21.0)	32/96 (33.3)	−12.3 (−24.7 to 0.0)	.05
Pneumothorax, No. (%)	3 (2.9)	2 (2.0)	0.9 (−3.4 to 5.2)	>.9
Bronchopleural fistula, No.	0	0	0	
Barotrauma, No. (%)[i]	6 (5.9)	5 (5.1)	0.8 (−5.5 to 7.1)	>.99

RECRUITMENT INFLATION RATIO



Lung Recruitability and Airway Opening Pressure

To test recruitability the PEEP must be changed from a higher PEEP to a lower level of PEEP (ideally by 10 cm H2O). Example: 15 cm H2O to 5 cm H2O. Addtionally, **Volume Assist Control** should be used. PLEASE USE A 0.3 SECOND INSPIRATORY PAUSE SETTING TO MEASURE PLATEAU PRESSURE. DO NOT PERFORM A MANUAL INSPIRATORY PAUSE. (Performing a manual inspiratory pause that is too long can often lead to erroneously low plateau pressure readings)

A test for Airway Closure should be done before this recruitability test. Please input the value into this form (instructional video for performing the test is at the end of this page).

The 'High PEEP' of the R/I ratio maneuver should be ideally AT LEAST 5 cm H2O above AOP provided Pplat is less than 30 cm H2O. Continue to use a delta pressure of 10 cmH2O (even though it may cross the AOP) to be consistent with the expiratory driving pressure used in the study. (Reference)

Reduce the respiratory rate to 6-8 bpm to ensure enough time to exhale when PEEP is dropped.
Perform the following steps (see the video demonstration below):

1. Input the exhaled volume at high PEEP with the respiratory rate set to 6-8 bpm
2. Change to the lower PEEP (do not do a gradual decrease), **observe the exhaled volume when the PEEP changes from high to low!**
3. Look at the plateau pressure (some ventilators it would be the end-inspiratory pressure) measured by the ventilator with 0.3 second inspiratory pause setting (as shown in the video at the bottom of this page).

Airway Opening Pressure
cmH2O
Leave empty if there is no airway closure

Note: High PEEP needs to be higher than AOP.

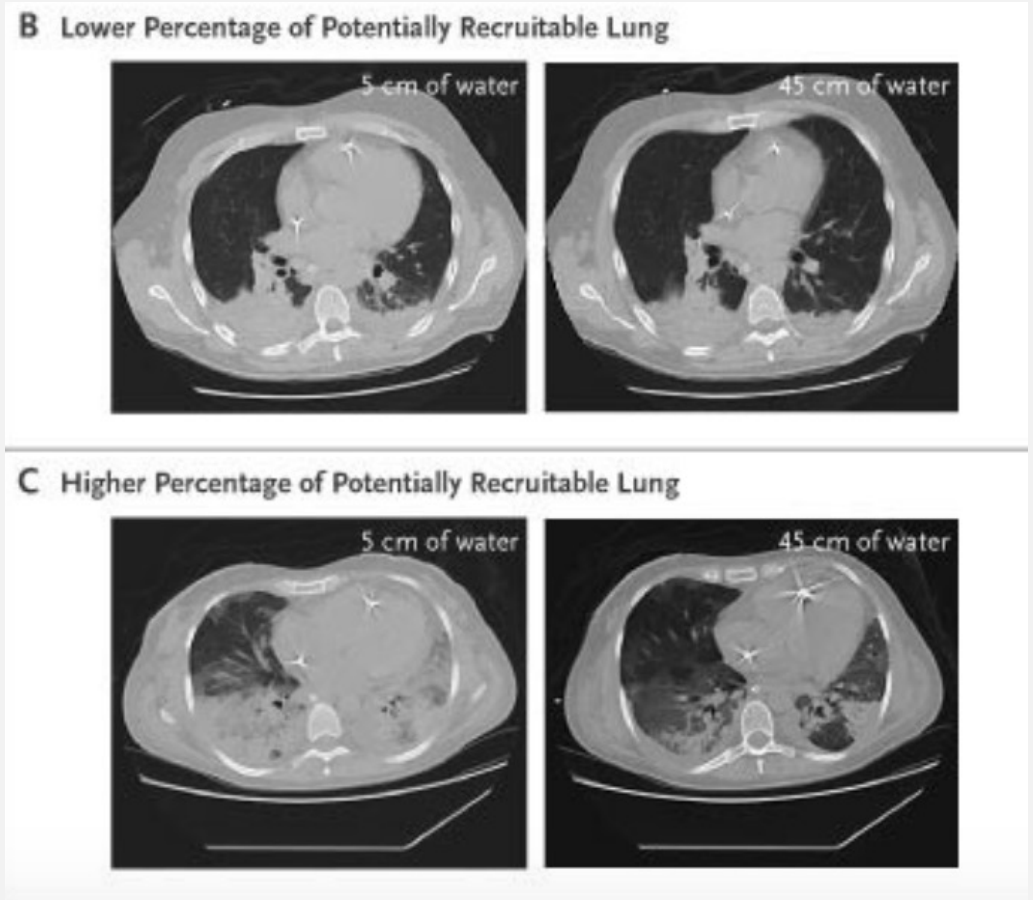
The R/I ratio is the ratio between the compliance of the recruited lung to that of the respiratory system.
Values >= 0.5 suggest more potential for lung recruitment with respect to lung inflation. (Reference)

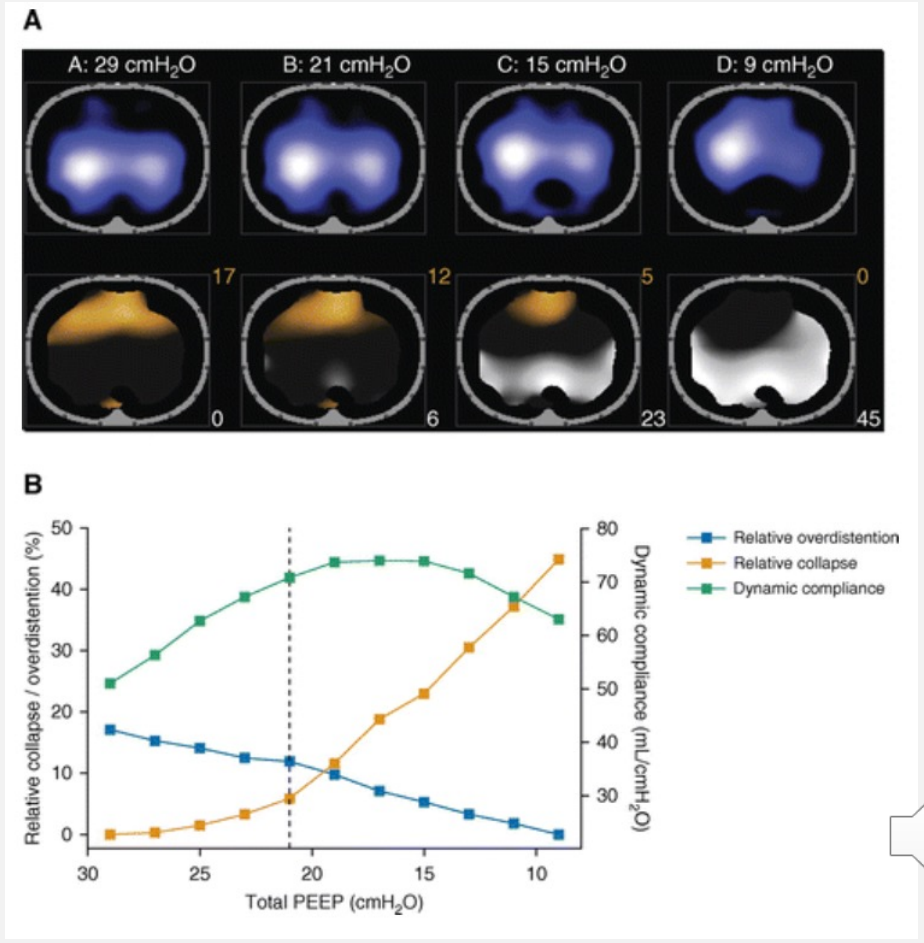
High PEEP	Set Tidal Volume (VT)	VT exhaled @ high PEEP	Low PEEP
cmH2O	ml	ml	cmH2O

VT exhaled from high to low PEEP	Plateau Pressure (at low PEEP)	
ml	cmH2O	Calculate

Chen L, Del Sorbo L, Grieco DL, et al. Potential for Lung Recruitment Estimated by the Recruitment-to-Inflation Ratio in Acute Respiratory Distress Syndrome. A Clinical Trial. *Am J Respir Crit Care Med*. 2020;201(2):178-187. doi:10.1164/rccm.201902-0334OC

IMAGING


B Lower Percentage of Potentially Recruitable Lung
5 cm of water
45 cm of water
C Higher Percentage of Potentially Recruitable Lung
5 cm of water
45 cm of water


A
A: 29 cmH2O
B: 21 cmH2O
C: 15 cmH2O
D: 9 cmH2O
17
12
5
0
0
6
23
45
B
Relative collapse / overdistention (%)
Dynamic compliance (mL/cmH2O)
Total PEEP (cmH2O)
Relative overdistention
Relative collapse
Dynamic compliance

2023 ESICM ARDS GUIDELINES

- Higher vs lower PEEP strategy No recommendation
- PEEP titration guided by respiratory mechanics vs PEEP/FiO2 strategy: No recommendation
- Use of prolonged high-pressure recruitment maneuvers (>35cmH2O for at least 1 min): Recommend against
- Routine use of brief high-pressure recruitment maneuvers (>25cmH2O for < 1 min): Suggest against

Grasselli G, Calfee CS, Camporota L, et al. ESICM guidelines on acute respiratory distress syndrome: definition, phenotyping and respiratory support strategies. *Intensive Care Med*. 2023;49(7):727-759. doi:10.1007/s00134-023-07050-7

PUTTING EVERYTHING TOGETHER

- Stratify patients based on degree of respiratory failure – patients with more severe disease probably require more careful management of PEEP
- Assess for PEEP sensitive comorbidities: RV/LV failure, obesity, abdominal hypertension, raised intracranial pressure, dynamic hyperinflation
- Lower PEEP/FiO2 table can be used as a starting point further refined by methods such as driving pressure or recruitment-inflation ratio
- Attention should also be paid to haemodynamics, ventilation and global oxygen delivery (e.g. ScvO2)
- Ultimately aiming for lung protection (recruitment, prevention of collapse), adequate gas exchange, stable haemodynamics

SUMMARY

- Concept of 'baby lung', disease heterogeneity and different compartmental pressures important in ARDS
- PEEP is a double-edged sword – can be both advantages and disadvantages in terms of gas exchange, lung protection and haemodynamics
- PEEP as a lung protective strategy – reduce inhomogeneity and improves distribution of strain, prevent atelectrauma
- Various methods to assess recruitability – each with its strengths and limitations. Available bedside options include PEEP/FiO2 table, driving pressure and recruitment inflation ratio
- Marked heterogeneity across patients, and even for the same patient across time – PEEP should be individualised
- Current clinical evidence limited, ongoing trials

How I set PEEP in ARDS: Professor Laurent Brochard

In this AVF Podcast: ICU Tips & Tricks episode, Professor Laurent Brochard shares his thoughts on the setting of positive end-expiratory pressure (PEEP) in...

Sep 2021 · 18 min 23 sec left

6. PEEP in ARDS Roundtable

This week on Pulm PEEPs, Dave Furfaro and Kristina Montemayor are joined by experts in the field of critical care medicine and ARDS to discuss all things PEE...

Jan 2022 · Played

PEEP titration: a practical guide Ewan Goligher ISICEM 2023

978 views • 11 months ago

nsicu ru

PEEP TITRATION: A PRACTICAL GUIDE [Tutorial] PEEP titration: a practical guide...

12 chapters Intro | Mechanisms of Injury Modulated by...

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QUESTIONS?