Prone Position & Esophageal Balloon

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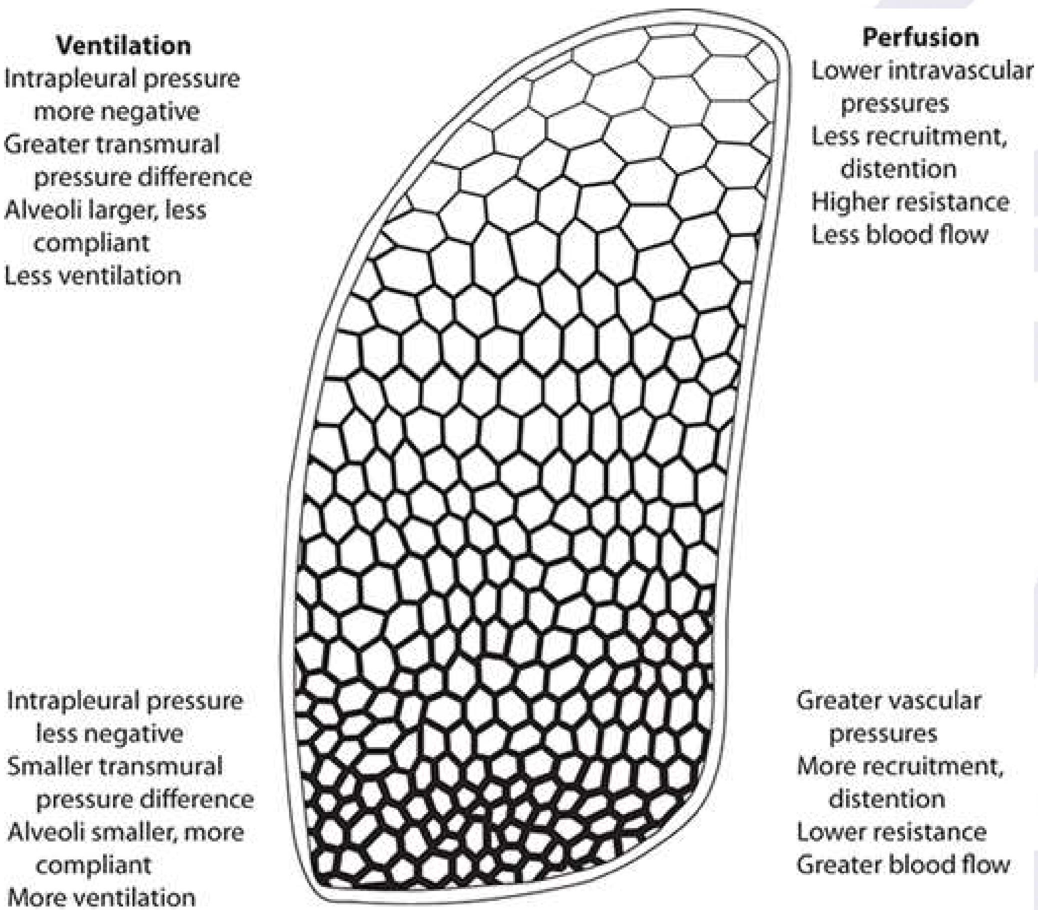
HSRC 2019

Objectives

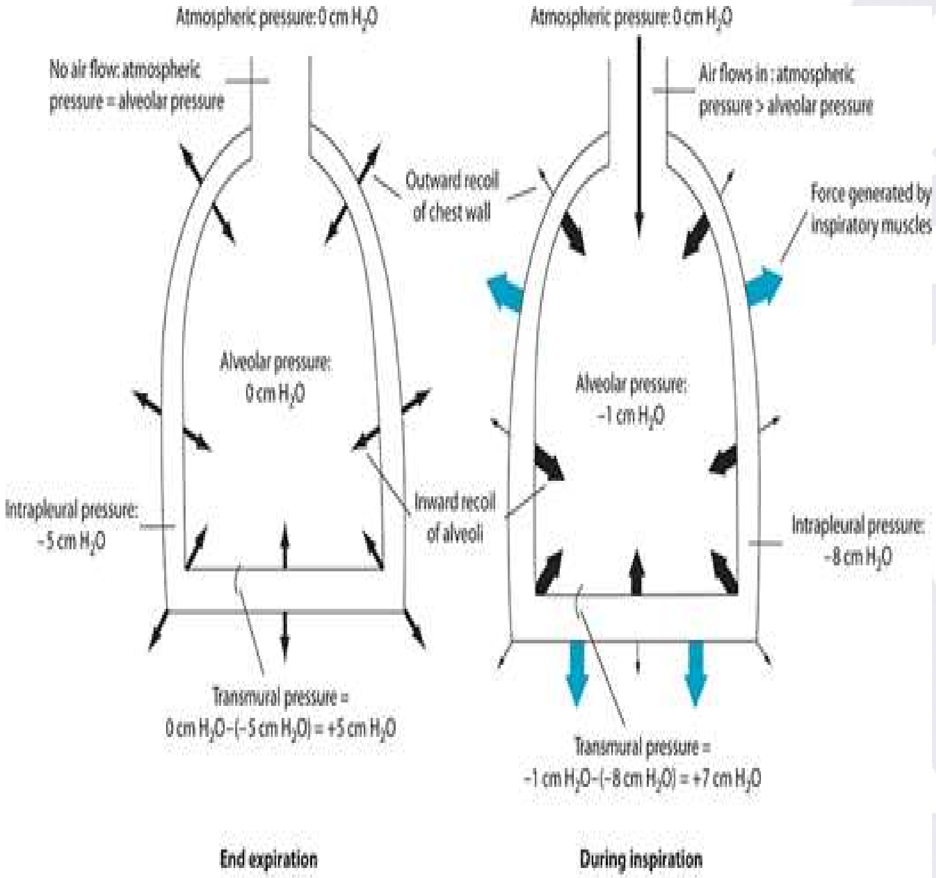
- **Prone Position**
  - Why/Benefits
  - Why not/Contraindications
  - How/Logistics
- **Esophageal Balloon Manometry**
  - Why/Benefits
  - Why not/Contraindications
  - How/Logistics

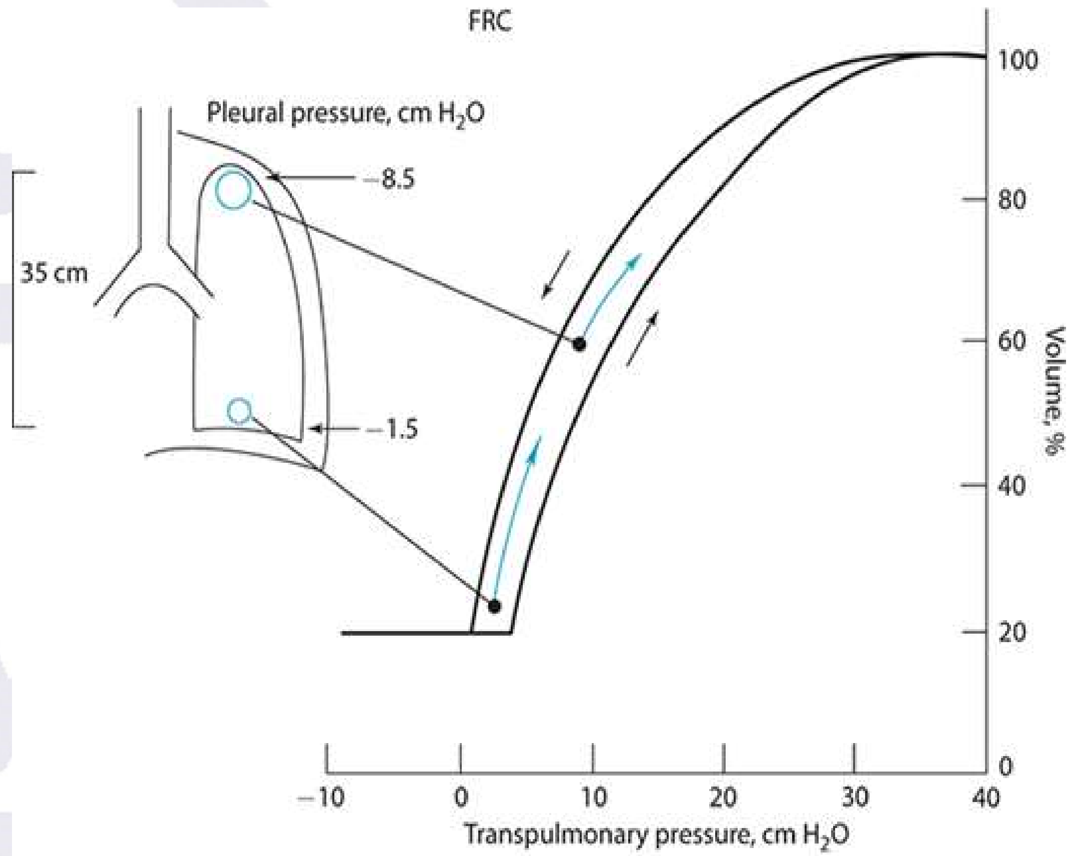
Our Lungs



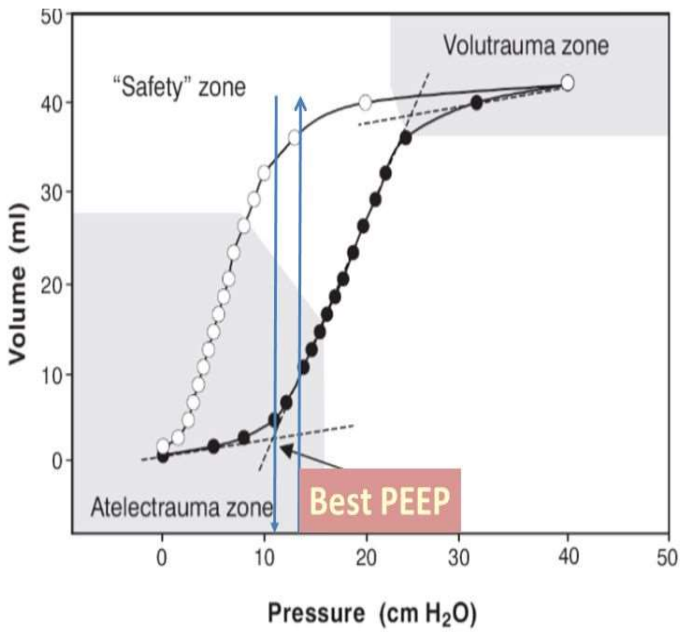
Source: Michael G. Levitzky: *Pulmonary Physiology*, 9e

How do we Breath

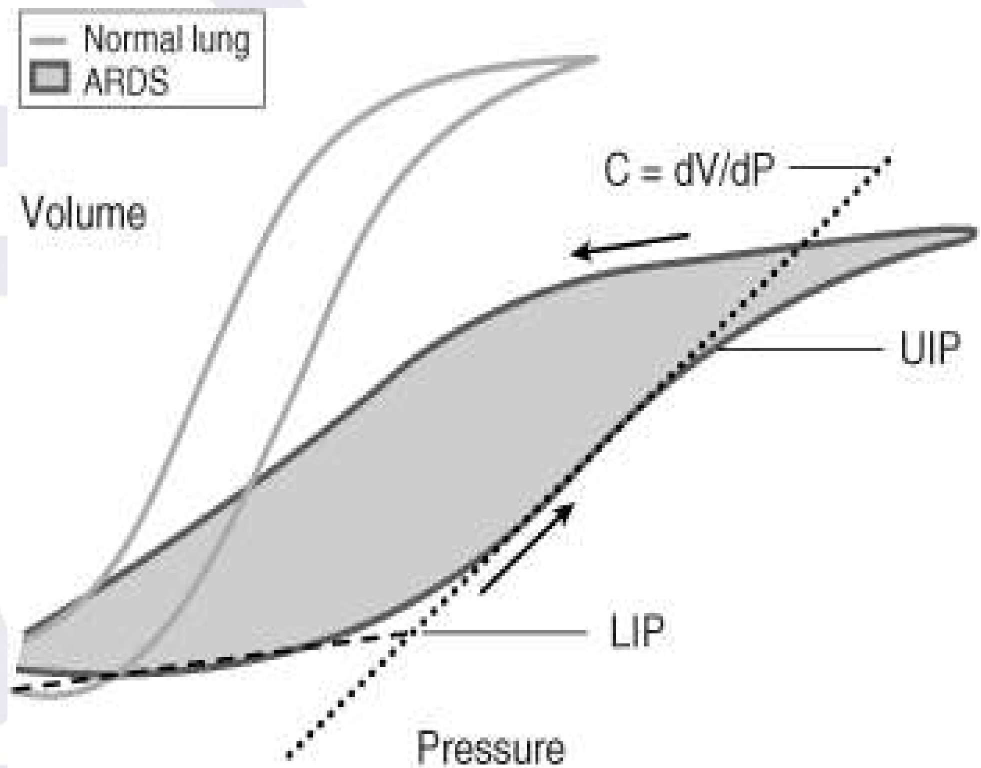




PV Curve



Rotta, J Pediatr (Rio J0 2003:79(Suppl 2):S149



Prone position

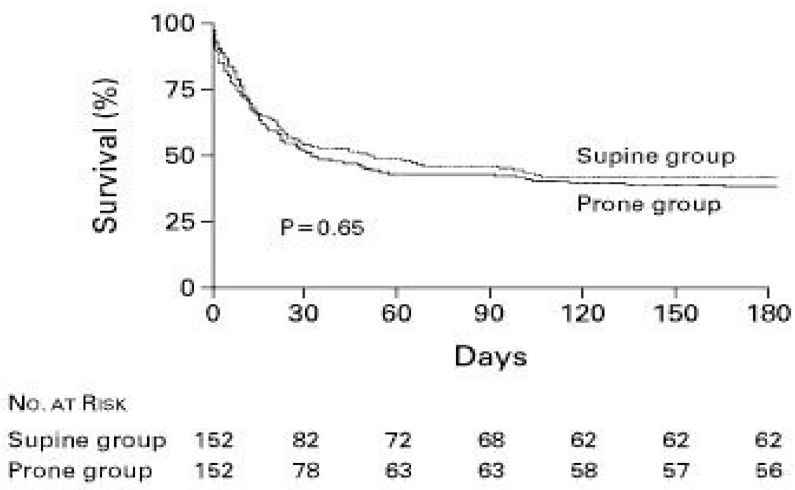
History

- 1974 Bryan et al suggested that anaesthetized and paralyzed patients in the prone position exhibit a better expansion of the dependent (dorsal) lung regions with consistent improvement in oxygenation, indicating prone's potential beneficial impact on lung mechanics.

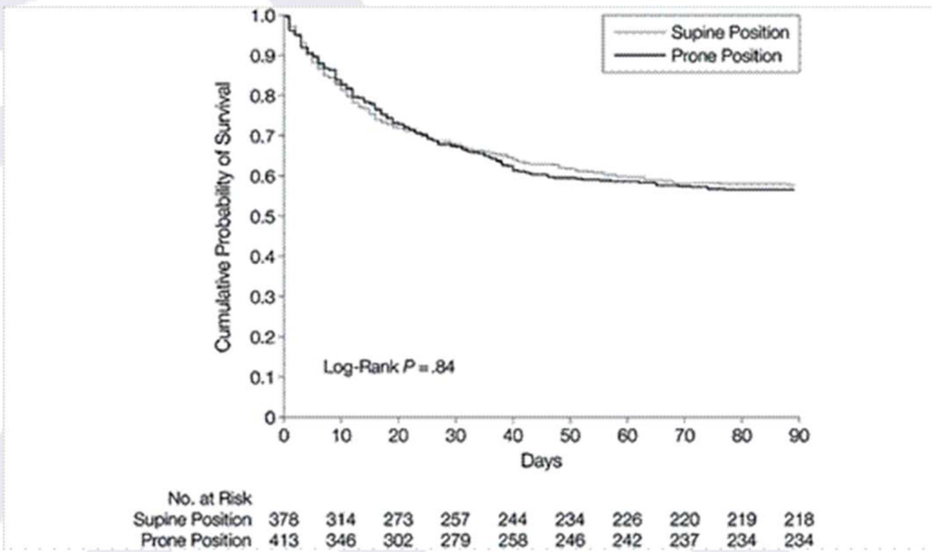
- 1976 Piehl et al reported dramatic effects on oxygenation improvement by prone position in five patients with ARDS

- 1977 Douglas et al. reported similar findings in six ARDS patients, confirming that prone positioning could effectively improve oxygenation in this patient group.

Early Prone studies
Short time 7-8 hrs/day

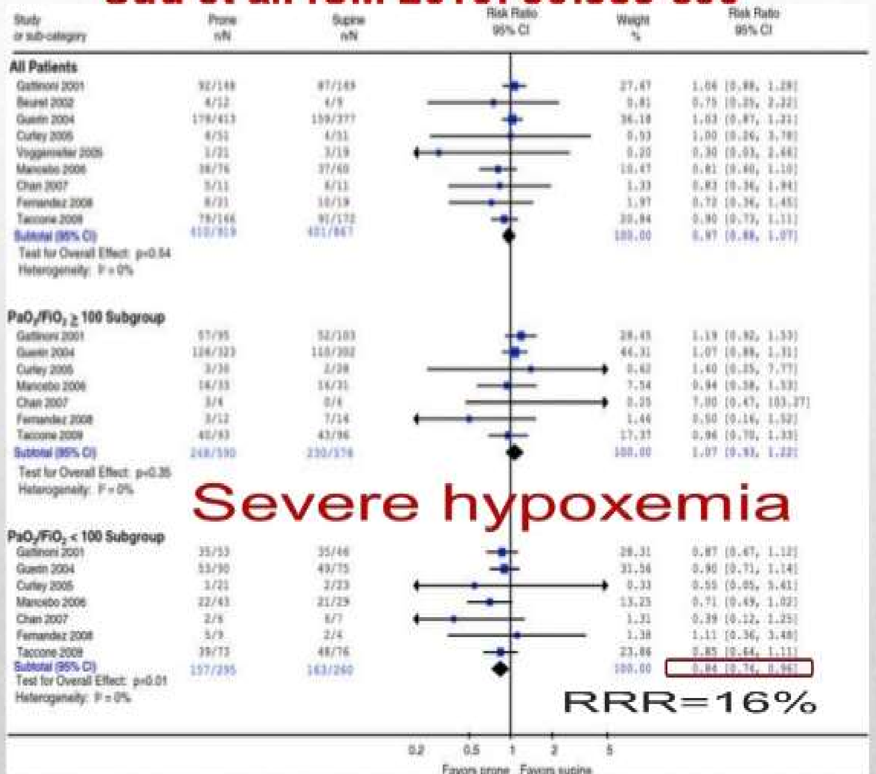


Gatinoni et al. N Engl J Med 2001; 345:568-573



Guerin et al. JAMA. 2004;292(19):2379-2387

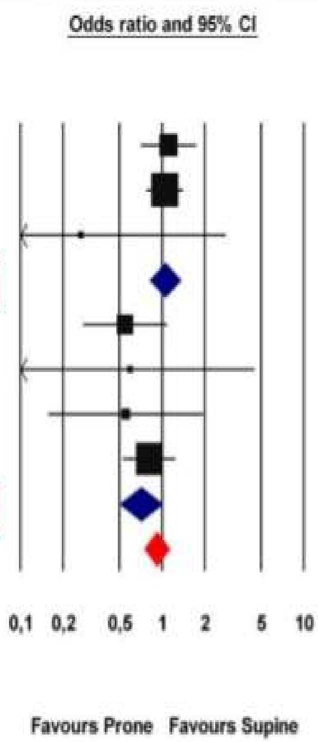
Sud et al. ICM 2010: 36:585-599



RR = 0.84 (95% CI, 0.74 - 0.96) P = 0.01

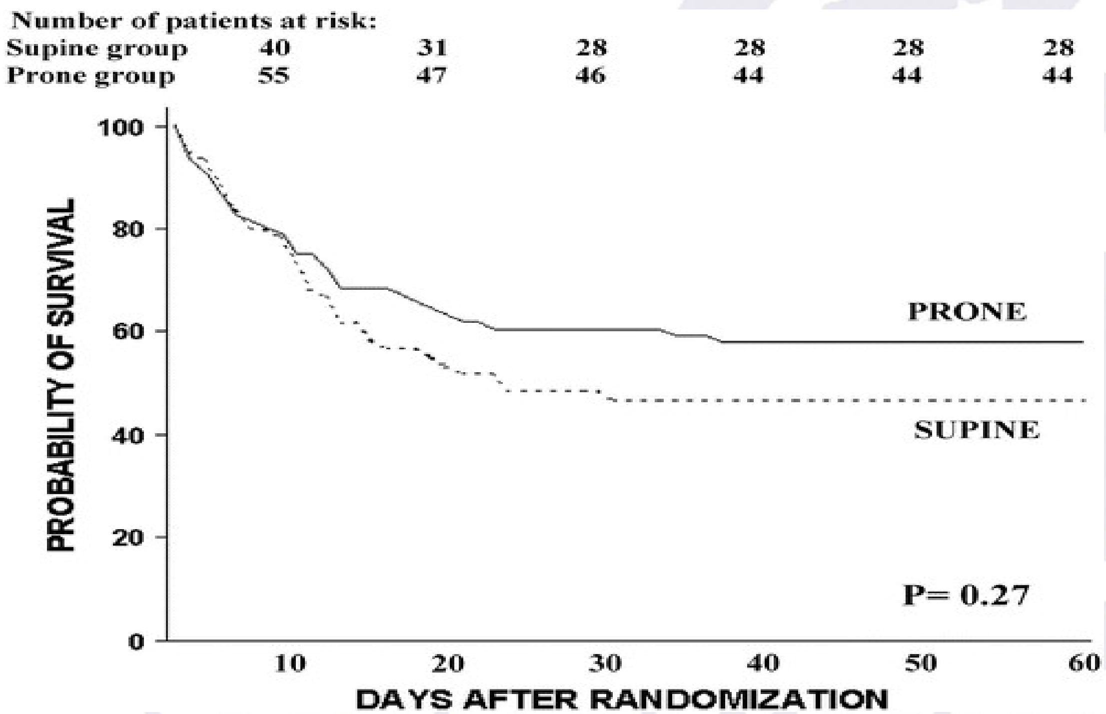
Abroug et al. Critical care 2011, 15:R6

Group by Patient Type	Study name	Odds ratio	Lower limit	Upper limit	p-Value
ALI/ARDS	Gattinoni_2001	1,111	0,709	1,742	0,646
ALI/ARDS	Guerin_2004	1,045	0,775	1,410	0,772
ALI/ARDS	Voggenreiter_2005	0,267	0,025	2,815	0,272
All studies with ALI/ARDS		1,049	0,819	1,344	0,706
ARDS	Mancebo_2006	0,548	0,276	1,087	0,085
ARDS	Chan_2007	0,593	0,078	4,498	0,613
ARDS	Fernandez_2008	0,554	0,157	1,952	0,358
ARDS	Taccone_2009	0,810	0,530	1,238	0,330
All studies with ARDS		0,708	0,503	0,997	0,048
Overall		0,916	0,750	1,120	0,392



Newer Studies
Early initiation, 20 hrs/day

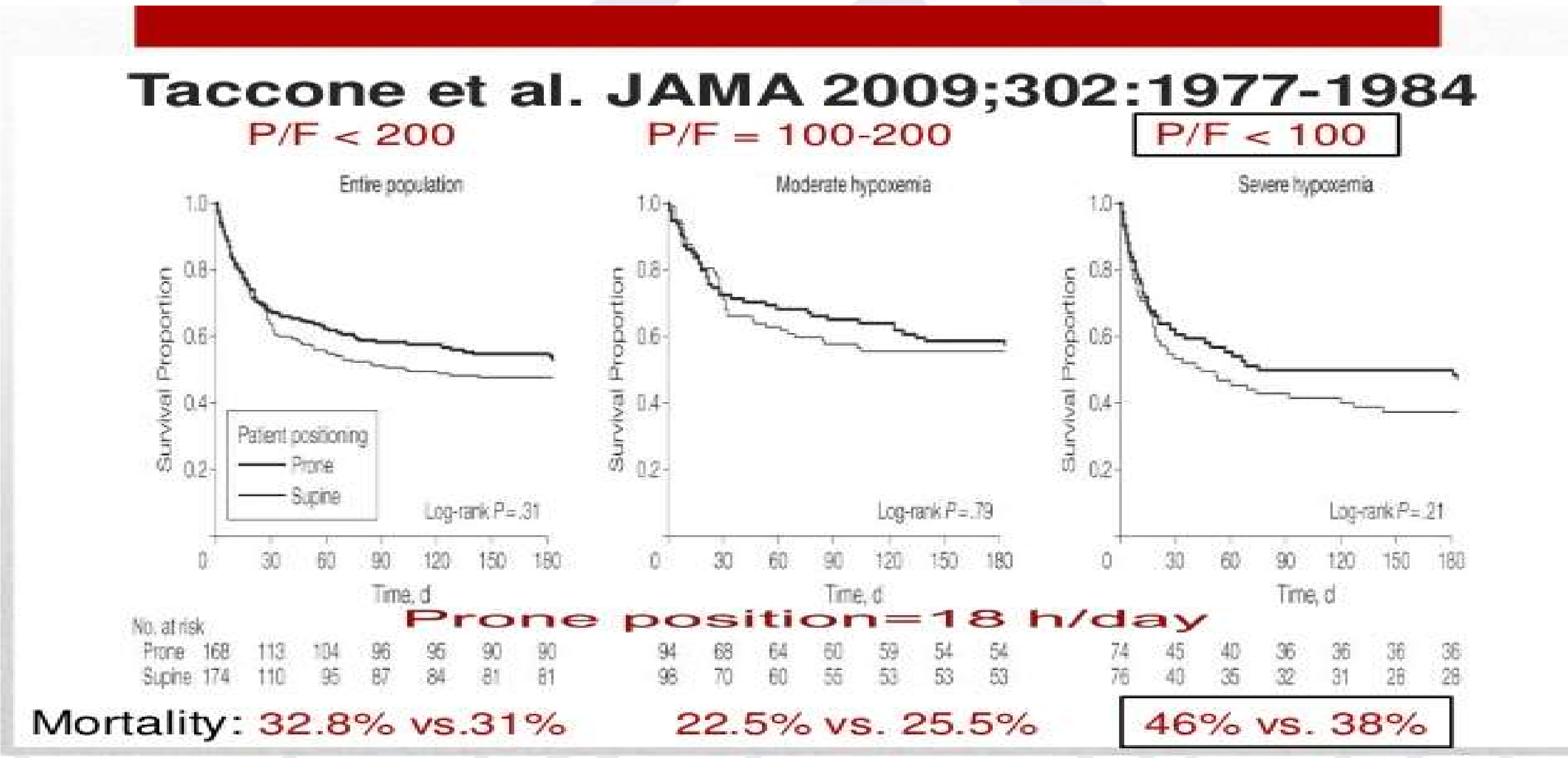
A Multicenter Trial of Prolonged Prone Ventilation in Severe Acute Respiratory Distress Syndrome



Conclusion: Prone ventilation is feasible and safe, and may reduce mortality in patients with severe ARDS when it is initiated early and applied for most of the day.

Mancebo et al. Am J Respir Crit Care Med Vol 173. pp 1233–1239, 2006

Newer Studies

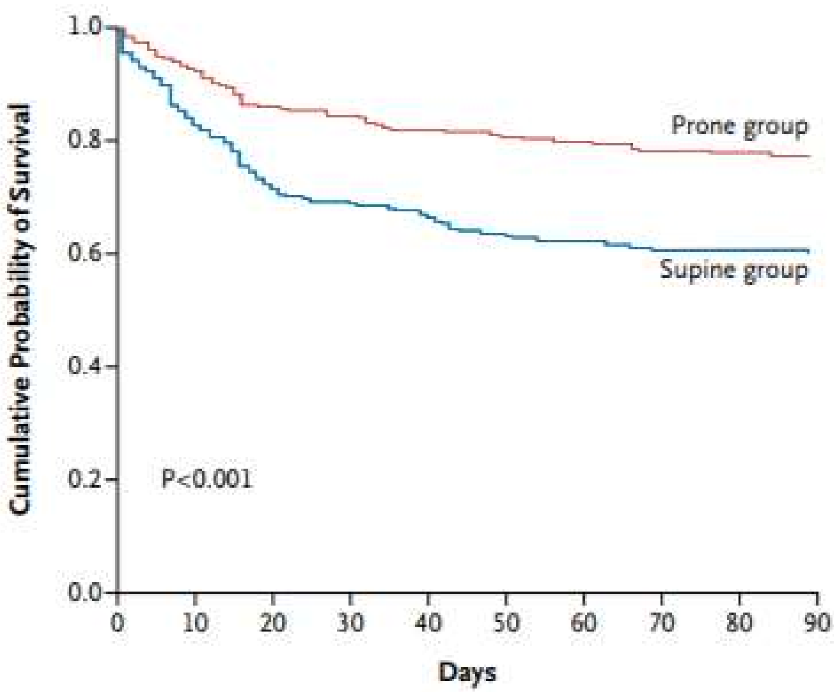


Newer Studies
PROSEVA

The NEW ENGLAND JOURNAL of MEDICINE

ESTABLISHED IN 1812 JUNE 6, 2013 VOL. 368 NO. 23

Prone Positioning in Severe Acute Respiratory Distress Syndrome



CONCLUSIONS

In patients with severe ARDS, early application of prolonged prone-positioning sessions significantly decreased 28-day and 90-day mortality. (Funded by the Programme Hospitalier de Recherche Clinique National 2006 and 2010 of the French Ministry of Health; PROSEVA ClinicalTrials.gov number, NCT00527813.)

Guerin et al. NEJM 368;23, 2159-2168

EDITORIAL

Prone position in ARDS: a simple maneuver still underused

Intensive Care Med (2018) 44:241–243

ORIGINAL

A prospective international observational prevalence study on prone positioning of ARDS patients: the APRONET (ARDS Prone Position Network) study

Intensive Care Med (2018) 44:22–37

Prone position underutilized ≈ 13%
More use in Europe compared to North America
Main reason for not using PP: Hypoxemia not considered severe
Complications rare and similar to supine position

JAMA | Original Investigation | CARING FOR THE CRITICALLY ILL PATIENT

Epidemiology, Patterns of Care, and Mortality for Patients With Acute Respiratory Distress Syndrome in Intensive Care Units in 50 Countries

JAMA. 2016;315(8):788-800.

Table 4. Use of Adjunctive and Other Optimization Measures in Invasively Ventilated Patients With Acute Respiratory Distress Syndrome[a]

	Patients of No. (%) [95% CI]				
	All (n = 2377)	Mild[a] (n = 498)	Moderate[a] (n = 1150)	Severe[a] (n = 729)	P Value[b]
Neuromuscular blockade	516 (21.7) [20.1-23.4]	34 (6.8) [4.8-9.4]	208 (18.1) [15.9-20.4]	274 (37.8) [34.1-41.2]	<.001
Recruitment maneuvers	496 (20.9) [19.2-22.6]	58 (11.7) [9.0-14.8]	200 (17.4) [15.2-19.7]	238 (32.7) [29.3-36.2]	<.001
Prone positioning	187 (7.9) [6.8-9.0]	5 (1.0) [0.3-2.3]	63 (5.5) [4.2-7.0]	119 (16.3) [13.7-19.2]	<.001
ECMO	76 (3.2) [2.5-4.0]	1 (0.2) [0.05-1.2]	27 (2.4) [1.6-3.4]	48 (6.6) [4.9-8.6]	<.001
Inhaled vasodilators	182 (7.7) [6.6-8.8]	17 (3.4) [02.0-5.4]	70 (6.1) [4.8-7.6]	95 (13.0) [10.7-15.7]	<.001
HFOV	28 (1.2) [0.8-1.7]	3 (0.6) [0.1-1.7]	14 (1.2) [0.7-2.0]	11 (1.5) [0.8-2.7]	.347
None of the above	1431 (60.2) [58.2-62.2]	397 (79.7) [75.9-83.2]	750 (65.2) [62.4-68.0]	284 (39.0) [35.4-42.6]	<.001
Esophageal pressure catheter	19 (0.8) [0.04-1.4]	2 (0.4) [0.04-1.4]	8 (0.7) [0.3-1.3]	9 (1.2) [0.6-2.3]	.233
Tracheostomy	309 (13.0) [11.6-14.4]	48 (9.6) [7.1-12.6]	155 (13.5) [11.6-15.6]	106 (14.5) [12.1-17.3]	.034
High-dose corticosteroids[c]	425 (17.9) [16.4-19.5]	61 (12.3) [9.5-15.5]	194 (16.9) [14.7-19.2]	170 (23.3) [20.3-26.6]	<.001
Pulmonary artery catheter	107 (4.5) [3.7-5.4]	9 (1.8) [0.8-3.4]	53 (4.6) [3.4-6.0]	45 (6.2) [4.5-8.2]	.001

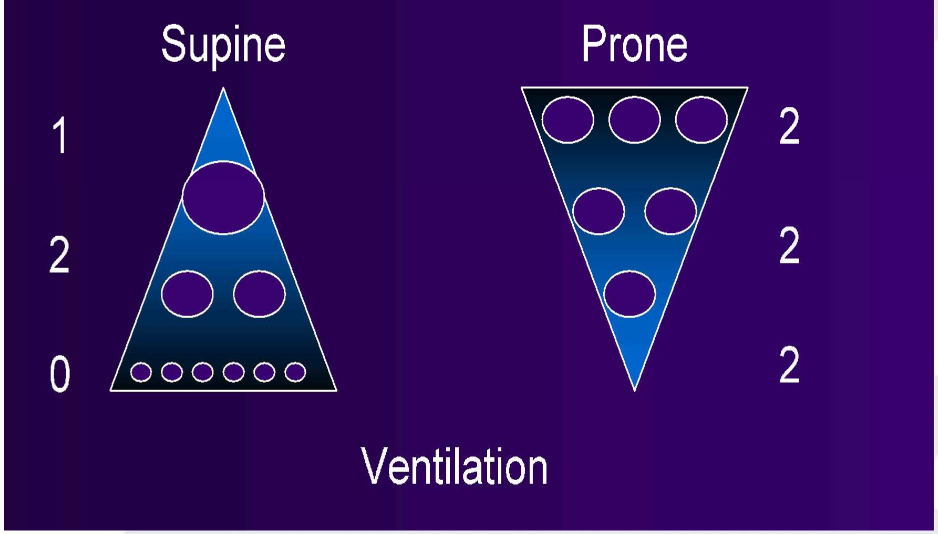
CONCLUSIONS AND RELEVANCE Among ICUs in 50 countries, the period prevalence of ARDS was 10.4% of ICU admissions. This syndrome appeared to be underrecognized and undertreated and associated with a high mortality rate. These findings indicate the potential for improvement in the management of patients with ARDS.

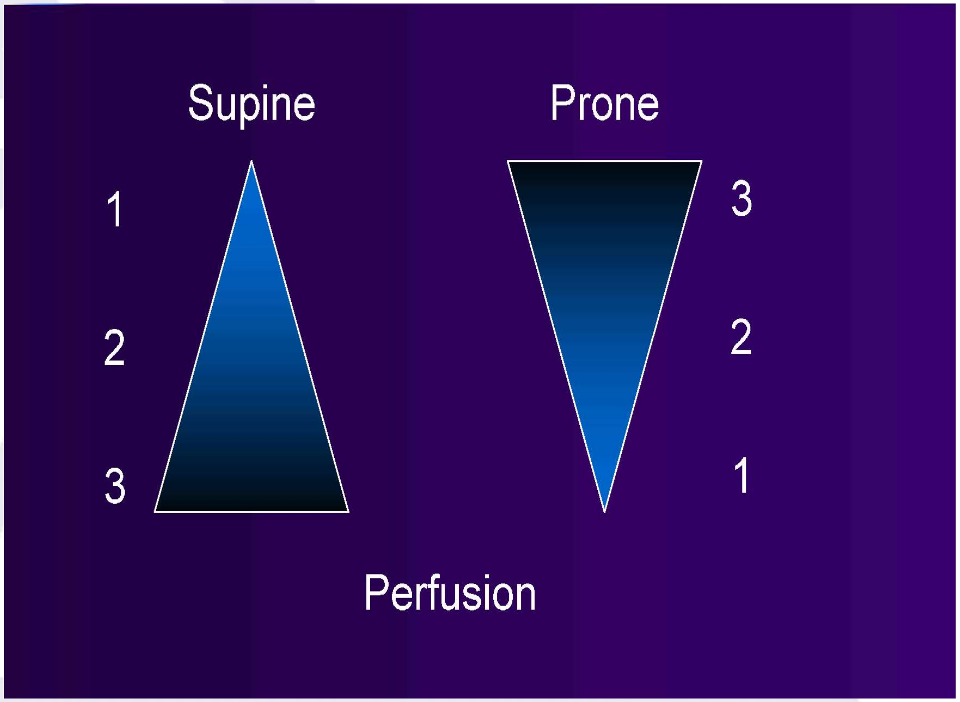
Prone Position Mechanisms

- Alteration of distribution of ventilation
- Redistribution of blood flow
- Improved matching of Ventilation & Perfusion (V/Q)
- Improved homogeneity of lung units
- Decreased alveolar Stress and Strain
- Recruitment maneuver
- Decrease VILI
- Relief of Left lower lung compression by the heart
- Relief dorsal lung compression by abdominal organs
- Enhanced secretion clearance
- Improved RV output and Pulmonary pressures

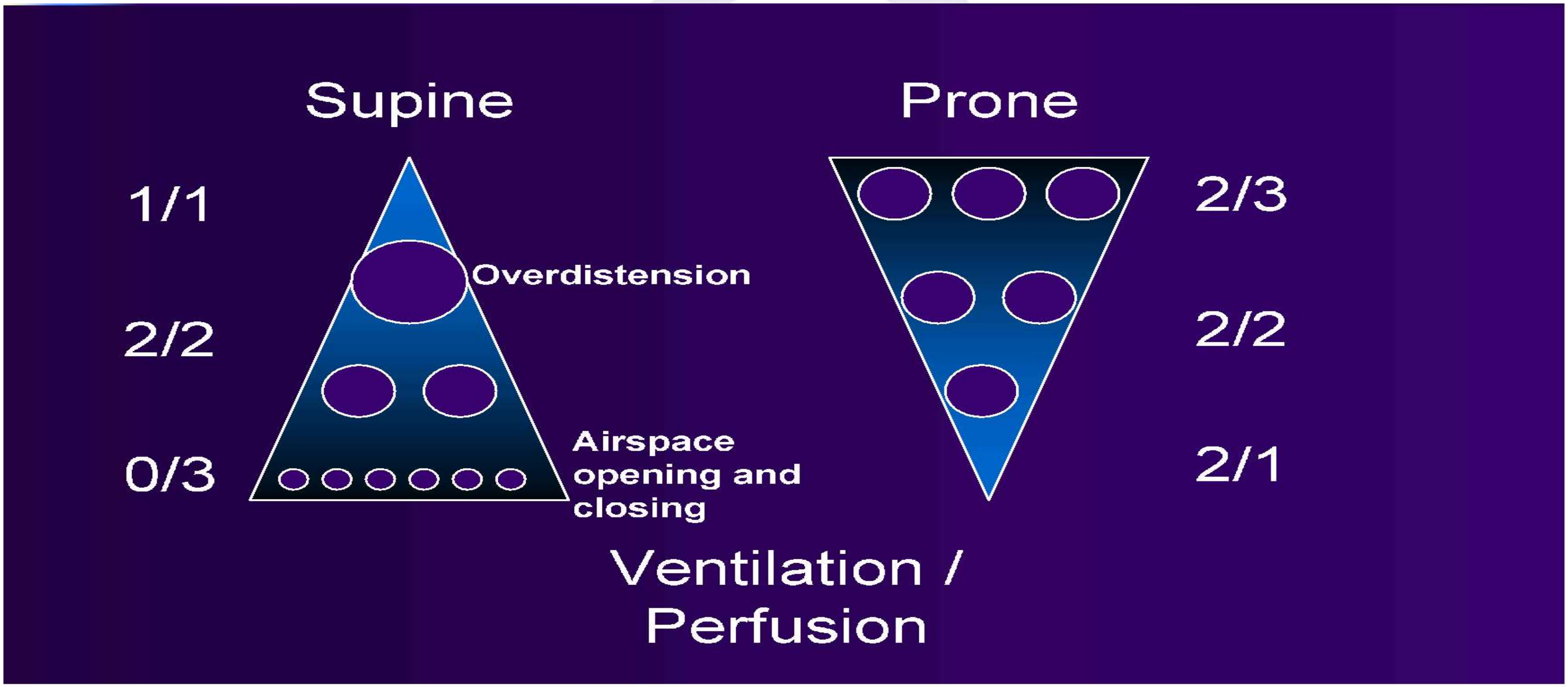
Ventilation and Perfusion

- In PP there is a more homogeneous distribution of Ptp and alveolar distension



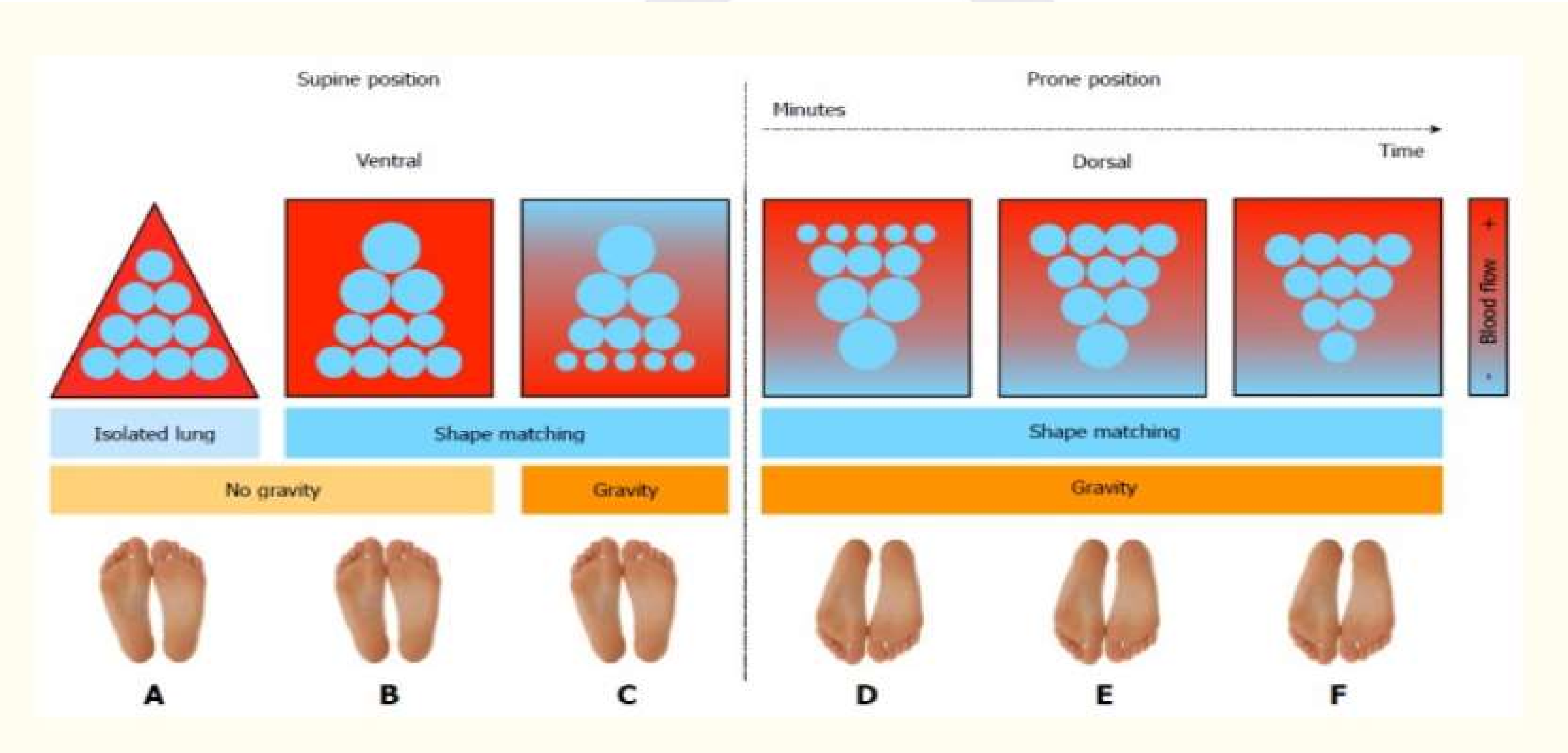


Ventilation/Perfusion (V/Q)



More homogeneous alveoli and more homogeneous Trans-Pulmonary pressures

Ventilation/Perfusion (V/Q)



Stress and Strain

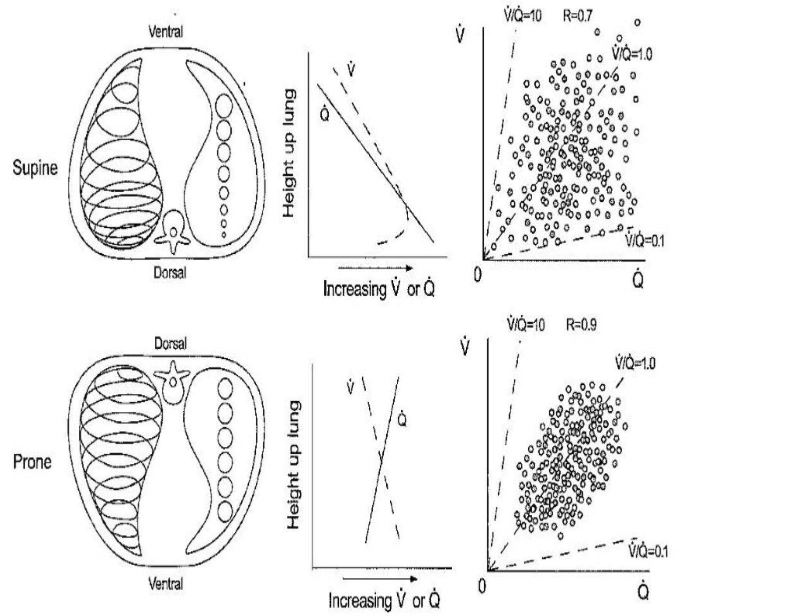
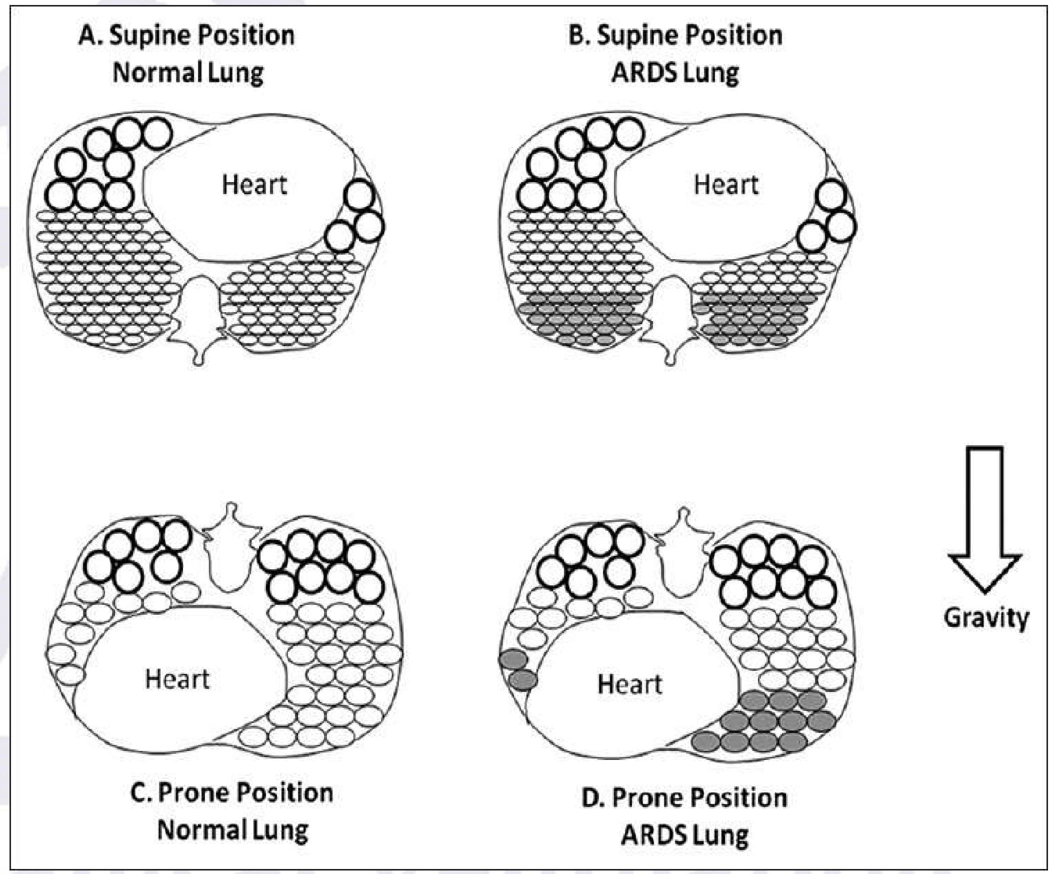
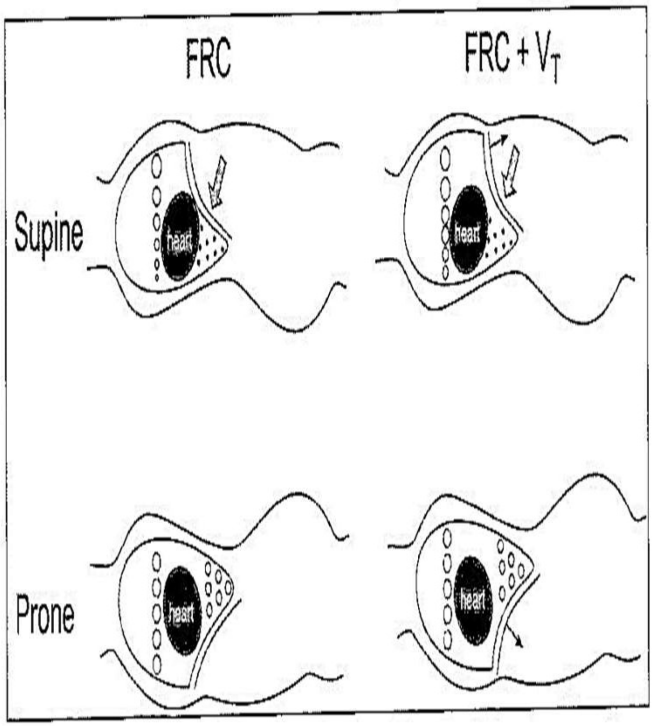
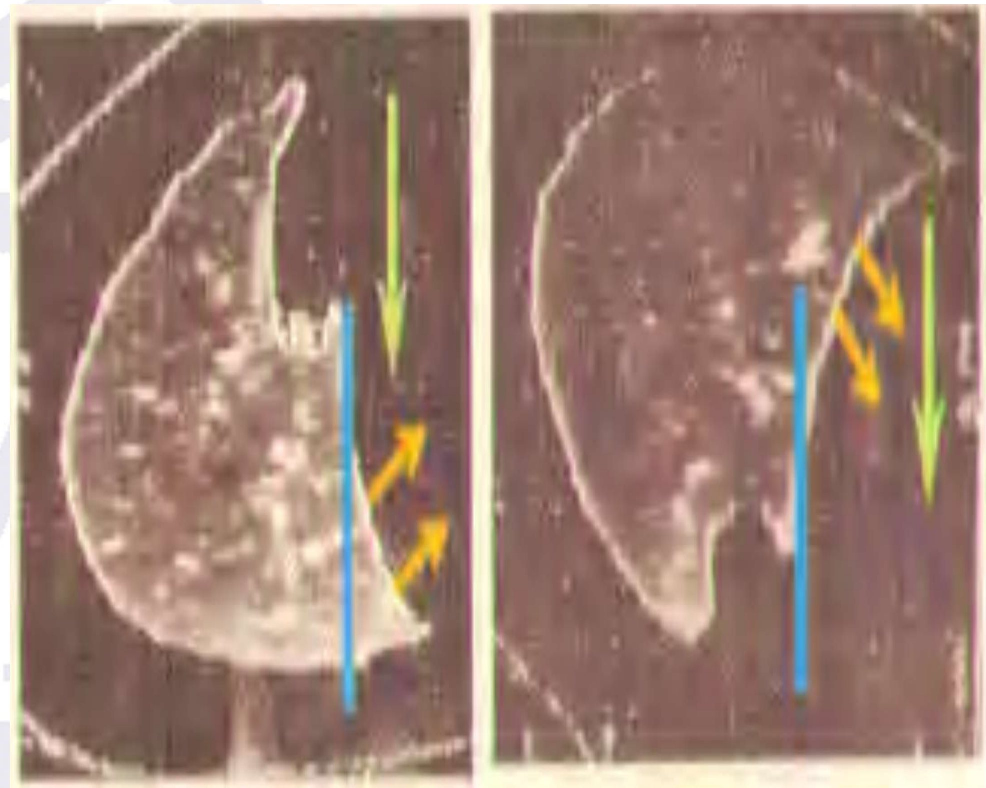


Fig. 4. Distribution of stress and strain and matching of ventilation and perfusion in the supine and prone postures. Considering the lung as a triangular-shaped spring (left), the combined effects of gravity and the greater tissue mass suspended from a larger dorsal chest wall produce more equal distribution of stress and strain in the lung, resulting in more uniform end-expiratory lung volume and alveolar size. On the right, each dot represents a single piece of lung. In the supine posture, there is close matching of ventilation and perfusion in the ventral lung but markedly poor matching in the dorsal lung, resulting a wide distribution of ventilation in perfusion (middle and right). In the supine posture, ventilation and perfusion are more closely matched throughout, resulting in a tighter distribution of ventilation/perfusion ratios.

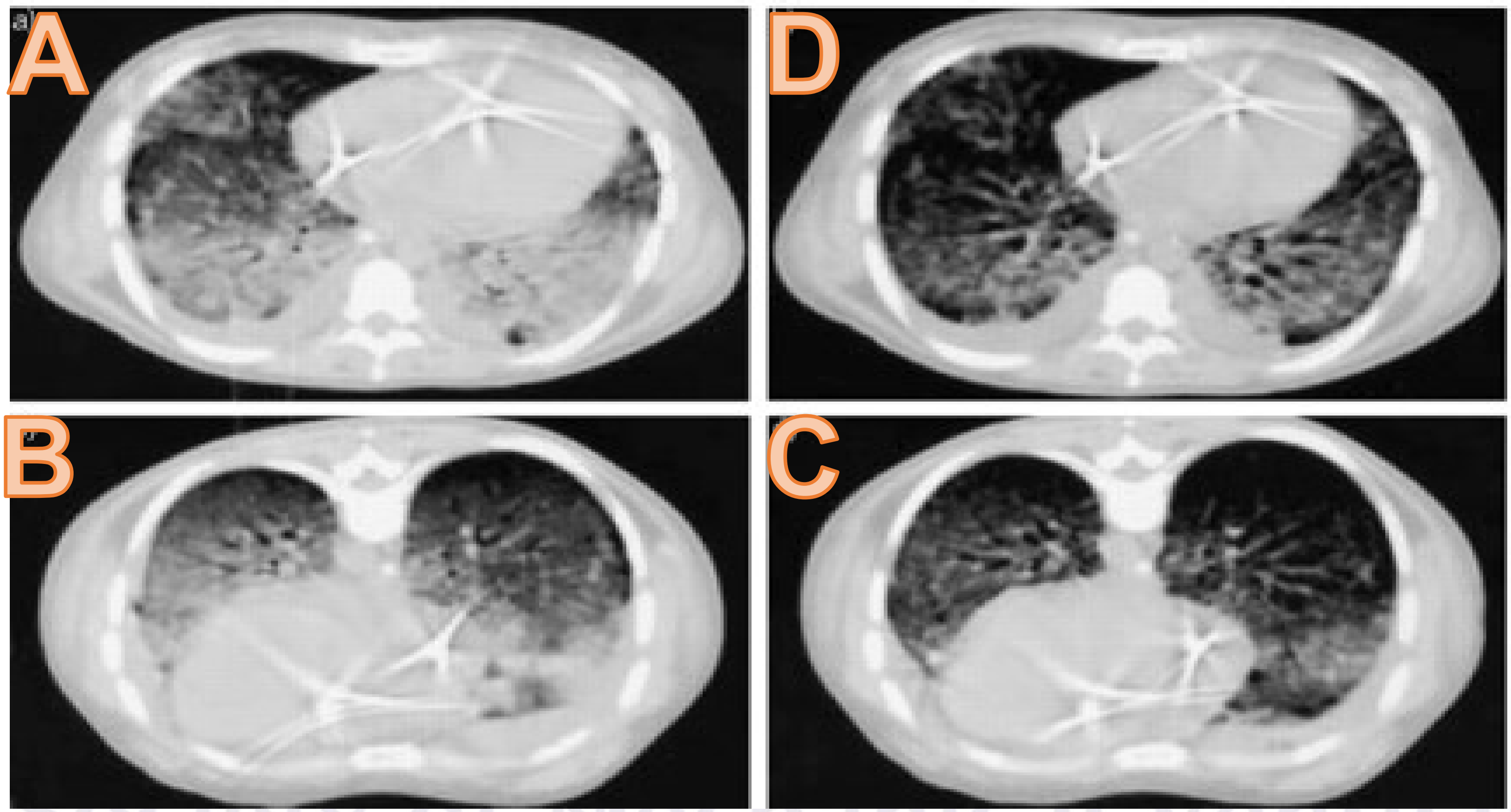


Effect of Abdominal pressure and abdominal contents on the lung





Heart weight and position



Complications

Table 5. Incidence of Complications During the 28 Days After Randomization

	Supine Position			Prone Position		
	Patient-Days	No. of Occurrences	Incidence per 100 Days (95% CI)	Patient-Days	No. of Occurrences	Incidence per 100 Days (95% CI)
Unplanned extubation	5188	47	0.91 (0.65-1.16)	5756	44	0.76 (0.54-0.99)
Selective intubation*	5188	0	0	5755	6	0.10 (0.02-0.19)
ETT obstruction†	5188	12	0.23 (0.10-0.36)	5755	34	0.59 (0.39-0.79)
Hemoptysis	5188	34	0.66 (0.44-0.88)	5755	45	0.78 (0.55-1.01)
Spo_2 <85%	5188	207	3.99 (3.45-4.53)	5755	236	4.10 (3.58-4.62)
Cardiac arrest	5188	88	1.70 (1.34-2.05)	5754	87	1.51 (1.19-1.83)
Heart rate <30/min	5188	72	1.39 (1.07-1.71)	5755	81	1.41 (1.10-1.71)
SAP <60 mm Hg	5188	148	2.85 (2.39-3.31)	5754	135	2.35 (1.95-2.74)
Pressure sores‡	5188	157	3.03 (2.55-3.50)	5756	208	3.61 (3.12-4.10)
Atelectasis	5188	28	0.54 (0.34-0.74)	5756	28	0.49 (0.31-0.67)
Intracranial hypertension	5188	3	0.06 (0.00-0.12)	5756	9	0.16 (0.05-0.26)
Pneumothorax	5188	28	0.54 (0.34-0.74)	5756	22	0.38 (0.22-0.54)

Abbreviations: CI, confidence interval; ETT, endotracheal tube; SAP, systolic arterial pressure; 95% Spo_2, transcutaneous oxygen saturation of arterial blood.
*P=.01.
†P=.002.
‡P=.005 between supine and prone position groups.

Contraindications

PRONE POSITION

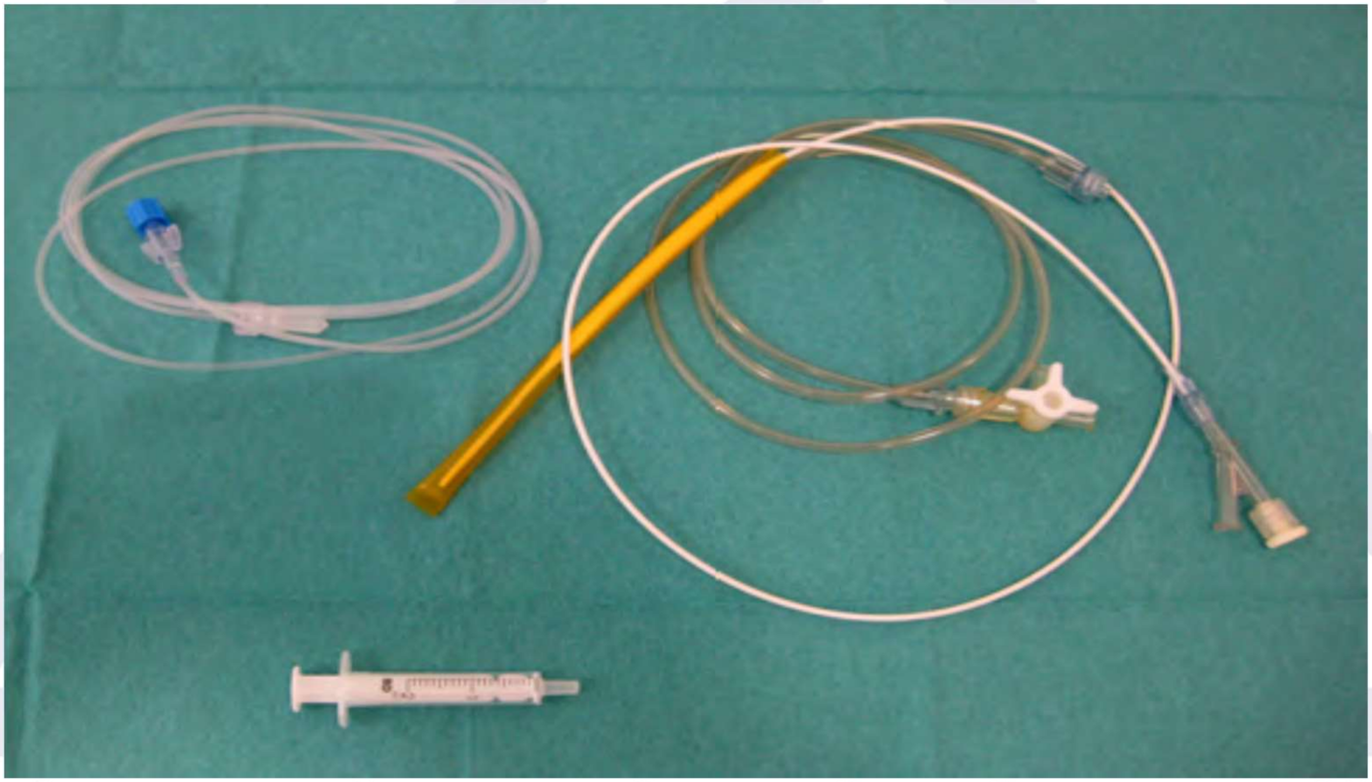
Relative contraindications for the prone position:

- Elevated ICP
- Intestinal ischemia
- Obesity
- Recent Abdominal Surgery

Absolute contraindications for the prone position:

- spinal cord instability,
- unstable facial fractures
- anterior burns, open abdomen
- increased abdominal pressures
- unstable pelvic fractures.

Esophageal Balloon Manometry



History

- 1949, Buytendijk first showed that it was possible to use esophageal pressure as a surrogate for pleural pressure.
- In 1952, Dornhorst and Leathart showed that changes in pleural and esophageal pressures were similar and useful to understand respiratory mechanics.
- In 1955, Cherniack and colleagues confirmed that changes in pleural pressure were similar to changes in esophageal pressure, although the absolute values of pressures in the pleural space were often more negative than in the esophagus

Esophageal Balloon Benefits

- Measuring Trans-Pulmonary pressure to set Inspiratory pressure and PEEP
- Assess WOB during spontaneous breathing
- Aid in diagnosing Patient-Ventilator dys-synchrony
- Aid in assessing recruitability during recruitment maneuver
- Measuring Chest wall and lung elastance separately
- Aid in weaning off mechanical ventilation
- Transmural vascular pressure (i.e. the difference between intravascular and extramural pressure reflected by *P*es)

Despite all those benefits, this tool remains confined to research
Used in less than 1% of ARDS patients

CONCISE CLINICAL REVIEW

The Application of Esophageal Pressure Measurement in Patients with Respiratory Failure

Am J Respir Crit Care Med Vol 189, Iss 5, pp 520–531, Mar 1, 2014

- A physiologically based ventilator strategy should take the trans-pulmonary pressure into account
- Despite all those benefits, this tool remains confined to research
- Used in less than 1% of ARDS patients

The NEW ENGLAND JOURNAL of MEDICINE

ESTABLISHED IN 1812 NOVEMBER 13, 2008 VOL. 359 NO. 20

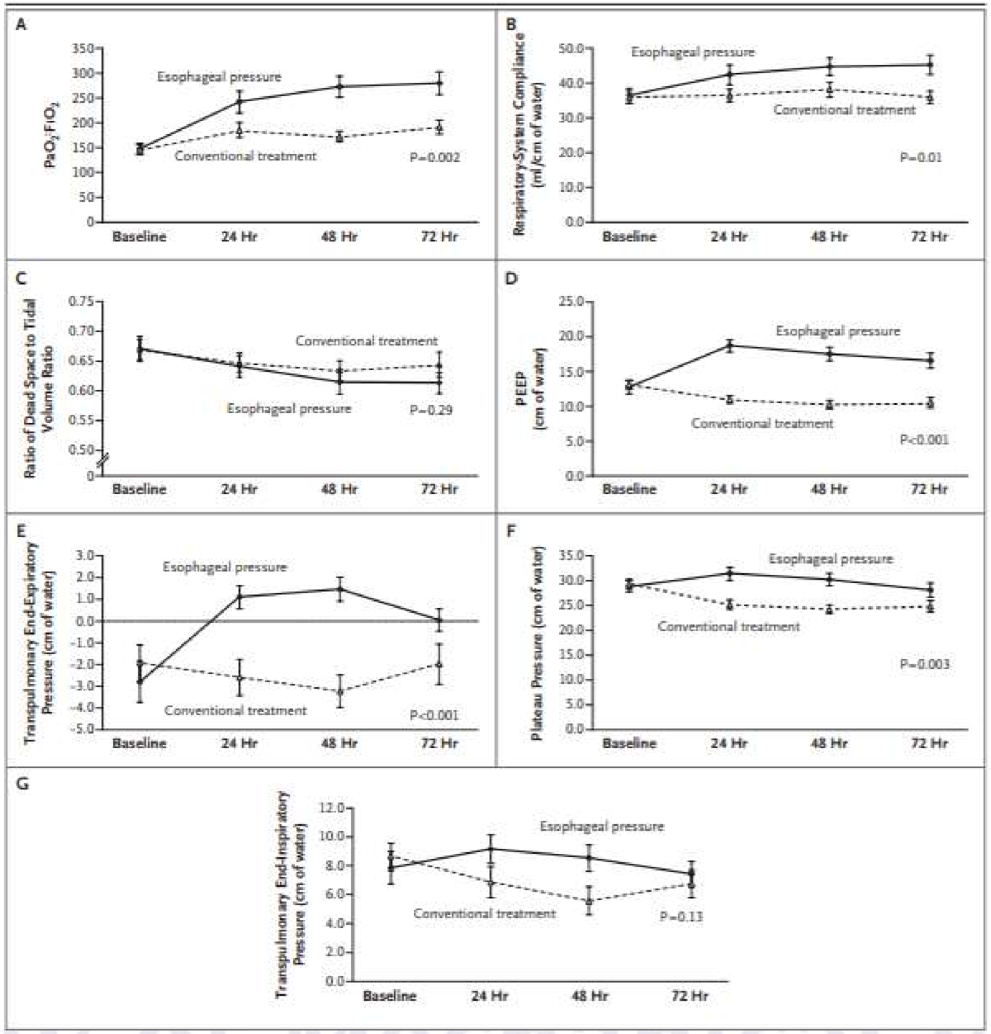
Mechanical Ventilation Guided by Esophageal Pressure in Acute Lung Injury

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	

CONCLUSIONS

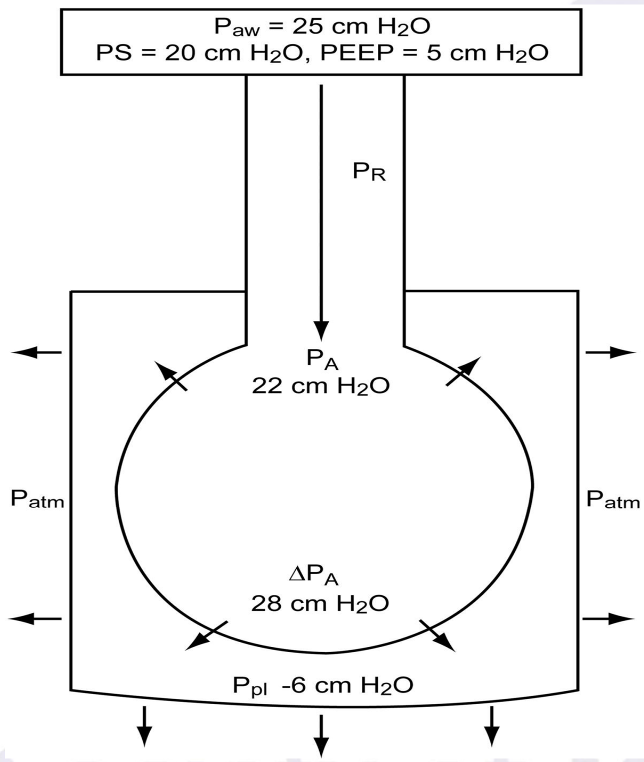
As compared with the current standard of care, a ventilator strategy using esophageal pressures to estimate the transpulmonary pressure significantly improves oxygenation and compliance. Multicenter clinical trials are needed to determine whether this approach should be widely adopted. (ClinicalTrials.gov number, NCT00127491.)



NEJM 2008;359:2095-104.

Trans-Pulmonary Pressure

$$P_{tp} = P_{alv} - P_{pl}.$$



Is the distending pressure of the alveoli

Too high during inhalation --→ boom rupture (stress)

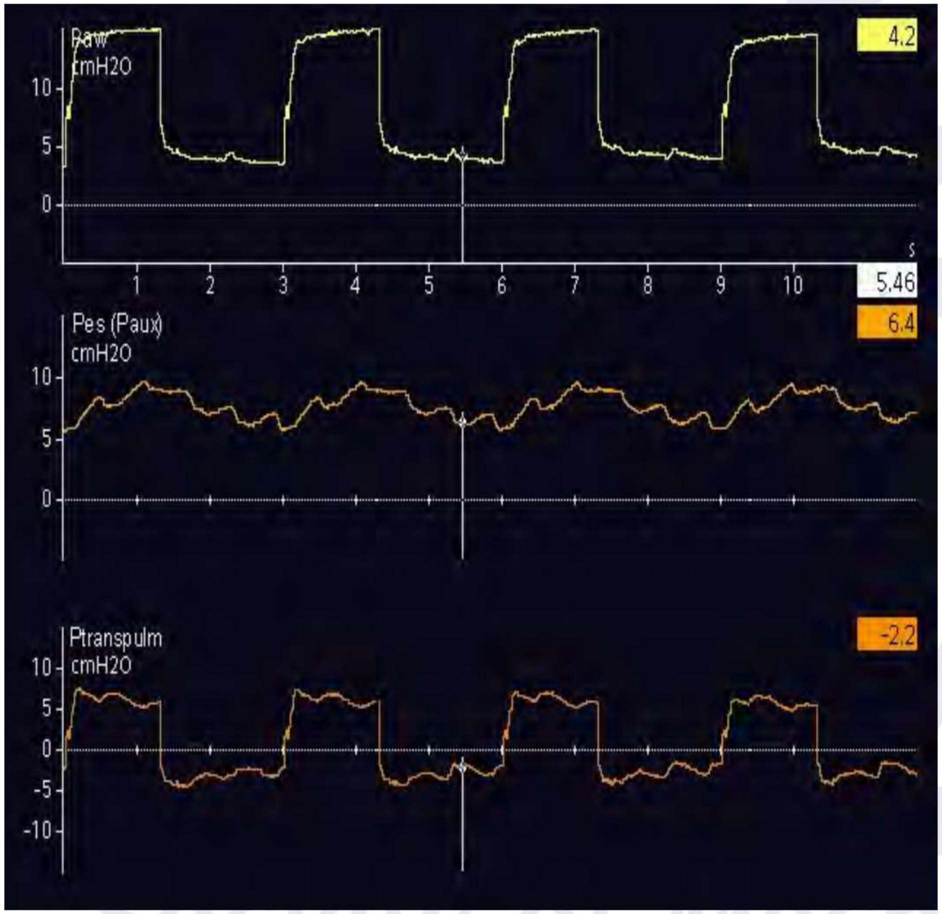
Too low during exhalation --→ fssss collapse (strain)

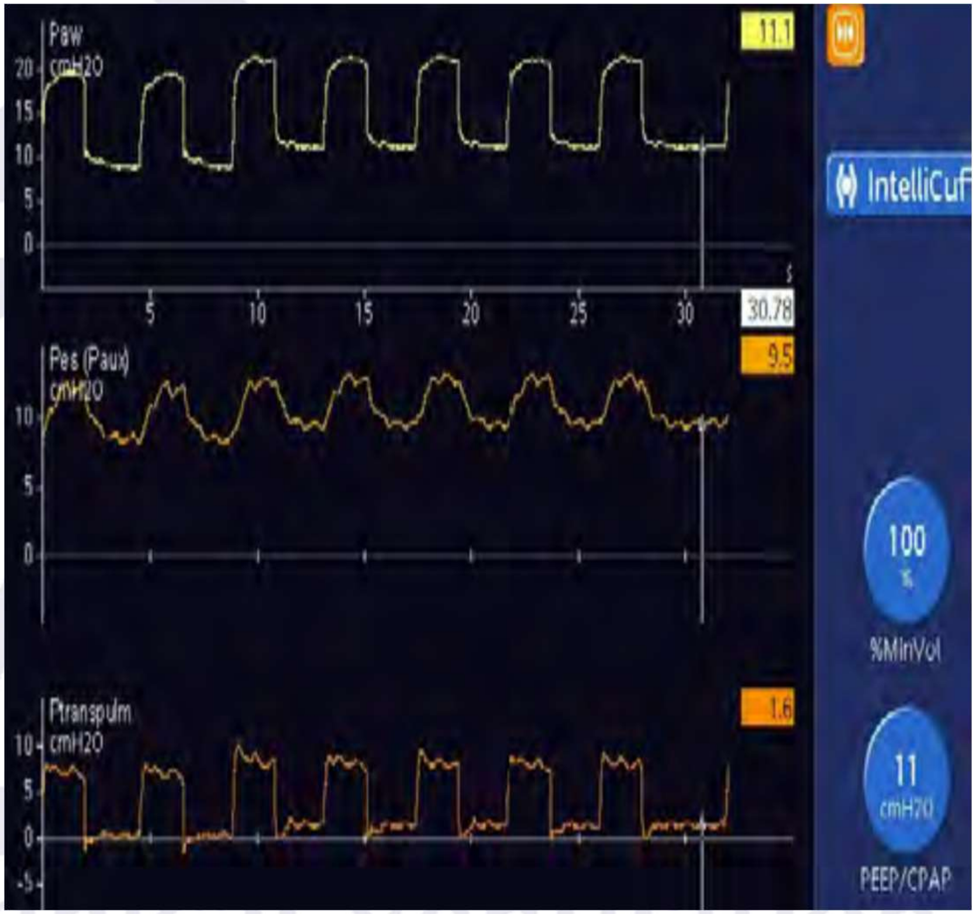
Trans-Pulmonary Measurement

- Goal is to keep Inspiratory PL < 15-20 cmH2O, to avoid lung stress (over distension, i.e. volutrauma and barotrauma) i.e. Stress
- Goal to keep Expiratory PL > 0 (0-5) cmH2O to avoid lung strain (repeated opening and closing of alveoli, i.e. atelectatotrauma) i.e. Strain

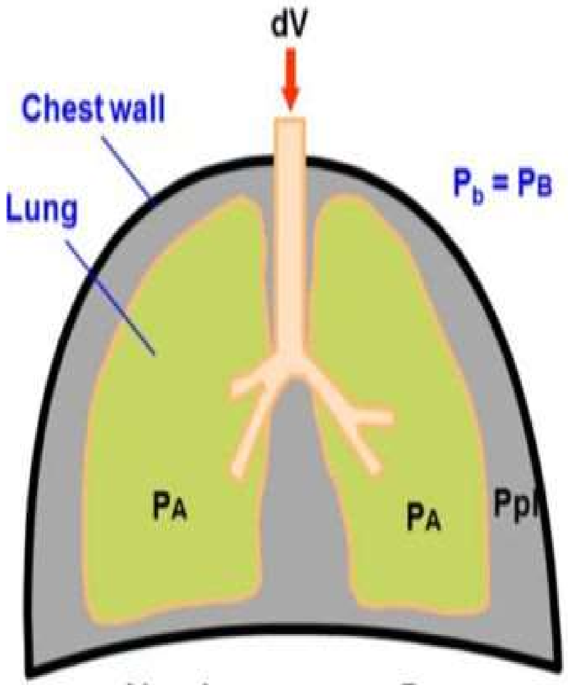
N Engl J Med 2008;359:2095-104

Transpulmonary Measurement





Compliance
Respiratory System, Chest Wall, Lung



$$C_L = \frac{dV}{d(P_A - P_{pl})}$$

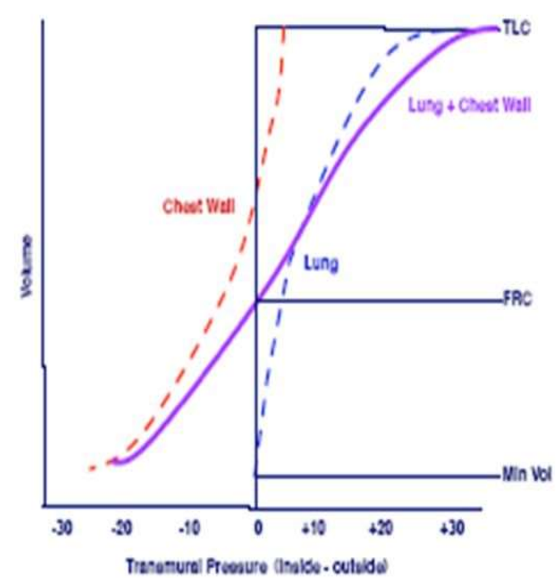
$$C_{CW} = \frac{dV}{d(P_{pl} - P_b)} = \frac{dV}{dP_{pl}}$$

$$C_{RS} = \frac{dV}{d(P_A - P_b)} = \frac{dV}{dP_A}$$

$$1/C_{RS} = 1/C_L + 1/C_{CW}$$

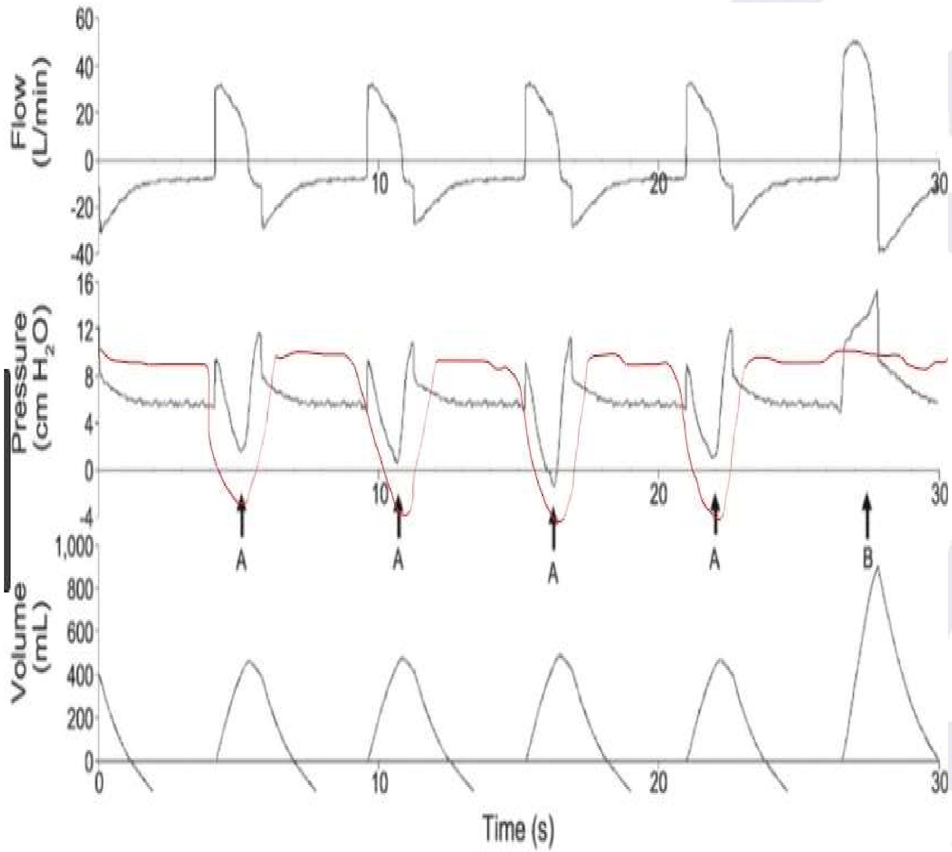
Alveolar pressure : P_A
Pleural pressure : Ppl
Body surface pressure : $P_b = P_B = 0$

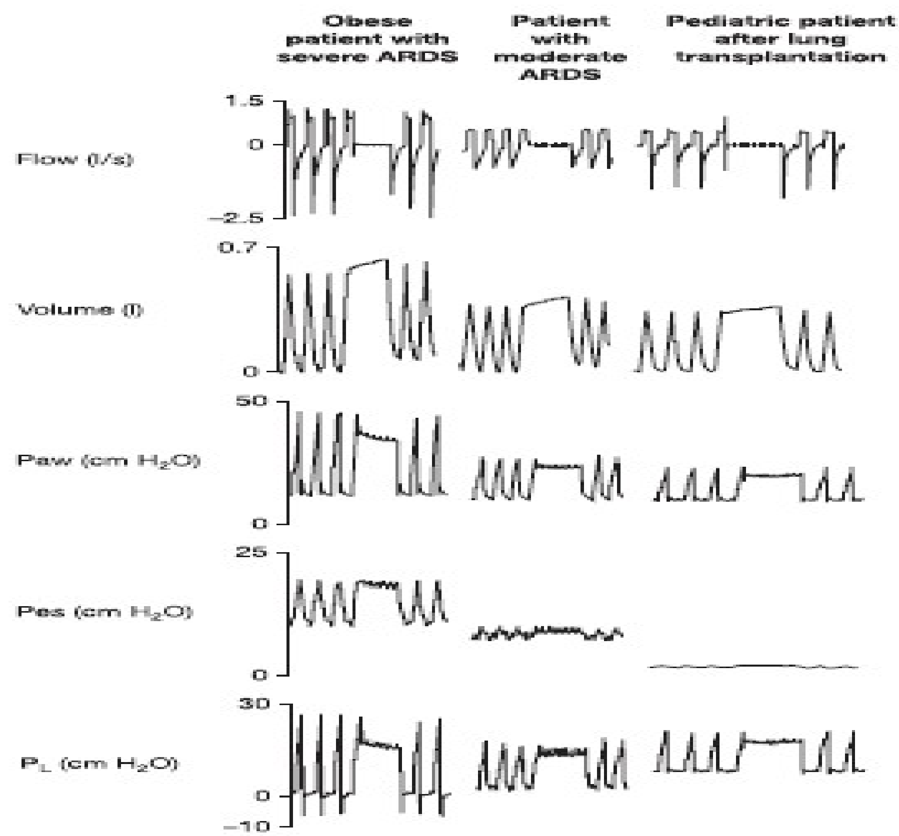
Pressure-Volume Curve for Lungs, Chest Wall, and Combined Lung/Chest Wall



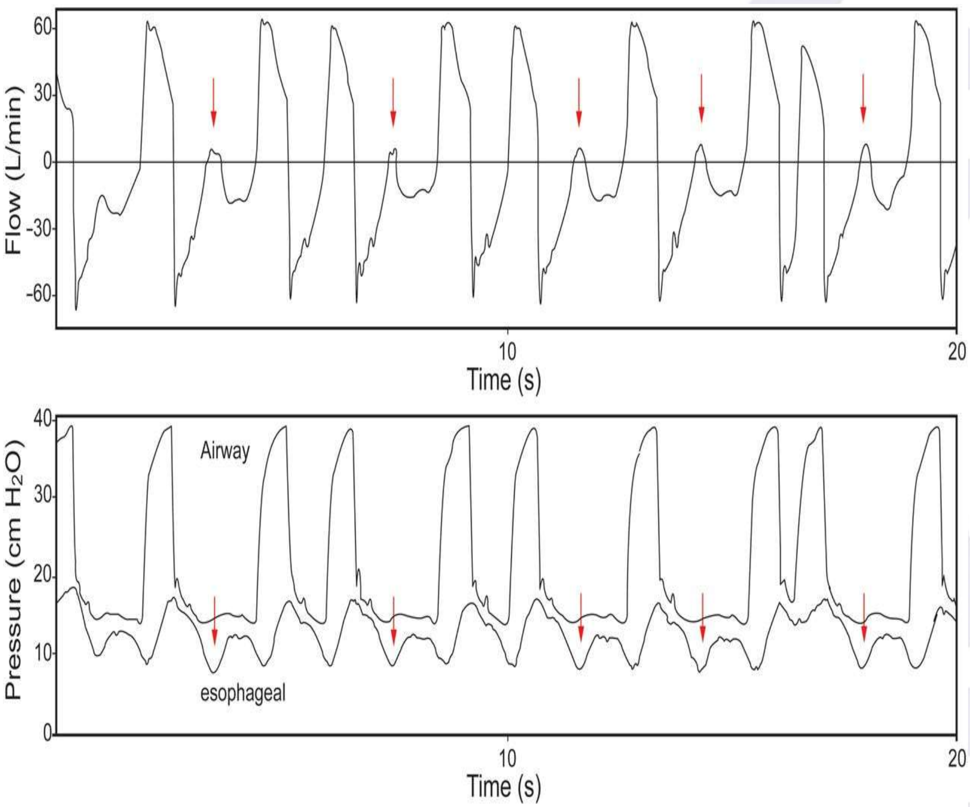
- Slope = compliance
- Transmural (in – out)
  - For lung
    - alveolar – pleural
  - For chest wall
    - pleural – atm
  - For unit
    - alveolar – atm
  - Lung pressures referred to atm press (zero)
- Chest wall likes to expand
- Lung likes to collapse

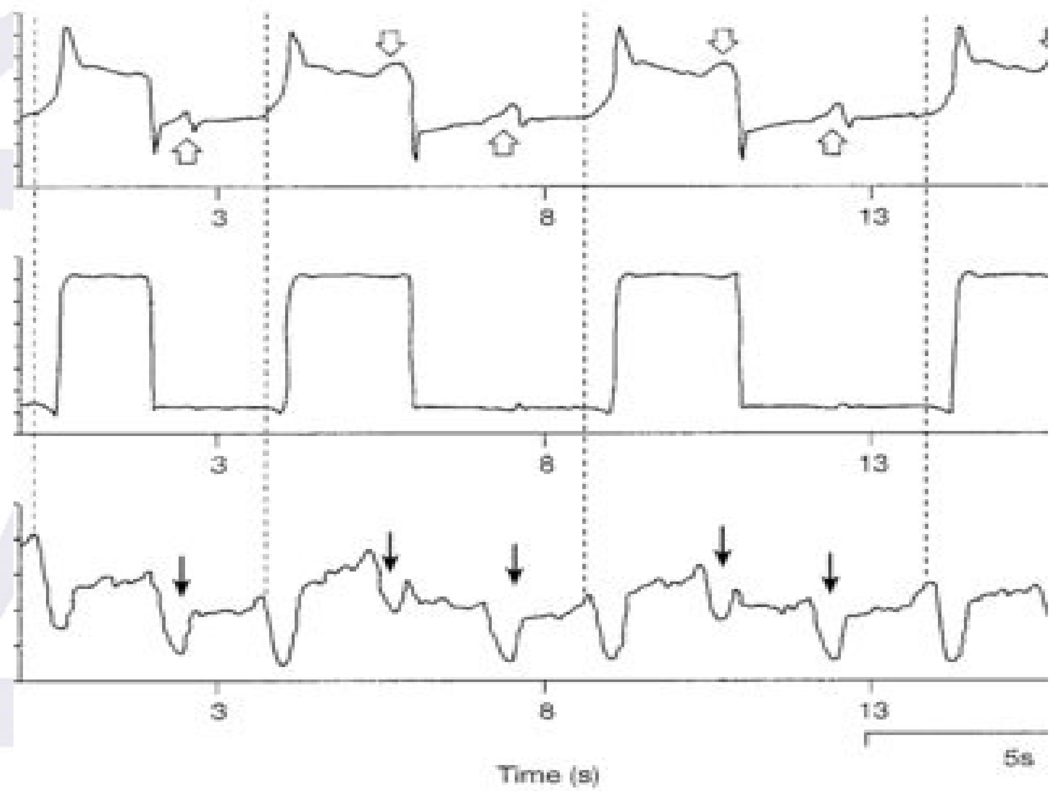
It is NOT enough to look for the Plateau pressure (1 side of the coin)





Patient – Ventilator Asynchrony





Weaning from mechanical ventilation

- Esophageal Balloon is needed to calculate both:

  Work Of Breathing (WOB)

  Pressure-Time Product (PTP)

- Multiple studies have shown the significance of monitoring the WOB & PTP during weaning trials. The higher the variables, the high likelihood of failing the trial

Am J Respir Crit Care Med 1997;155:906–915

Understanding the real Filling pressure of the Heart

Mean Pes is the more convenient technique to estimate extramural pressure and therefore the transmural filling pressures, that is, the intravascular minus the surrounding extravascular pressure

CVP-Pes

PAWP-Pes

LVEDP-Pes

New: Use in APRV

Can J Respir Ther Vol 54 No 3 Fall 2018

THANK
YOU

Be Happy, Be Thankful and Appreciate what you have

MAHALO