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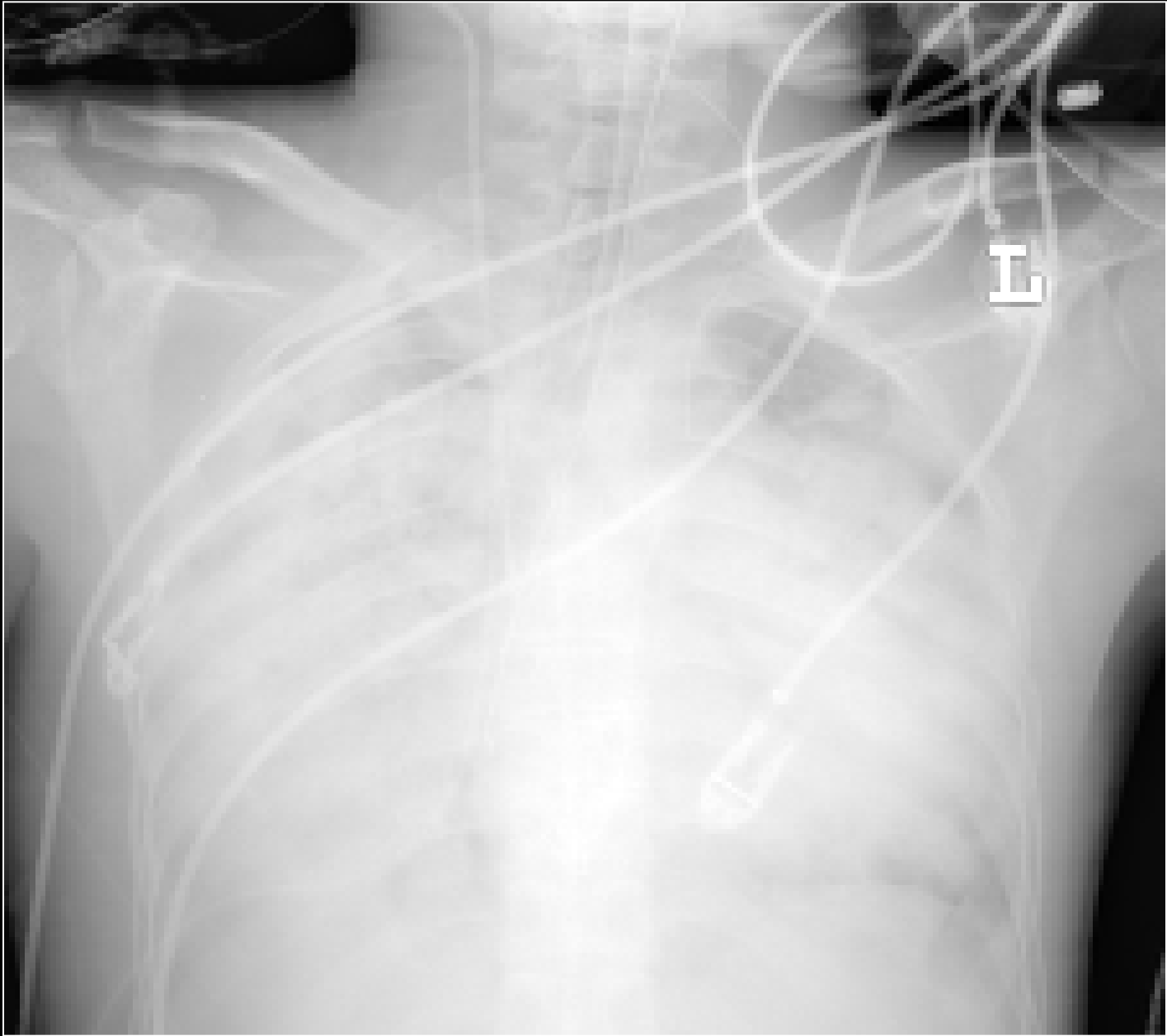
# Ventilator-Induced Lung Injury

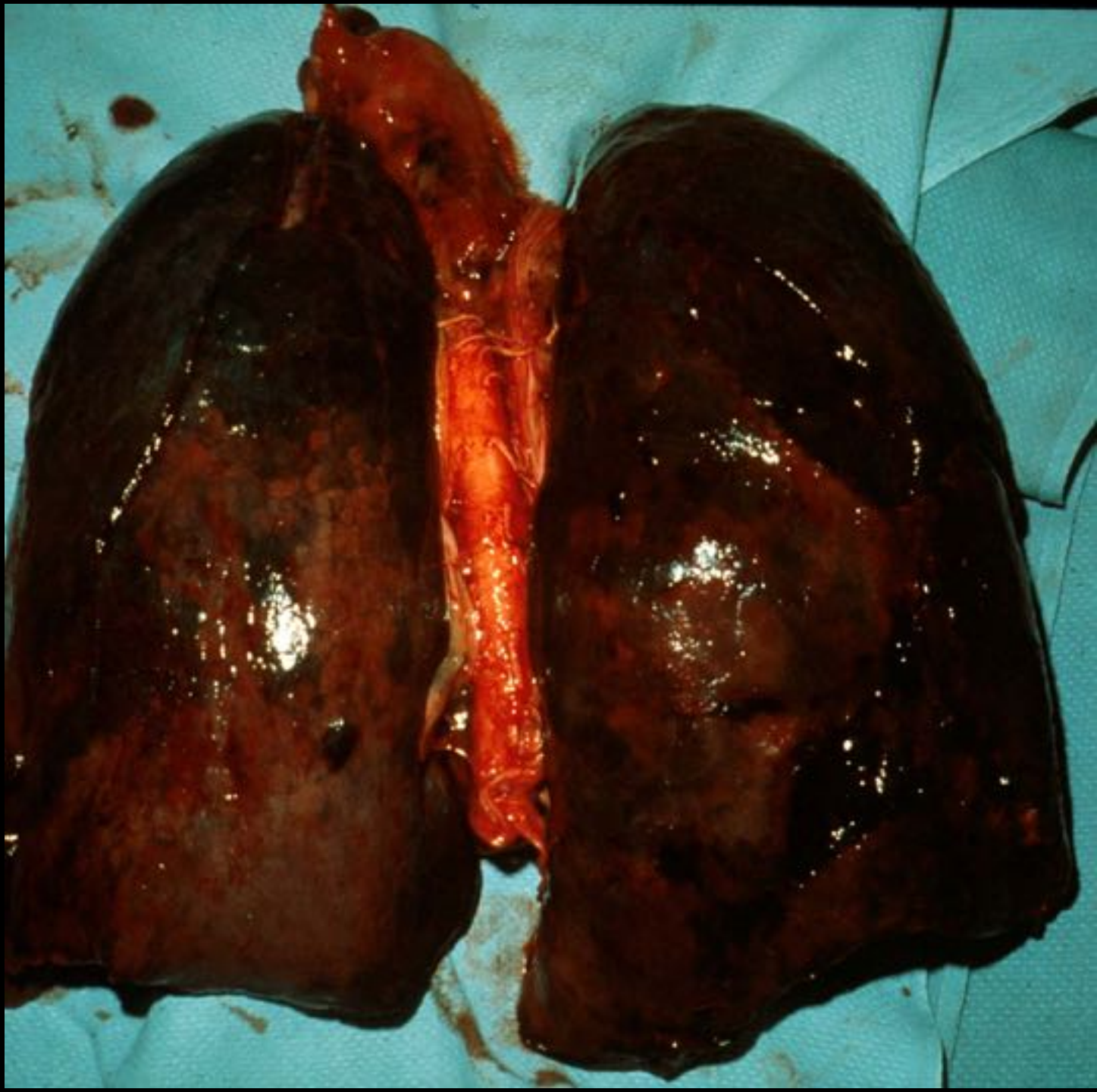
William E. Hurford, MD, FCCM  
Professor and Chair  
Department of Anesthesiology  
University of Cincinnati

# Overview

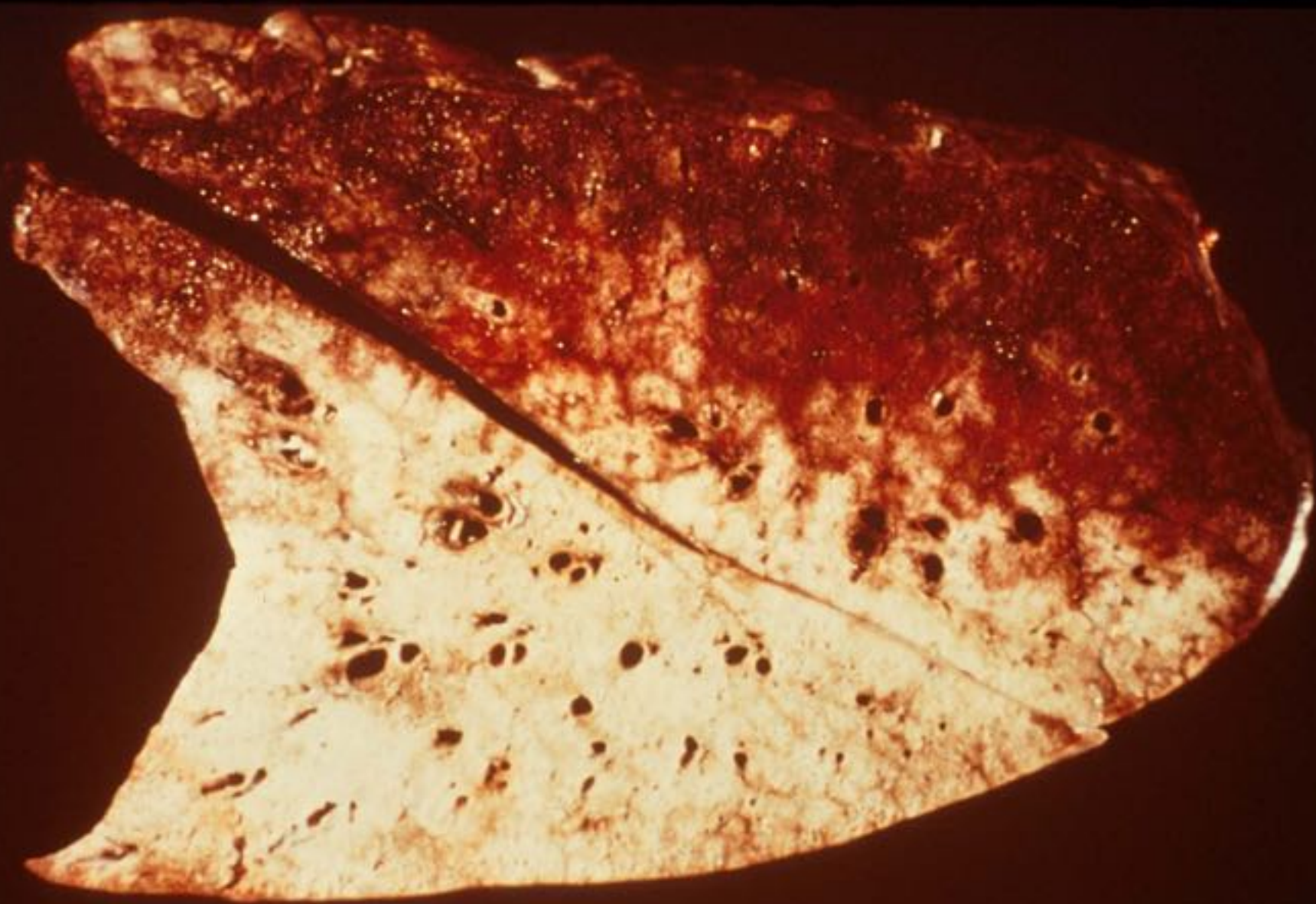
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- Regional lung mechanics vary considerably in ARDS patients
- Abnormal shear stress can produce alveolar epithelial and endothelial damage, which can produce a systemic inflammatory response
- Ventilatory strategies that reduce lung heterogeneity and atelectasis as well as limit overdistension may reduce ventilator-associated lung injury and improve outcomes



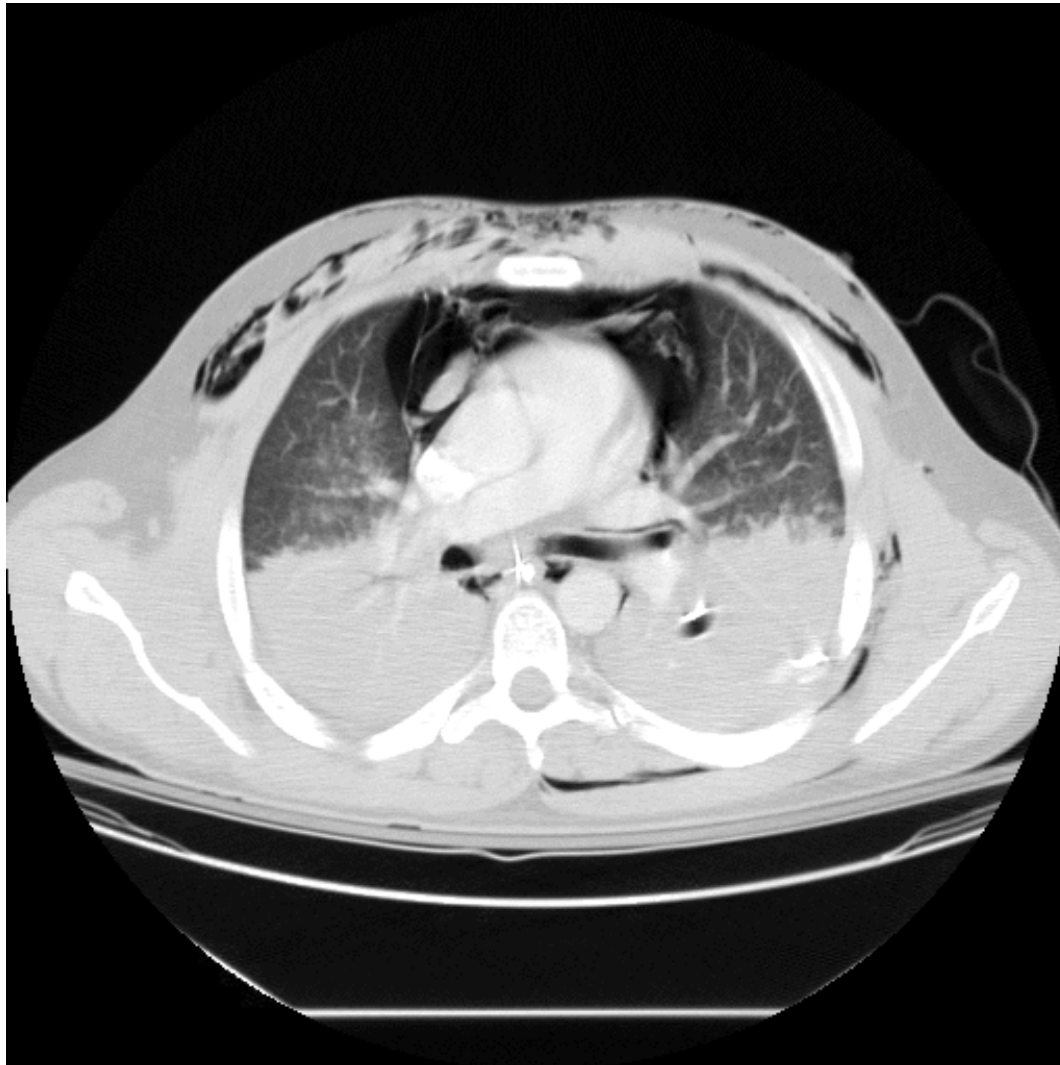


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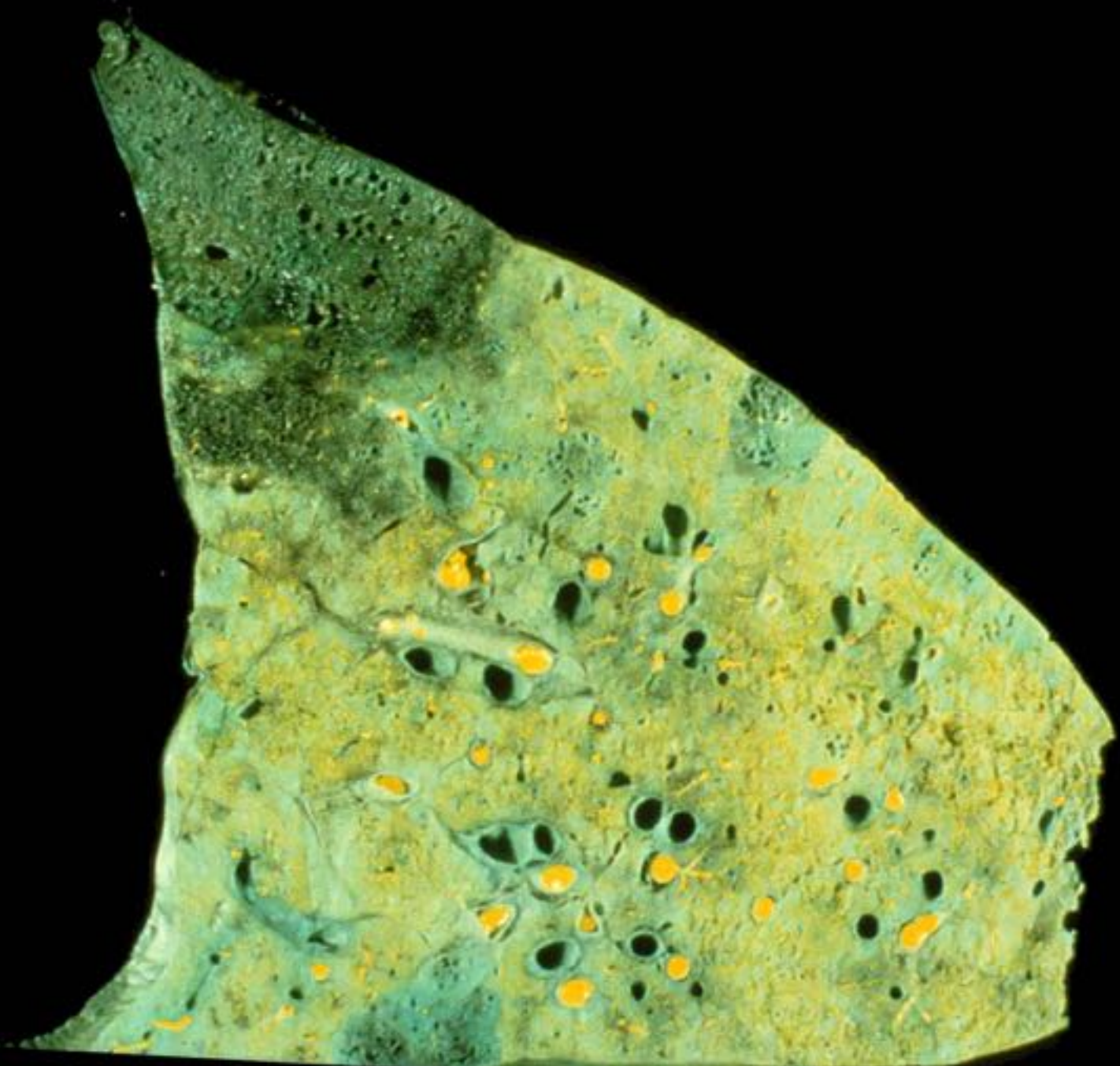
# Chest CT in ARDS

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38,898

metric 11 21 31 41 51 61 71 81 91 100 111





METRIC 1 2 3 4

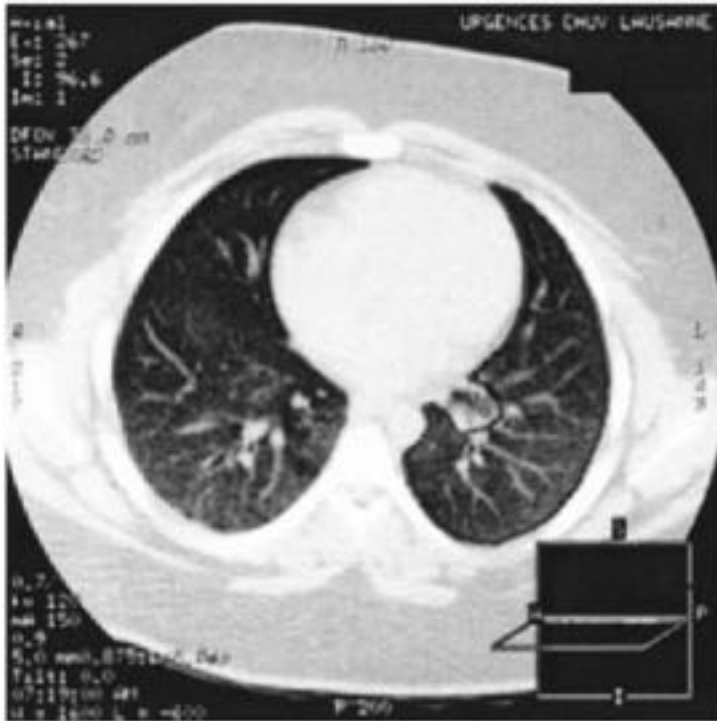


# Heterogeneous Lung Mechanics



# Atelectasis during Induction of General Anesthesia in Obese Patients

Coussa M et al., *Anesth Analg* 2004;98:1491



Before induction

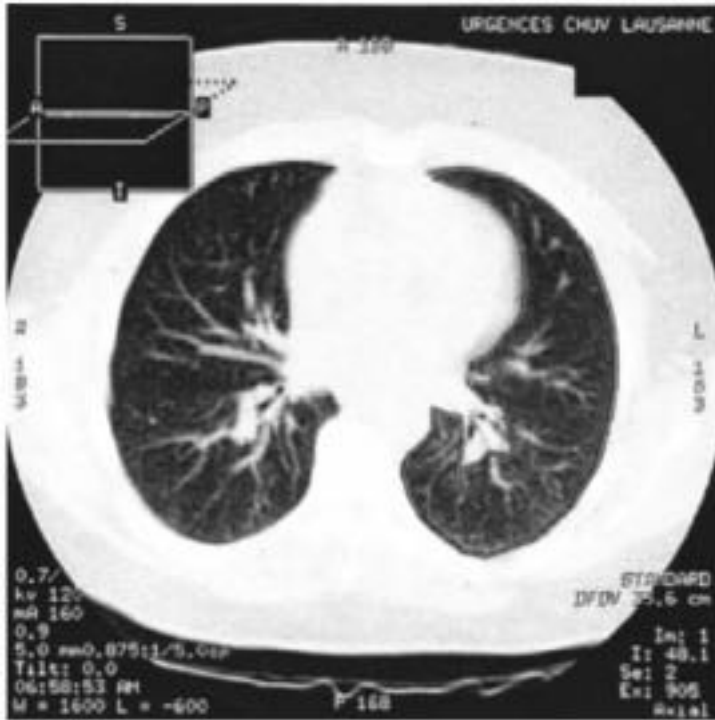


After intubation

With 0 cm H<sub>2</sub>O PEEP

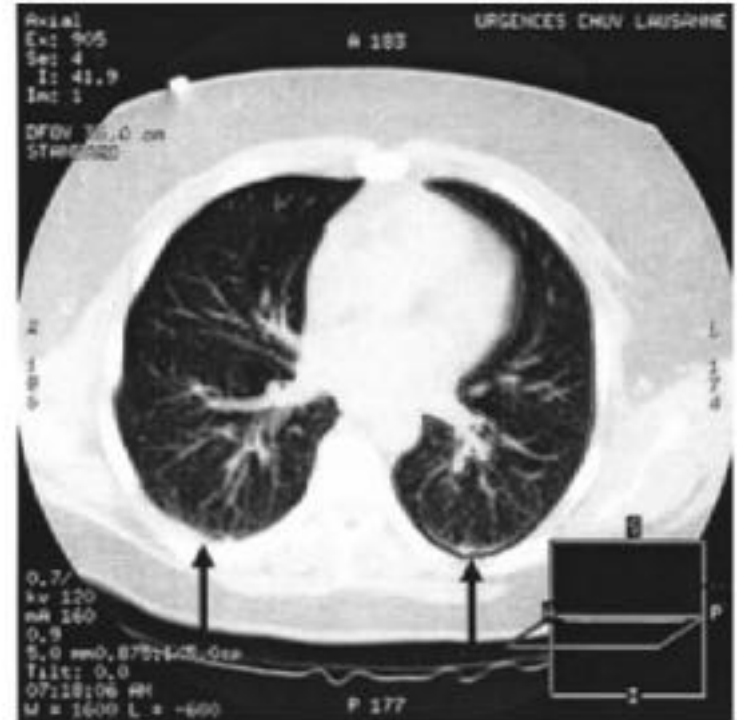
# Atelectasis during Induction of General Anesthesia in Obese Patients

Coussa M et al., *Anesth Analg* 2004;98:1491



Before induction

With 10 cm H<sub>2</sub>O PEEP



After intubation

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**VALI**

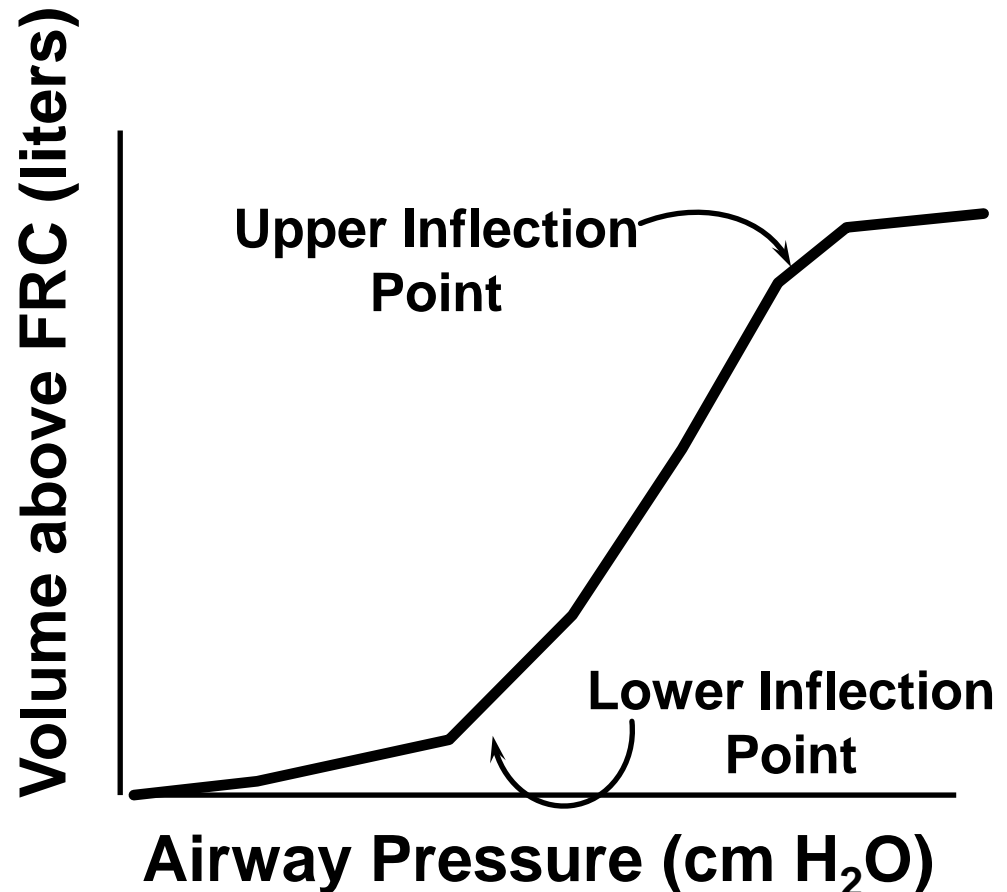
**Ventilator Associated  
Lung Injury**

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# Volutrauma

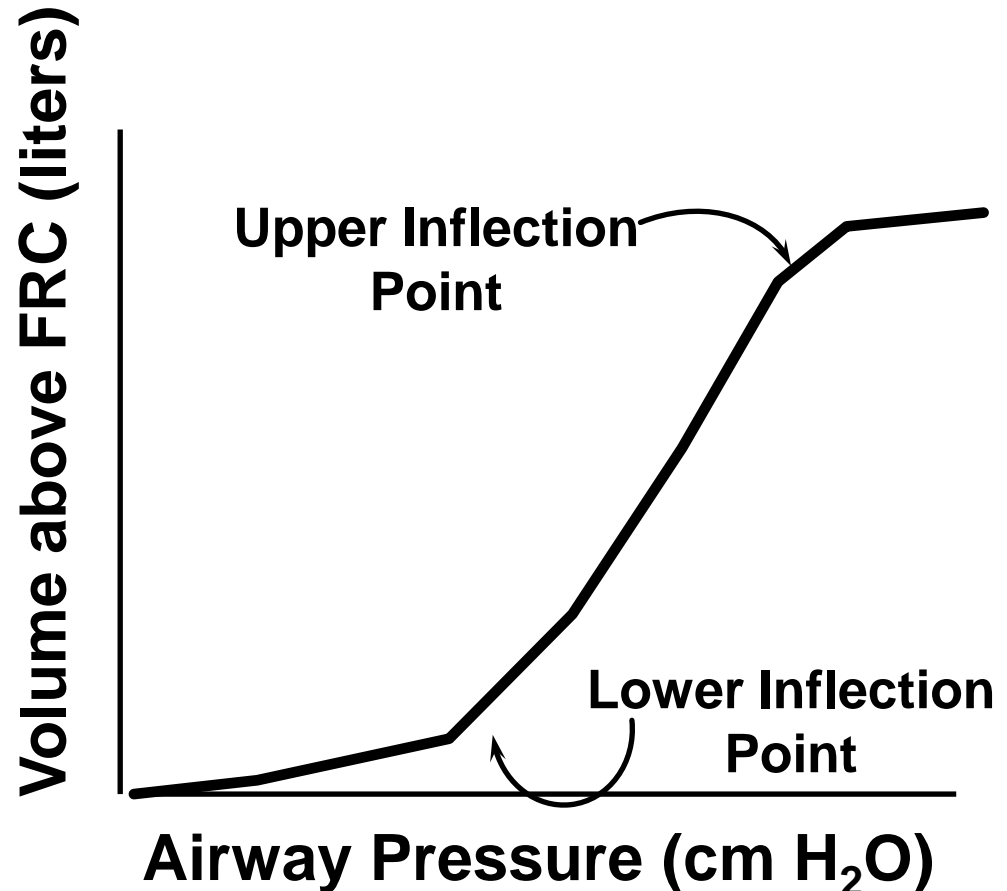
# Static Pressure-Volume Curve of the Respiratory System

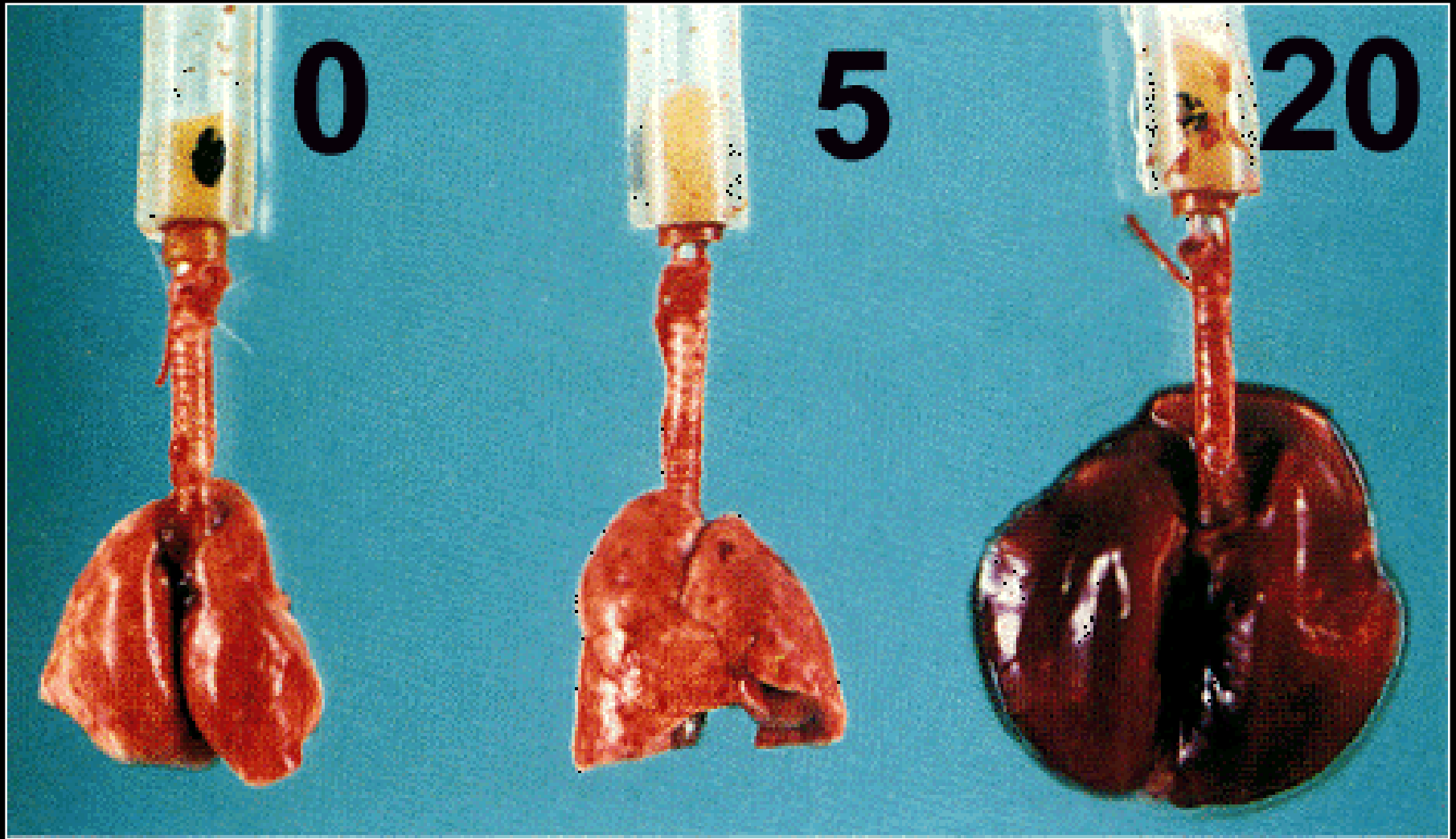
- In animal studies, high volume mechanical ventilation produces acute lung injury similar to ARDS
- This injury is associated with local overdistention of lung units



# Static Pressure-Volume Curve of the Respiratory System

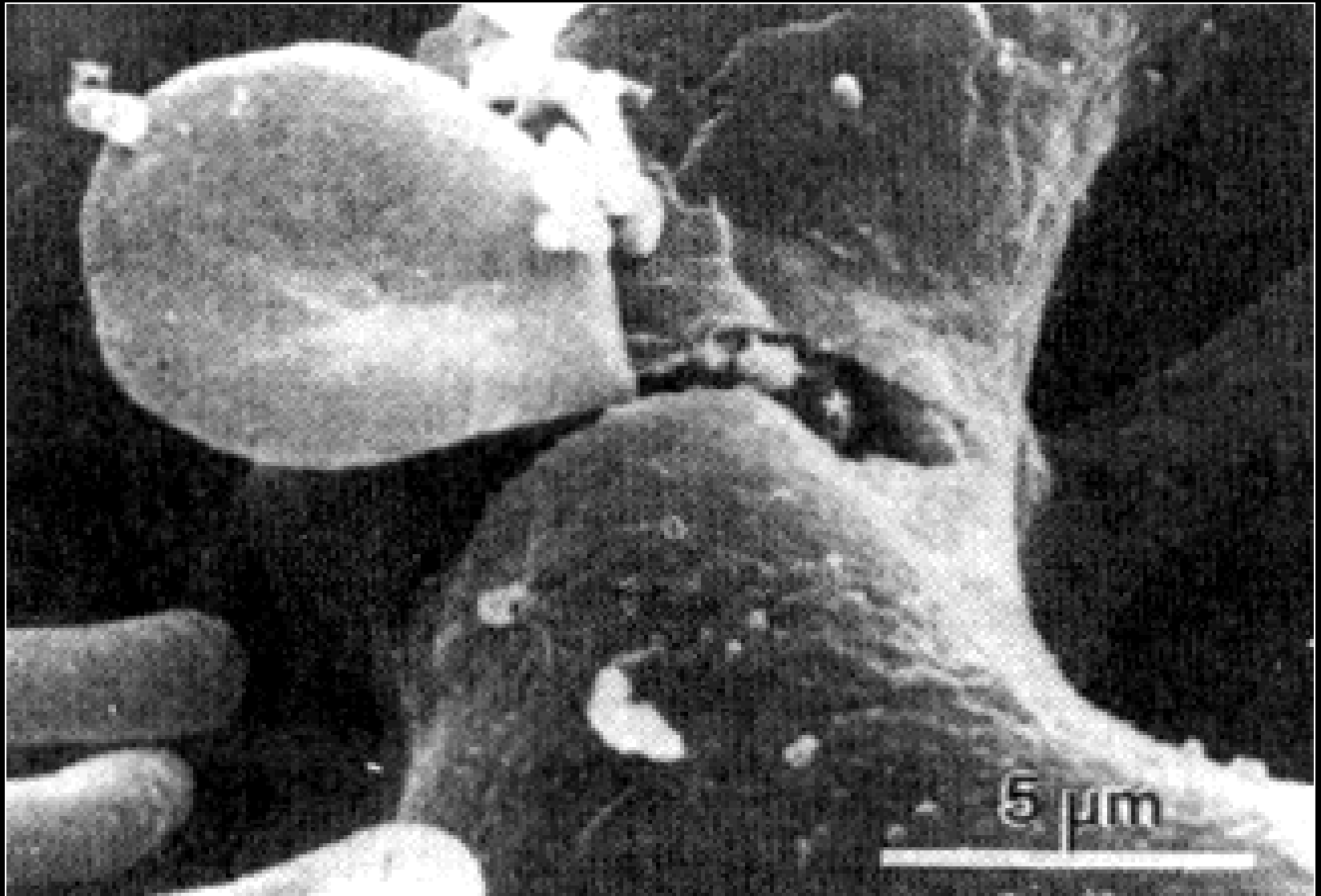
- A minimal level of PEEP is necessary to prevent closure of newly-opened alveoli, increase FRC, and improve effective lung compliance
- This level of PEEP may reduce trauma associated with the repetitive re-opening of collapsed alveoli





Dreyfuss et al., *AJRCCM* 157:294, 1998



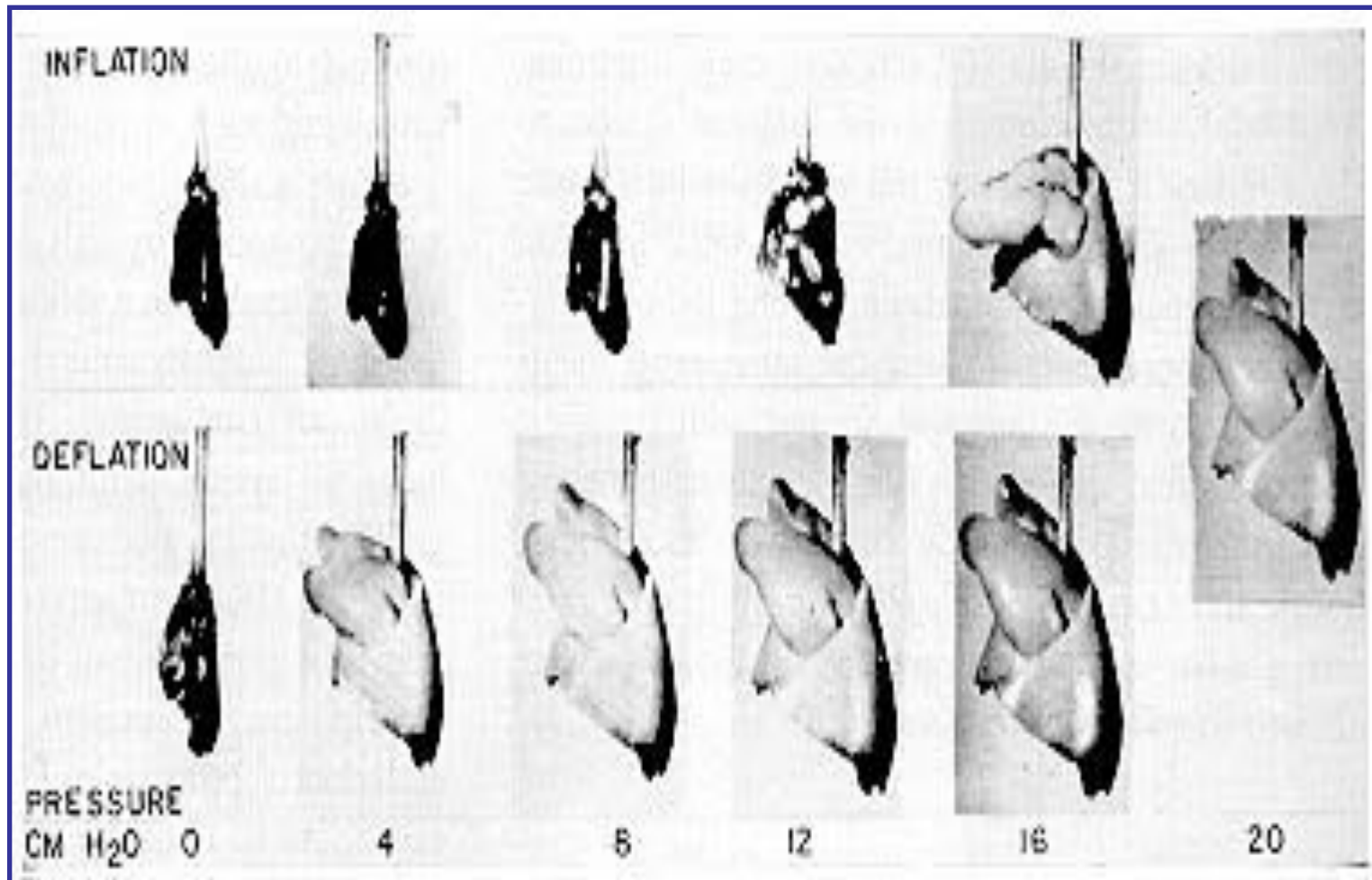


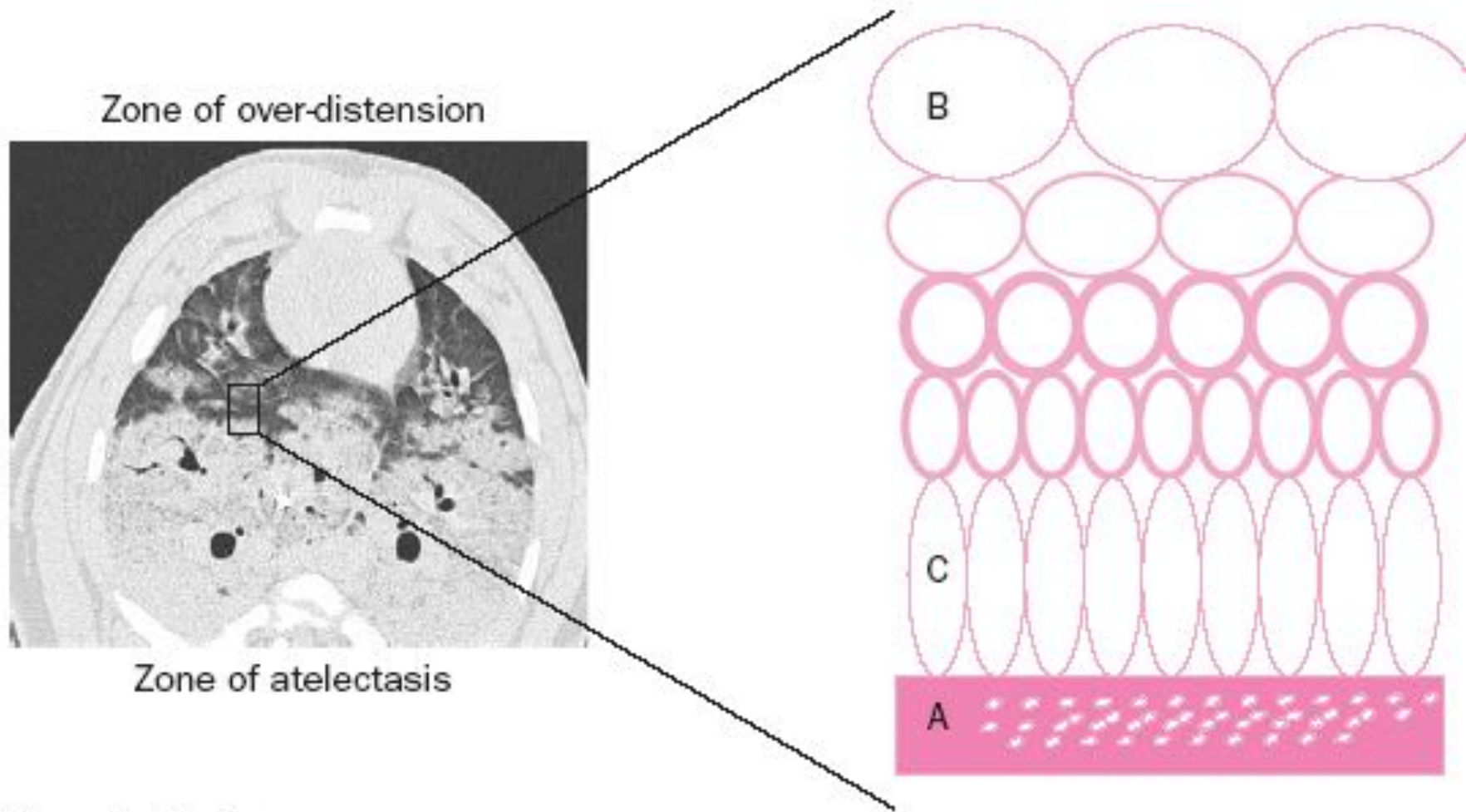
Fu Z et al., *J Appl Phys* 73:123, 1992

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# Atelectotrauma

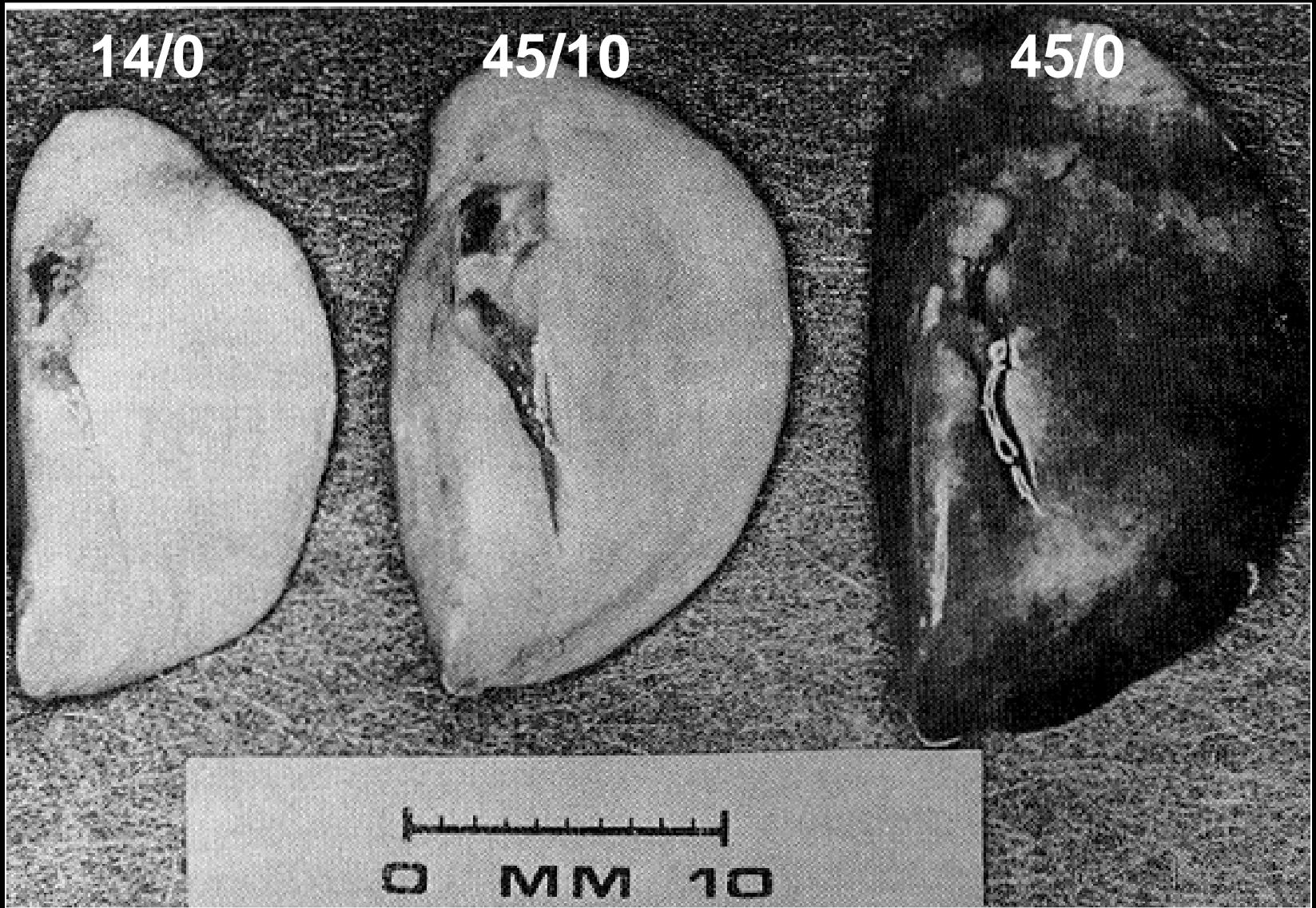
# What's Wrong with a Little Atelectasis?





**Figure 1: Atelectotrauma**

The interface between collapsed and consolidated lung (A) and over-distended lung units (B) is heterogeneous and unstable. Depending on ambient conditions this region is prone to cyclic recruitment and derecruitment and localised asymmetrical stretch of lung units (C) immediately apposed to regions of collapsed lung.



Webb & Tierney, *AJRCCM* 110:556, 1974

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# Biotrauma

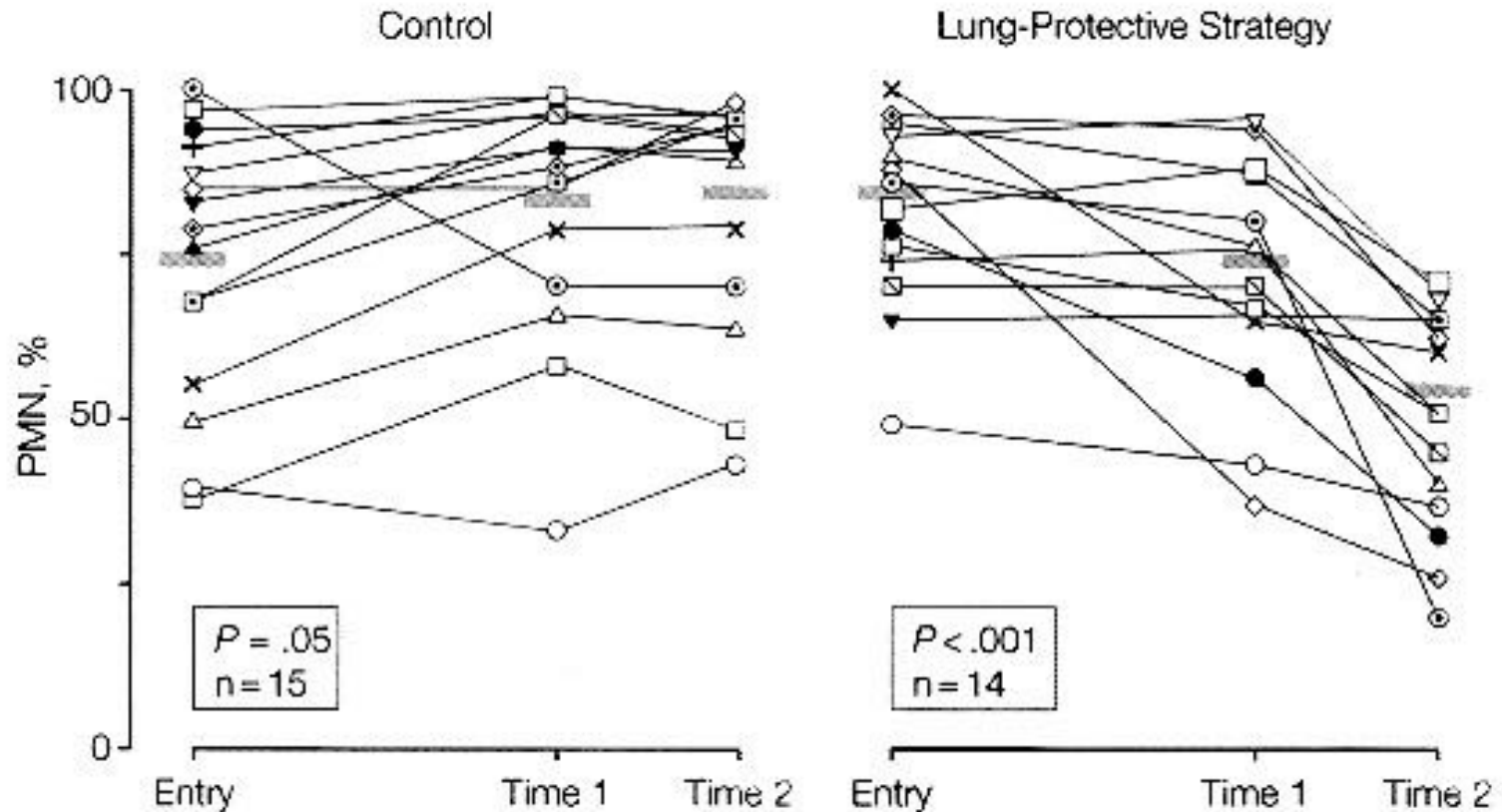
# Effect of Mechanical Ventilation on Inflammatory Mediators in ARDS Patients

Ranieri VM, et al., *JAMA*, 282:54, 1999

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- 37 patients with ARDS randomized
- Controls: TV 11.1 ml/kg, 6.5 cm H<sub>2</sub>O PEEP (best PaO<sub>2</sub>), normal PaCO<sub>2</sub>
- Lung protective strategy: TV 7.6 ml/kg, 14.8 cm H<sub>2</sub>O PEEP (both based on P-V curve)
- Inflammatory mediators and cells in BAL increased in controls and decreased in experimental group after 36 hours

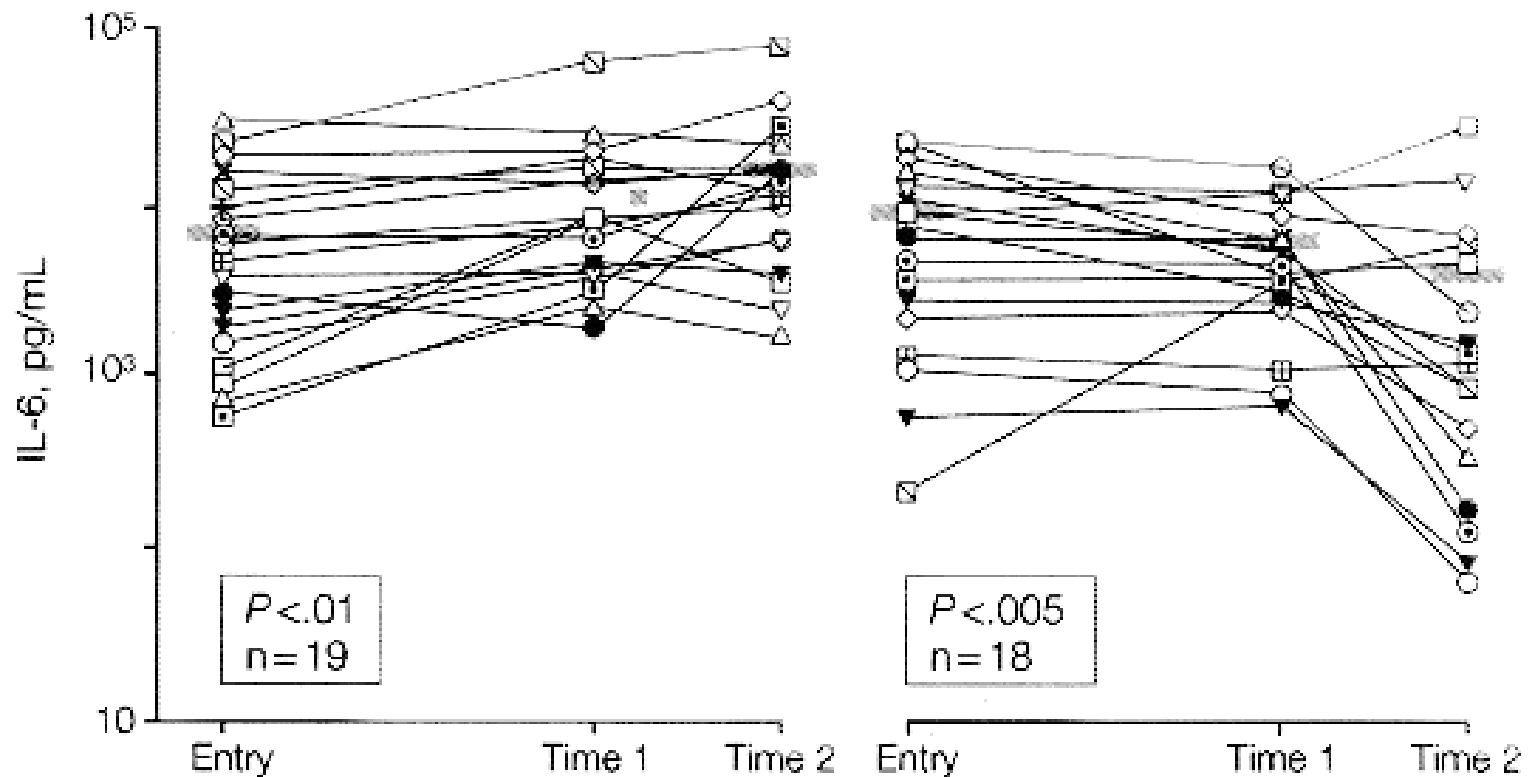
# PMNs in BAL Fluid



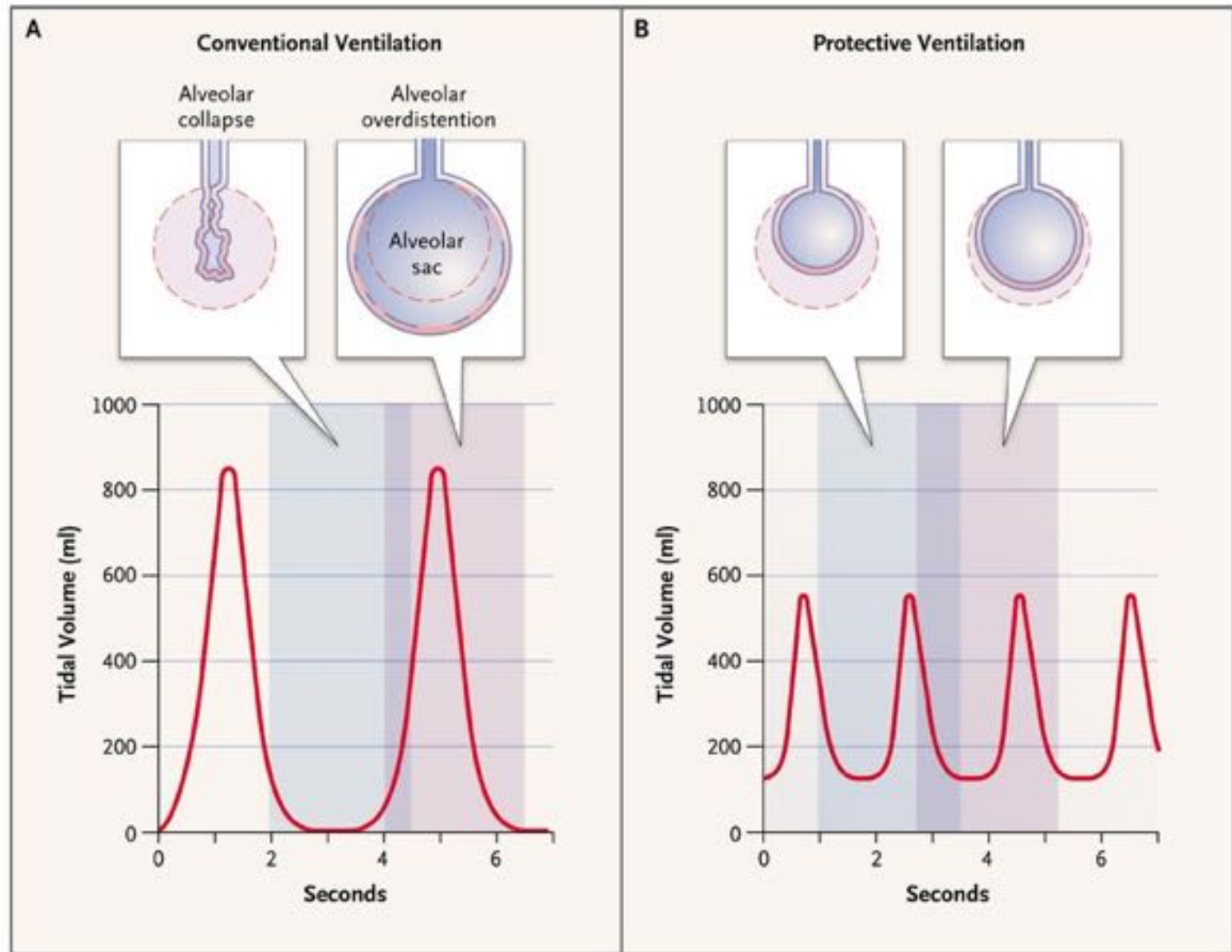
Ranieri VM, et al., *JAMA*, 282:54, 1999



# IL-6 Levels in BAL Fluid



Ranieri VM, et al., *JAMA*, 282:54, 1999



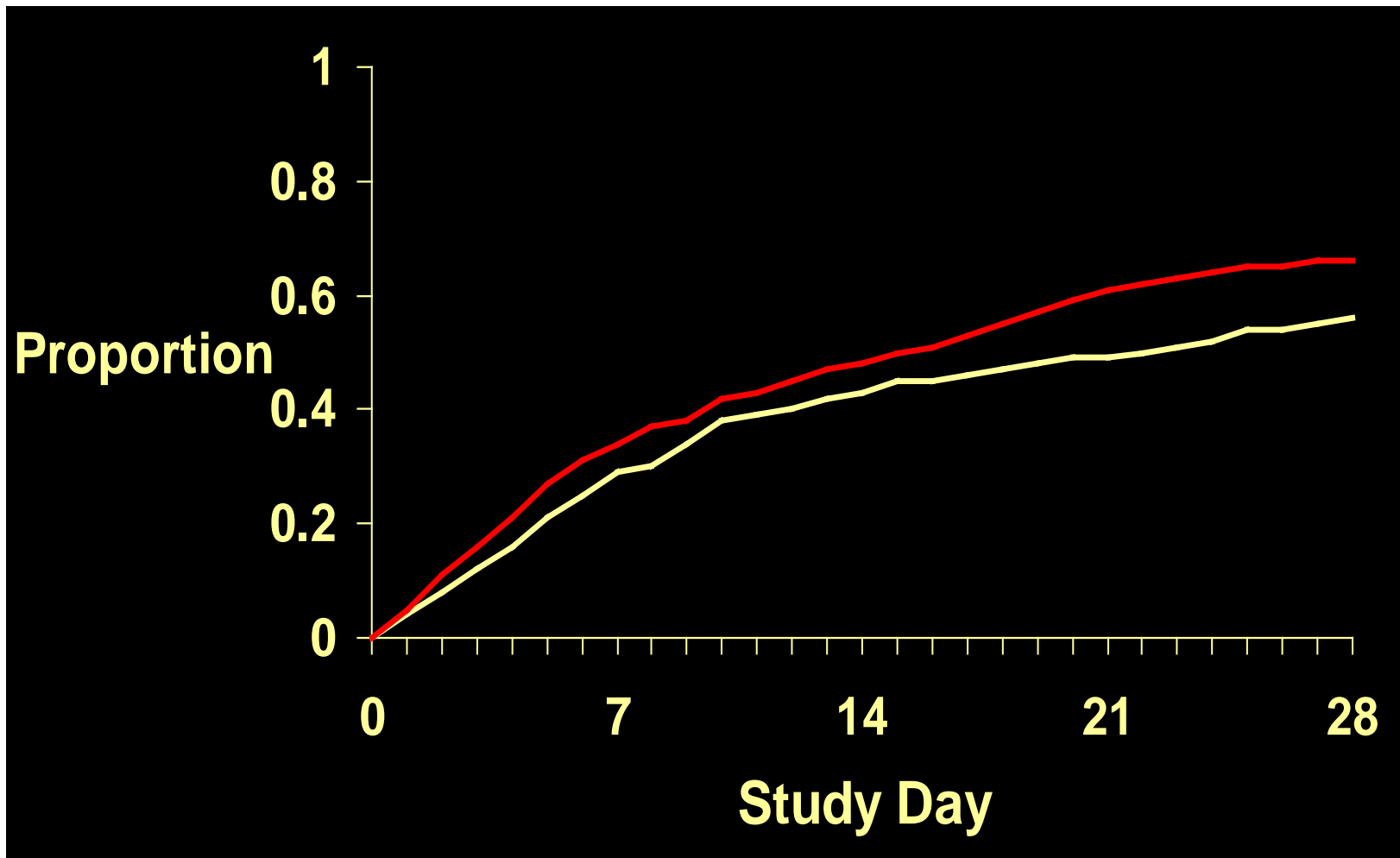
# NIH NHLBI ARDS Network

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Prospective, Randomized, Multi-Center  
Trial of 12 ml/kg Vs 6 ml/kg Tidal  
Volume Positive Pressure Ventilation for  
Treatment of Acute Lung Injury and  
Acute Respiratory Distress Syndrome

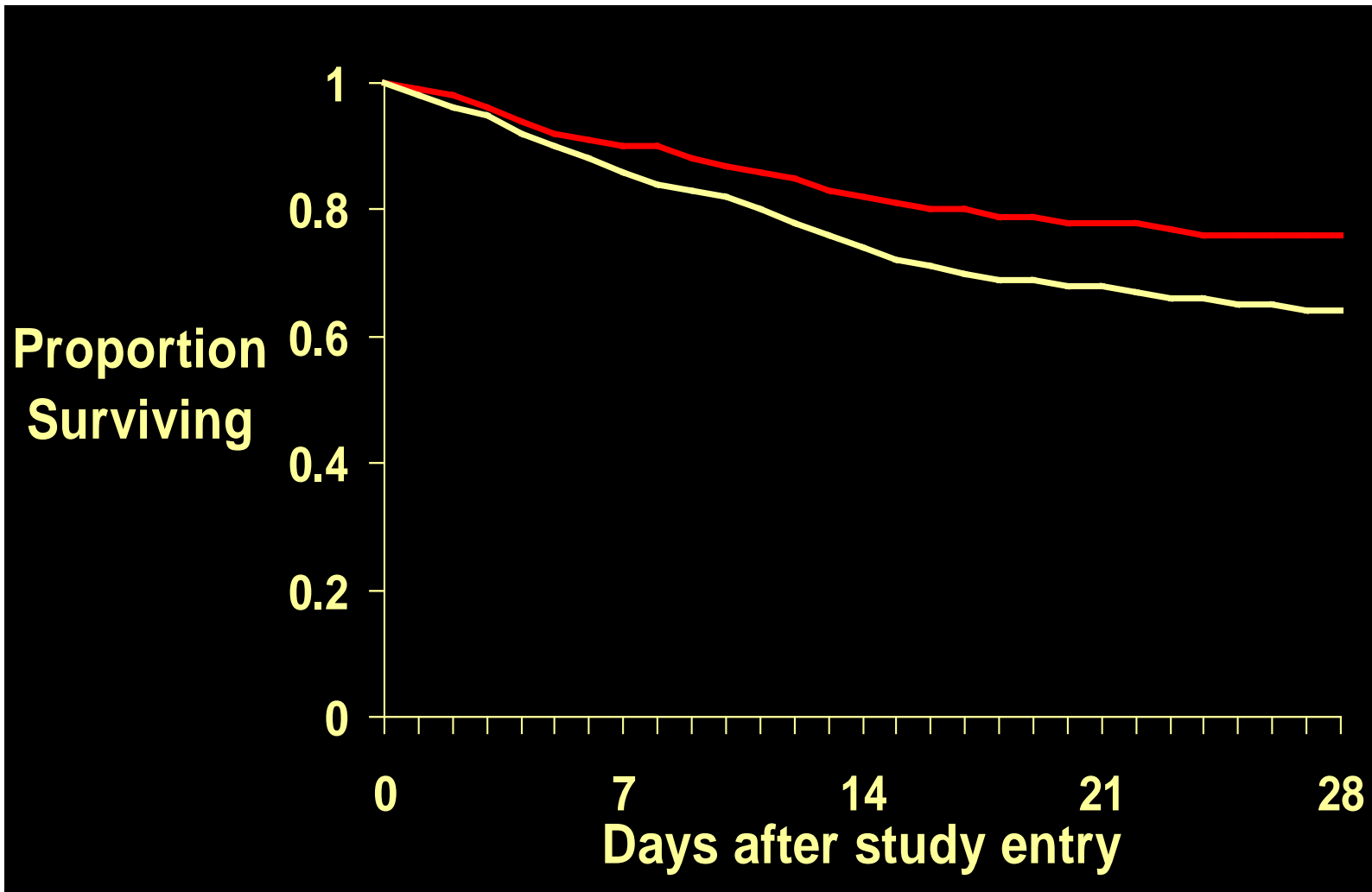
***NEJM*, 342:1301-8, 2000**

# Proportion Alive and Off Ventilator



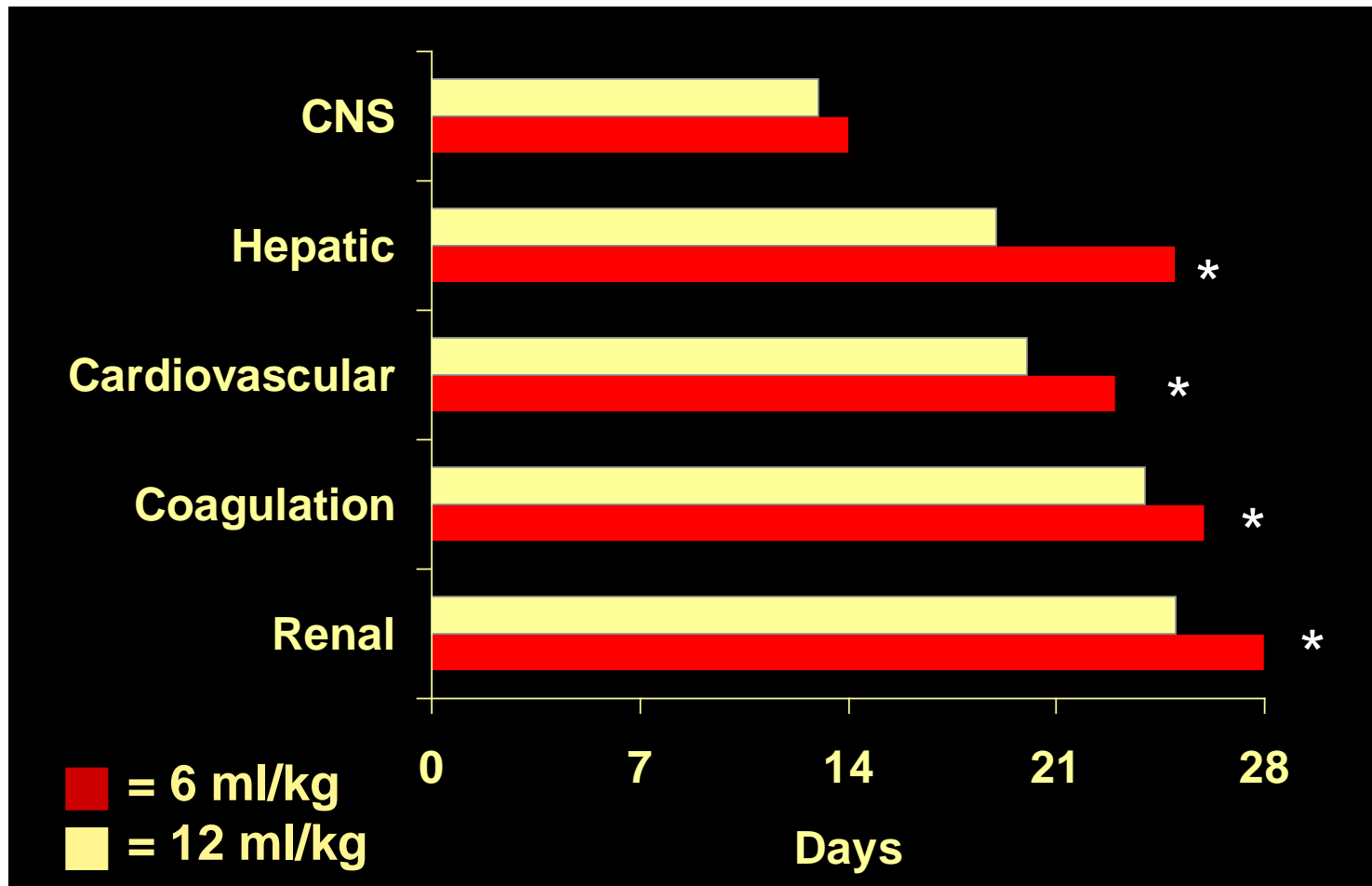
*NEJM*, 342:1301-8, 2000

# 28 Day Survival



*NEJM*, 342:1301-8, 2000

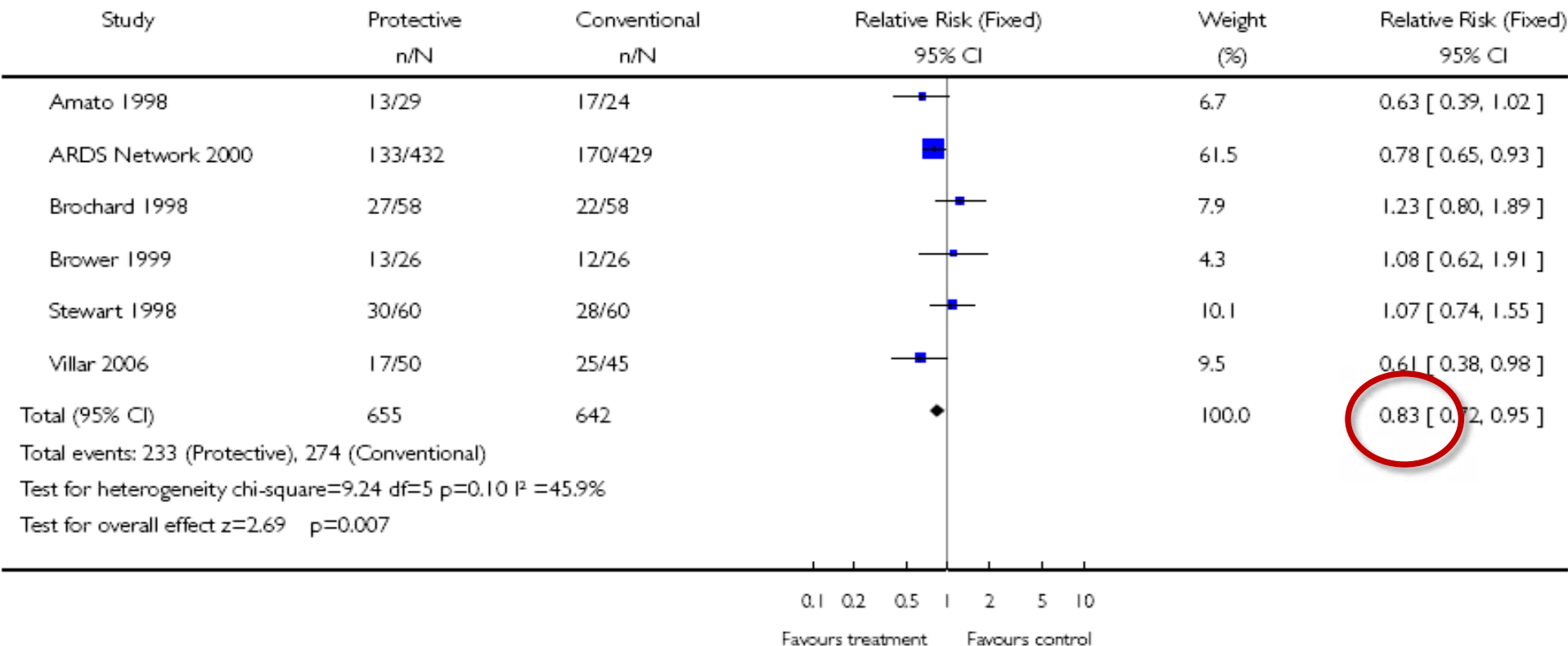
# Median Organ Failure Free Days



NEJM, 342:1301-8, 2000

# Lung protective ventilation strategy for ARDS

Petrucci N, Iacovelli W. *Cochrane Database of Systematic Reviews* 2007, Issue 3. Art. No.: CD003844



Mortality at end of follow-up period

# Alternative Protective Strategies

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- Prone positioning
- PEEP – how much and how
  - PV curve, transpulmonary/esophageal pressure, electrical impedance, optimal lung compliance, open lung, ARDSnet table
- Ventilator modes – HFOV, APRV
- Neuromuscular blockade
- ECMO; ECCO<sub>2</sub>R



# Summary

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- Lung mechanics are often heterogeneous, even without injury
- Lung injury can further alter regional lung mechanics
- Mechanical ventilation can cause lung injury
- Certain patterns of ventilation may worsen lung injury
- Encouraging lung recruitment and limiting overdistention may reduce barotrauma and improve outcome

