Acute Respiratory Distress Syndrome (ARDS)

Cardiac output x Hb x % Sat O2

Preload

Effective blood volume
Capacitance
Obstruction
Septal shift
IV fluid
- volume
- C.O.P.

Pump failure

Arrhythmias
Ischaemia
Valvular problems
Septal shift

Afterload

RAA adaptaion
Sepsis
Valvular problems
Pulmonary embolism
Hypertension
Shunts

Heart rate

Anaemia

Fe def
Dilutional
Inflammatory
Vitamin deficiency
Aplastic

Abnormal Hb

Sickle cell
Thalassaemia
met Hb
CO Hb

Hemolysis

free Hb and NO
Pulmonary hypertension
Hypercoagulability

Hyperviscosity

PRV
Acclimatisation

Inspired O2

Altitude
Hyperbaric O2

Hypoventilation

Decreased respiratory drive
- drug induced

CVA
Fatigue (asthma)
Obstruction
- Sleep apnoea syndrome
- Decreased consciousness

Ventilation/perfusion abnormalities

Shunt
- Pneumonia
- Pulmonary oedema

Dead space
- Pulmonary embolism
- Fat embolism

Mixed
- ARDS
- COPD
- Asthma

THE LANCET

[Close]

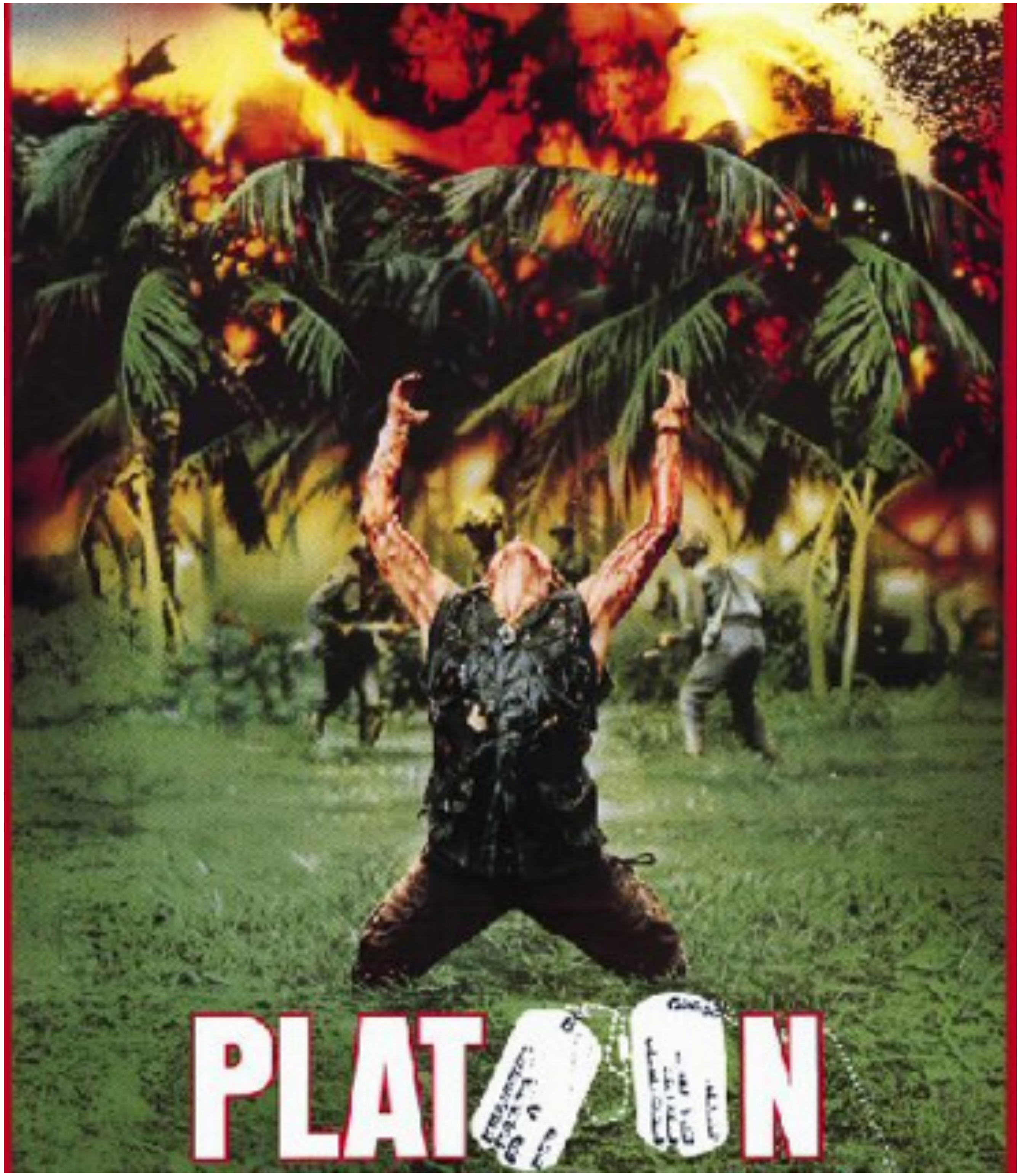
The Lancet, Volume 290, Issue 7511, Pages 319 - 323, 12 August 1967
doi:10.1016/S0140-6736(67)90168-7

ACUTE RESPIRATORY DISTRESS IN ADULTS

DavidG. Ashbaugh M.D. Ohio State , D. Boyd Bigelow M.D. Colorado , ThomasL. Petty M.D. Colorado , BernardE. Levine M.D. Michigan [1]

"The acute onset of severe respiratory distress and cyanosis that was refractory to oxygen therapy and associated with diffuse CXR abnormality and decreased lung compliance"

ARDS- "Danang Lung"



Ashbaugh, Bigelow, Petty Lancet 1967

Acute Lung Injury/ARDS

American-European consensus definition

- Acute onset after “at risk” dx
- Bilateral infiltrates on CXR
- **PaO2/FiO2** < 40 (ALI)
- **PaO2/FiO2** < 27 (ARDS)
- No left atrial hypertension

Bernard, et al. AJRCCM 1994; 149:818-24

ARDS-Berlin Definition 2012

Table 3. The Berlin Definition of Acute Respiratory Distress Syndrome

	Acute Respiratory Distress Syndrome
Timing	Within 1 week of a known clinical insult or new or worsening respiratory symptoms
Chest imaging[a]	Bilateral opacities—not fully explained by effusions, lobar/lung collapse, or nodules
Origin of edema	Respiratory failure not fully explained by cardiac failure or fluid overload Need objective assessment (eg, echocardiography) to exclude hydrostatic edema if no risk factor present
Oxygenation[b]	
Mild	200 mm Hg < PaO_2/FIO_2 ≤ 300 mm Hg with PEEP or CPAP ≥5 cm H_2O[c]
Moderate	100 mm Hg < PaO_2/FIO_2 ≤ 200 mm Hg with PEEP ≥5 cm H_2O
Severe	PaO_2/FIO_2 ≤ 100 mm Hg with PEEP ≥5 cm H_2O

Abbreviations: CPAP, continuous positive airway pressure; FIO_2, fraction of inspired oxygen; PaO_2, partial pressure of arterial oxygen; PEEP, positive end-expiratory pressure.

[a] Chest radiograph or computed tomography scan.

[b] If altitude is higher than 1000 m, the correction factor should be calculated as follows: [PaO_2/FIO_2 × (barometric pressure/760)].

[c] This may be delivered noninvasively in the mild acute respiratory distress syndrome group.

Features shared by ARDS and other causes of acute respiratory failure

Feature	ARDS	Severe pneumonia	Pulmonary embolism	Cardiogenic oedema
Acute onset	√	√	√	√
Fever, leukocytosis	√	√	√	if acute MI
Bilateral infiltrates	√	√	-	-
P/F <27	√	√	√	-
PAOP <18	√	√	√	-

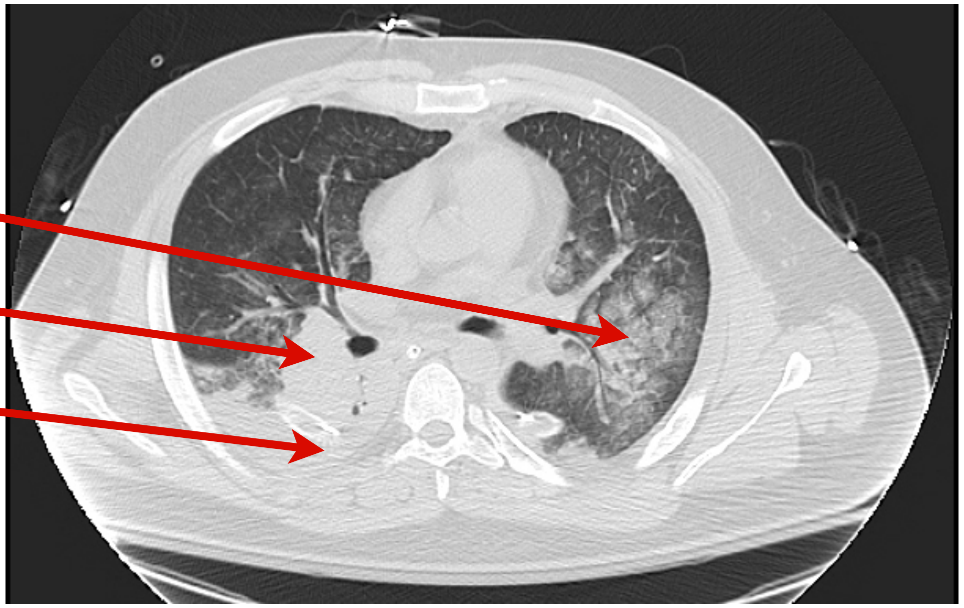
Image Findings in ARDS

CXR findings:

No initial findings wait 24 hours

Diffuse, bilateral pulmonary (alveolar) infiltrates

CT findings:



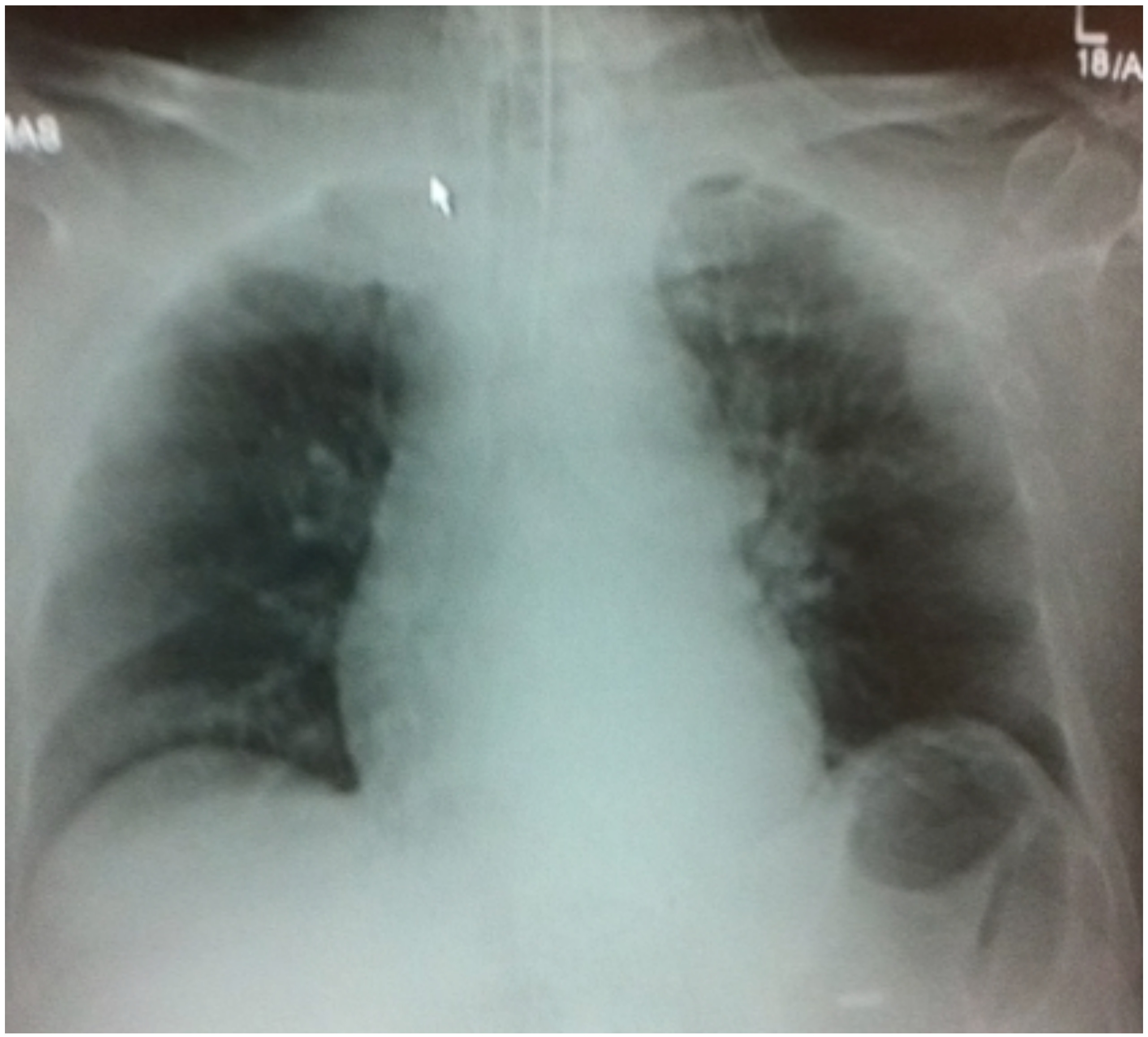
Ground glass opacities patchy and diffuse

Air bronchograms, bronchial dilation

Consolidation mostly in dependent regions

Pleural effusions common but not necessary

A patient admitted with H1N1 pneumonitis

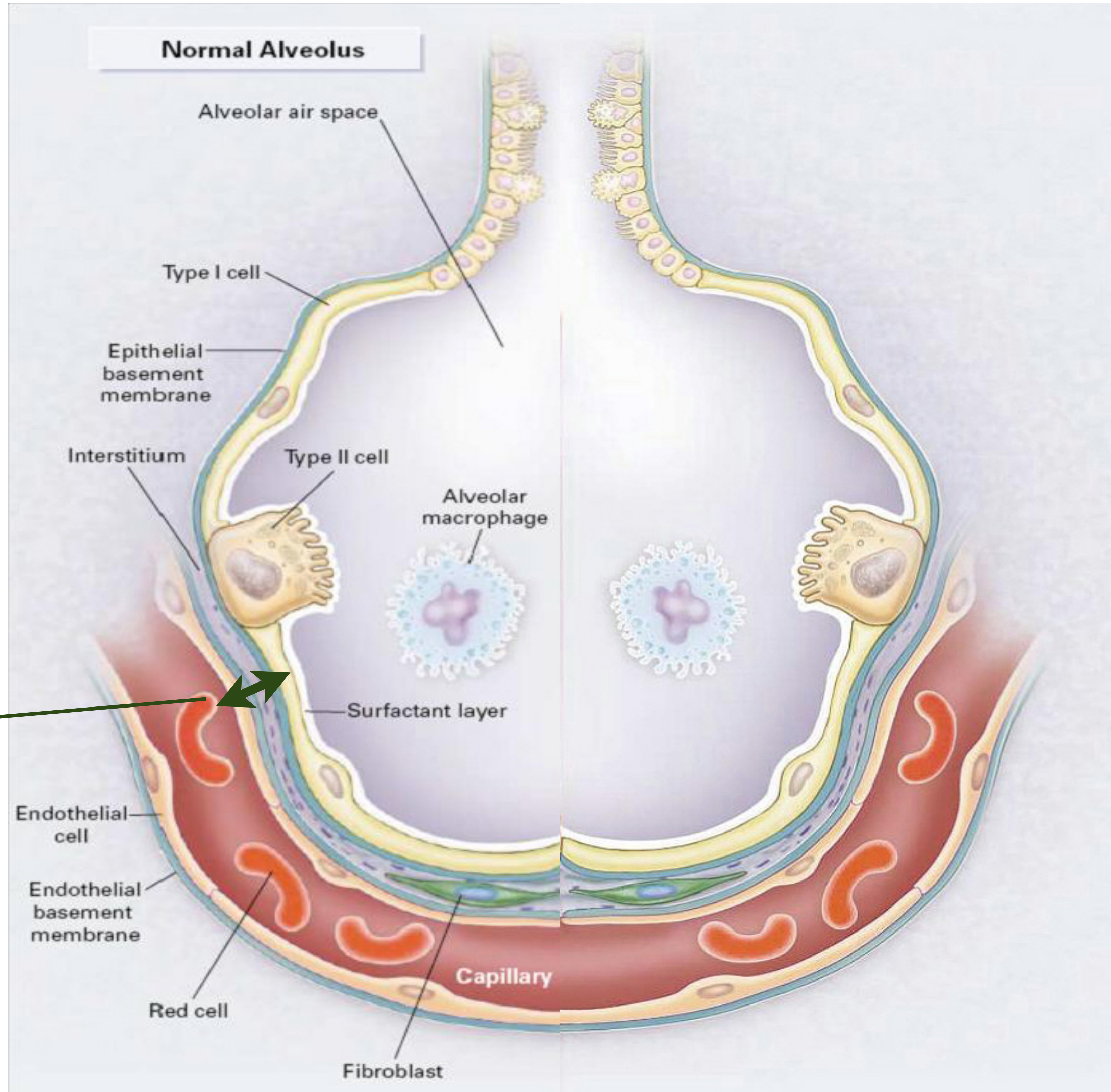


24 hours later

Histopathology of ARDS

Normal alveolus

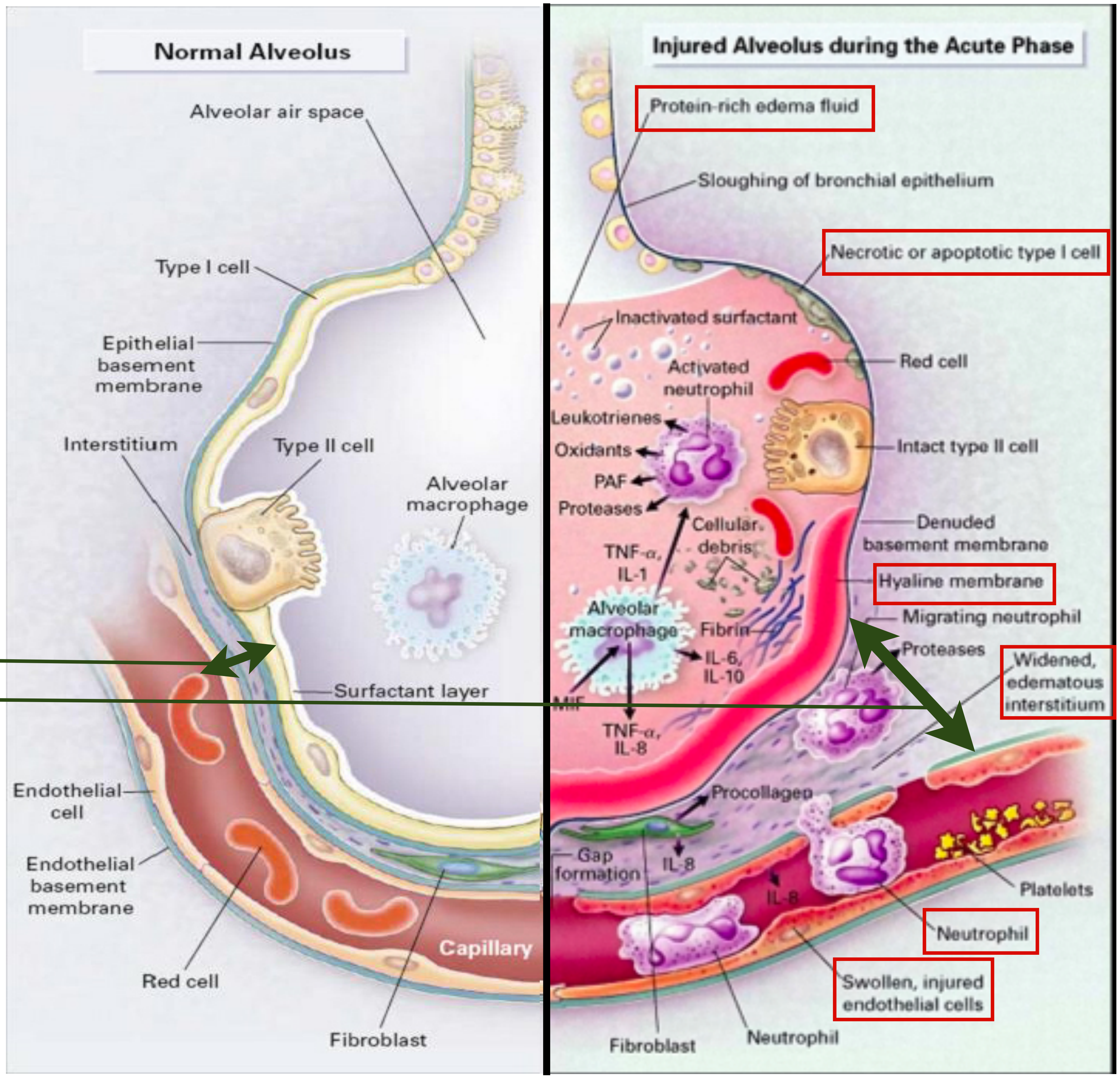
Normally respiratory membrane thickness = 0.2-0.3 micron



Ware LB, Matthay MA. The acute respiratory distress syndrome. NEJM. 2000;342:1334

ARDS alveolus

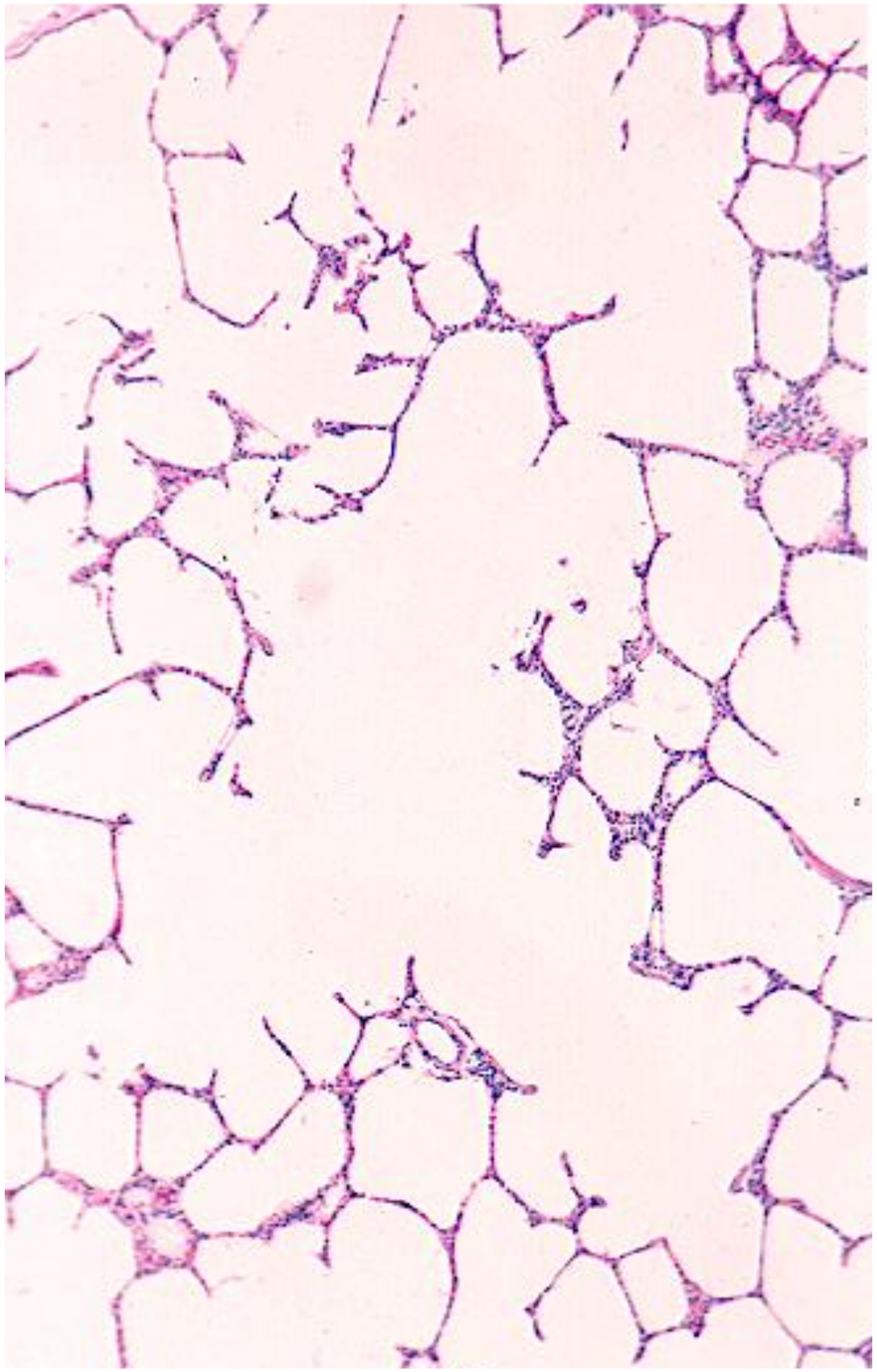
Normally respiratory membrane thickness = 0.2-0.3 micron



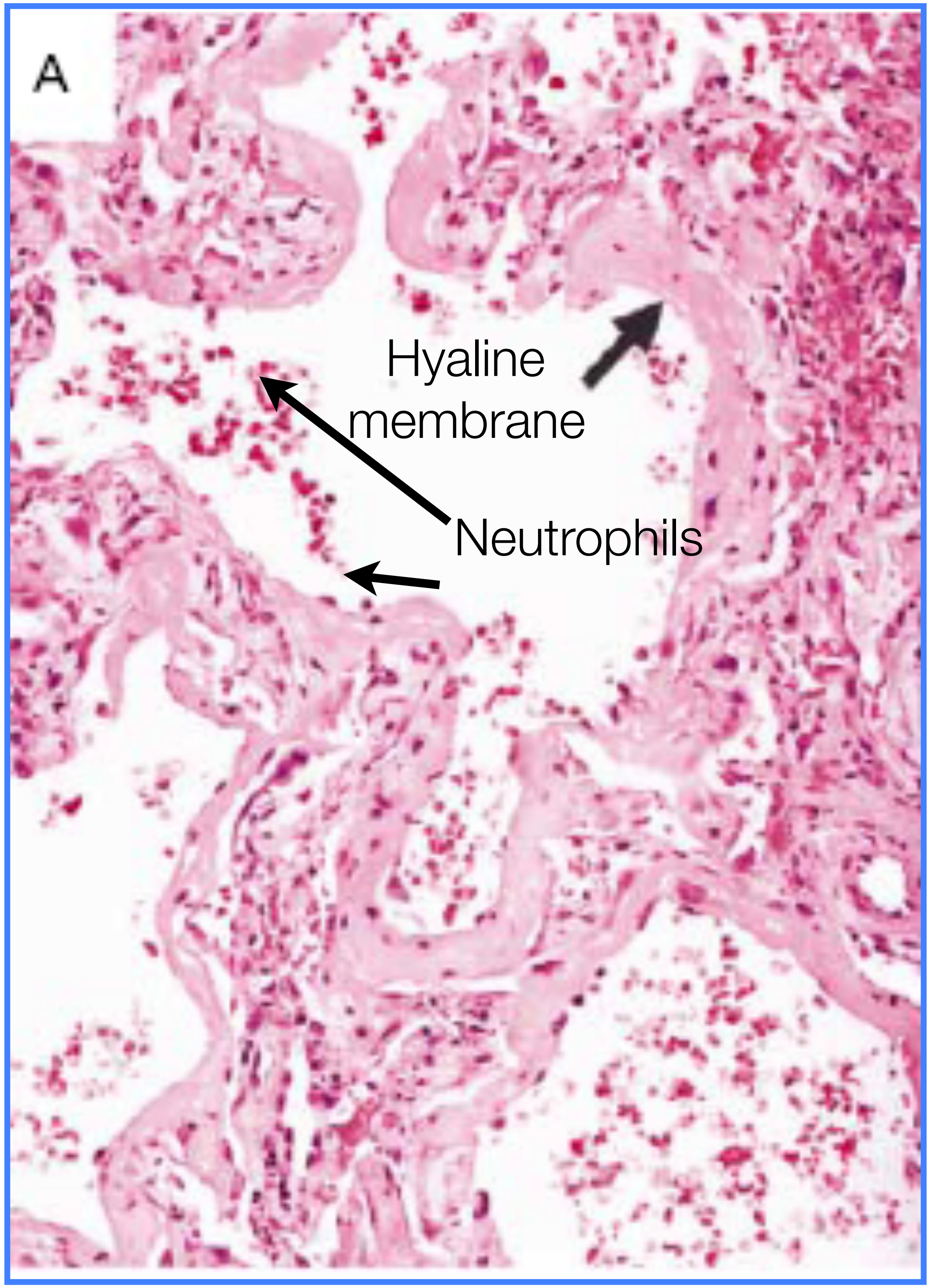
Ware LB, Matthay MA. The acute respiratory distress syndrome. NEJM. 2000;342:1334

ARDS Histology

Normal lung histology



Destruction of lung/alveolar architecture

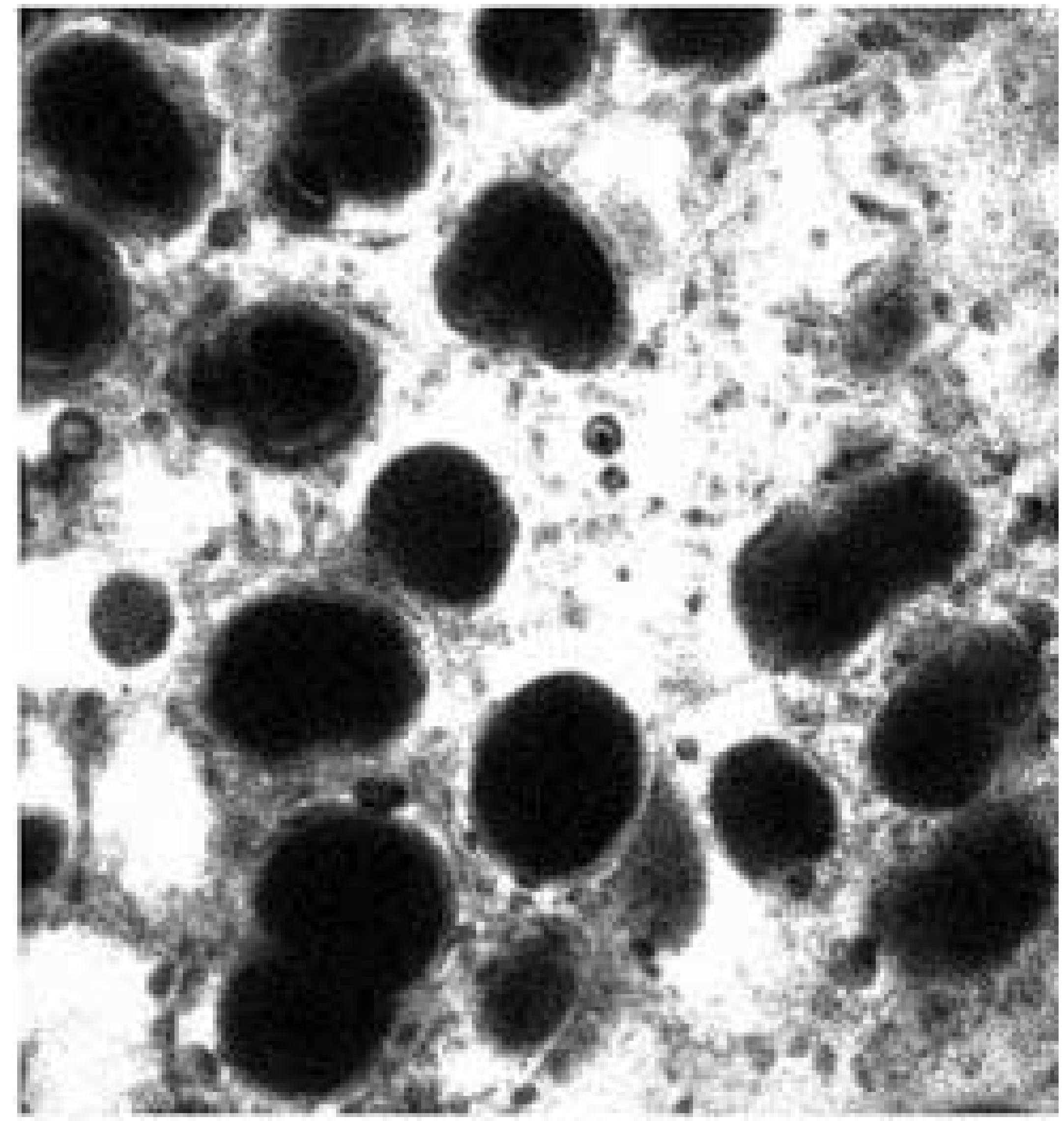


Ware LB, Matthay MA. The acute respiratory distress syndrome. NEJM. 2000;342:1334

ARDS Histology

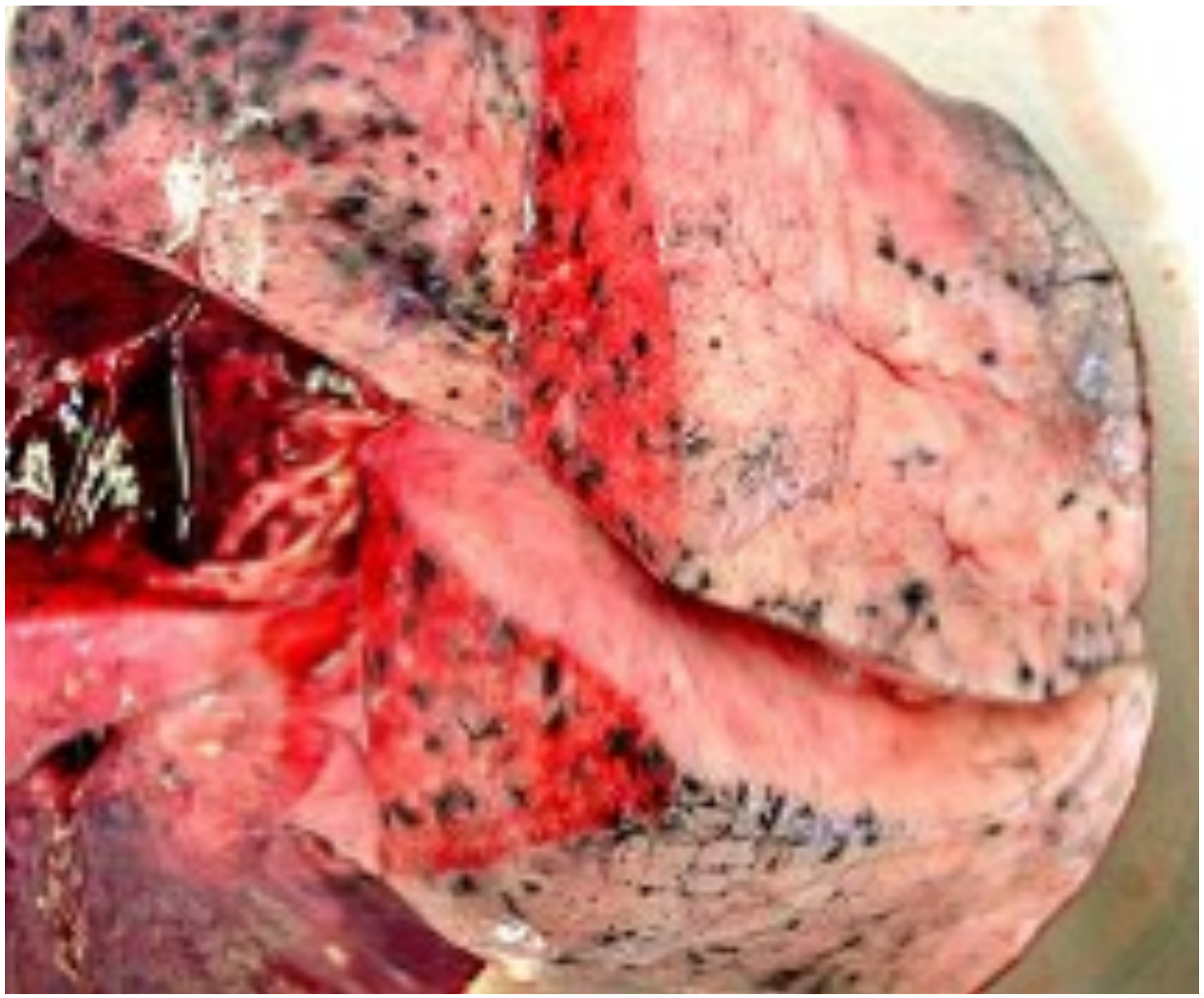
Normal

Oedematous



Am J Respir Crit Care Med Vol 165. pp 1647–1653, 2002

ARDS Pathology



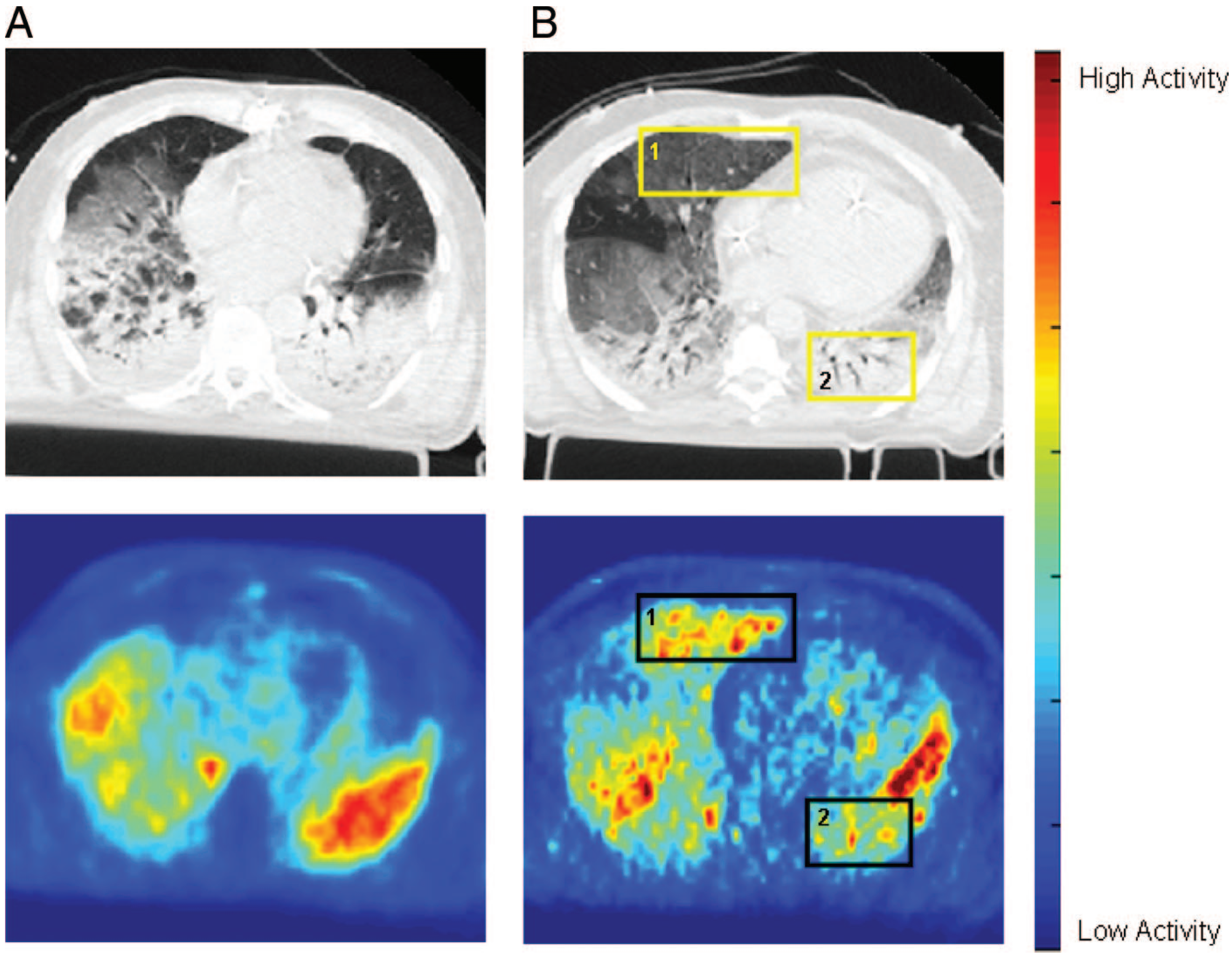
Normal lung

weight 800 gms

ARDS lung

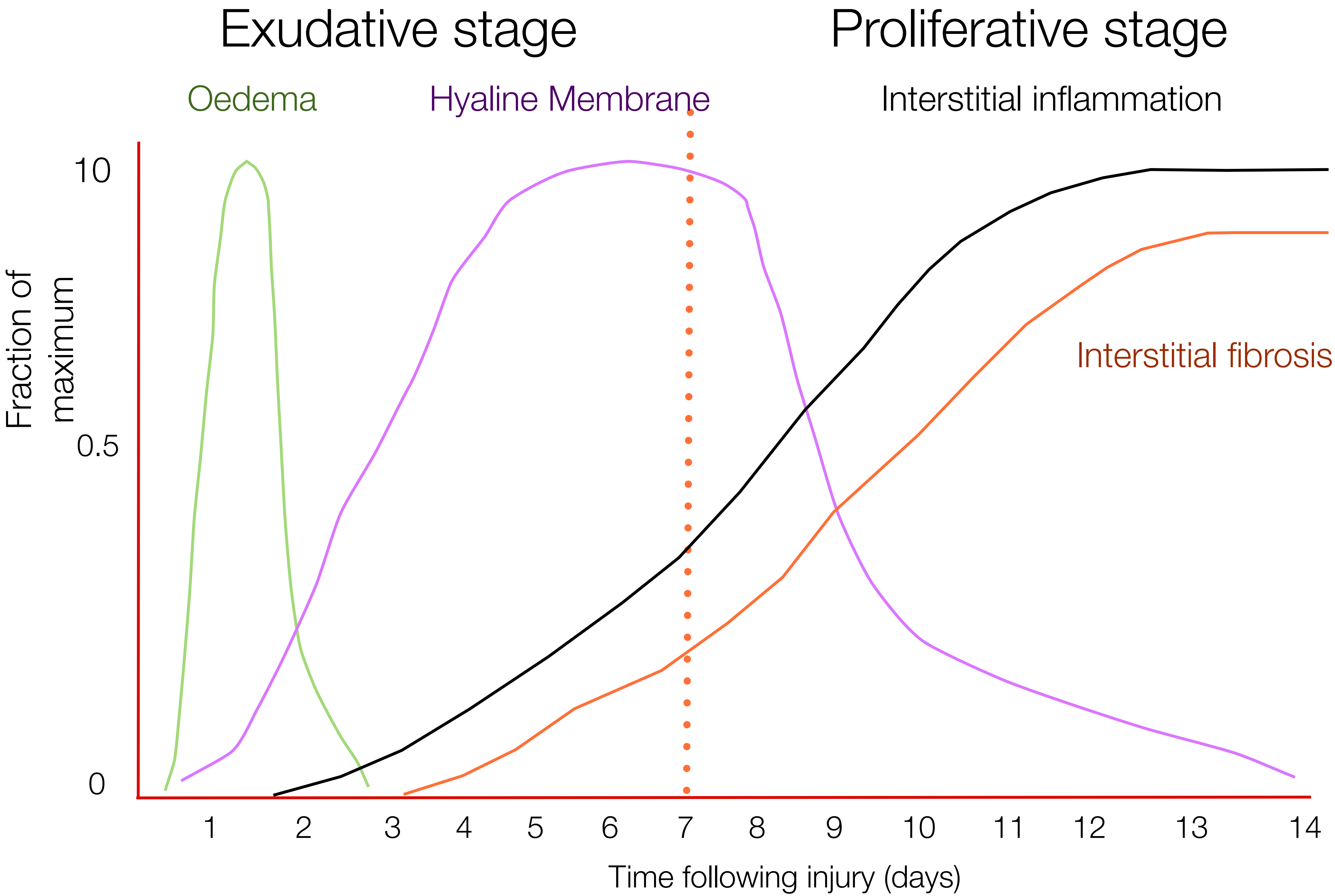
weight 1600 gms

Lungs of patients with ARDS show diffuse inflammation in normally aerated regions on PET

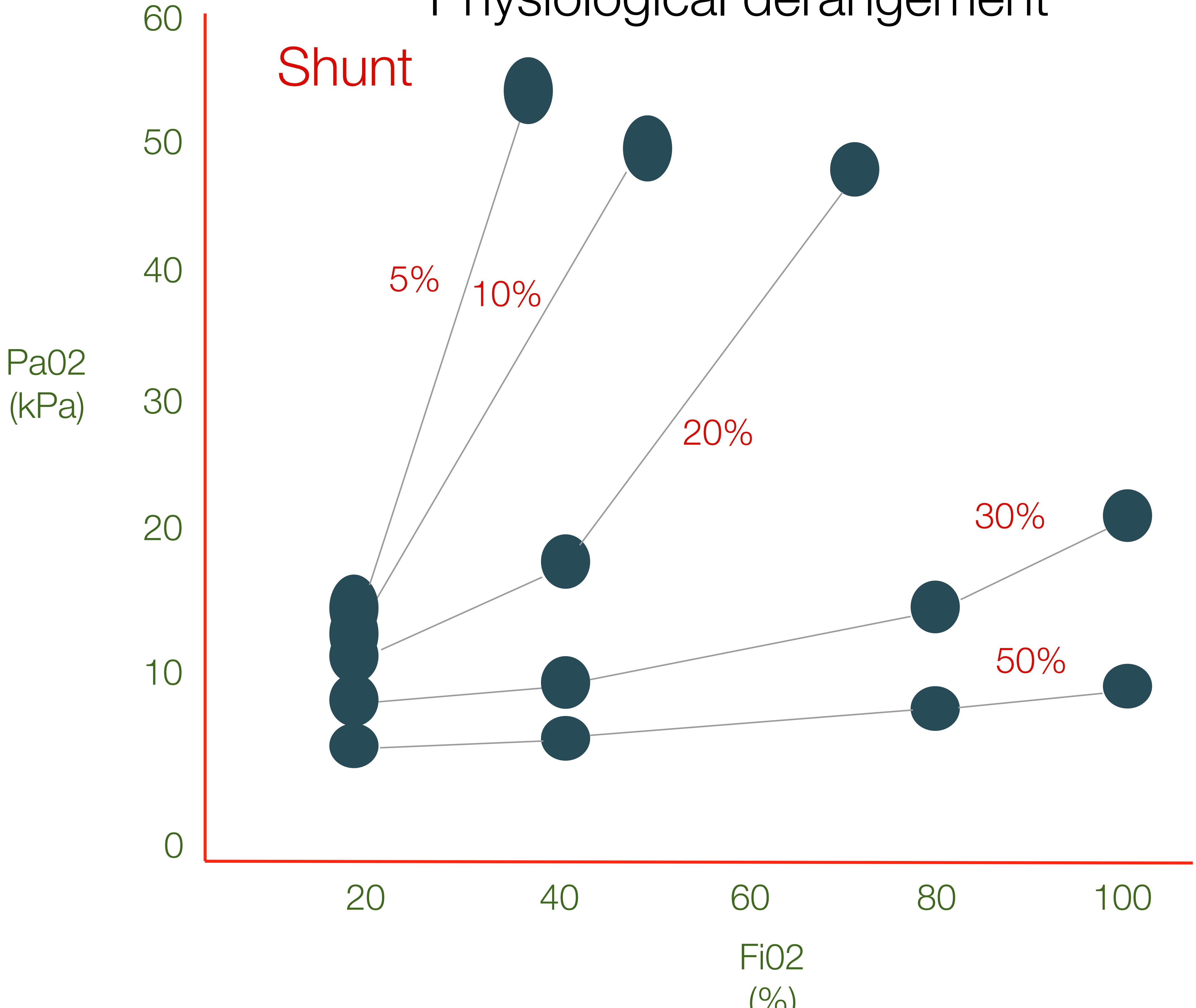


Crit Care Med 2009 Vol. 37, No. 7

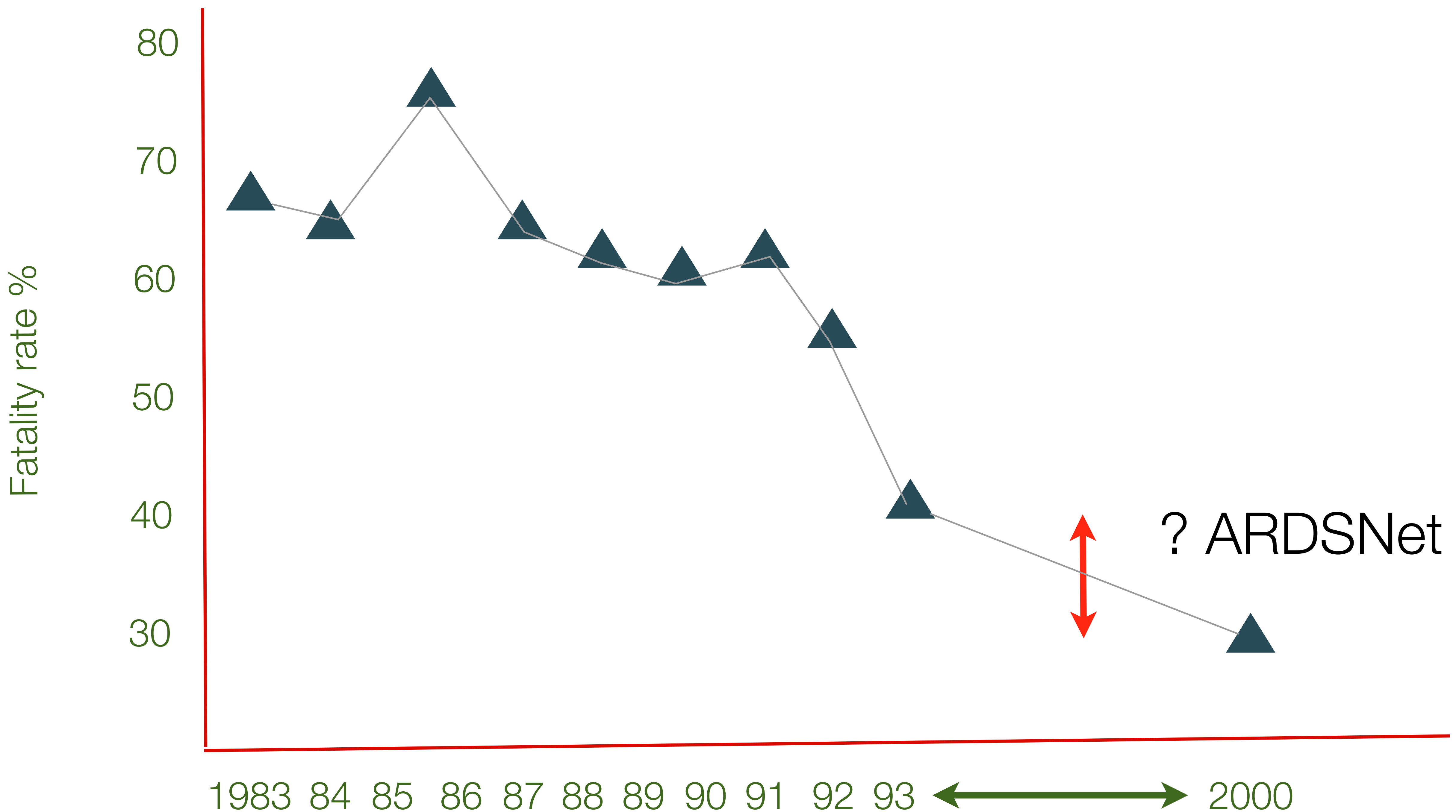
Time course of evolution of ARDS



Physiological derangement

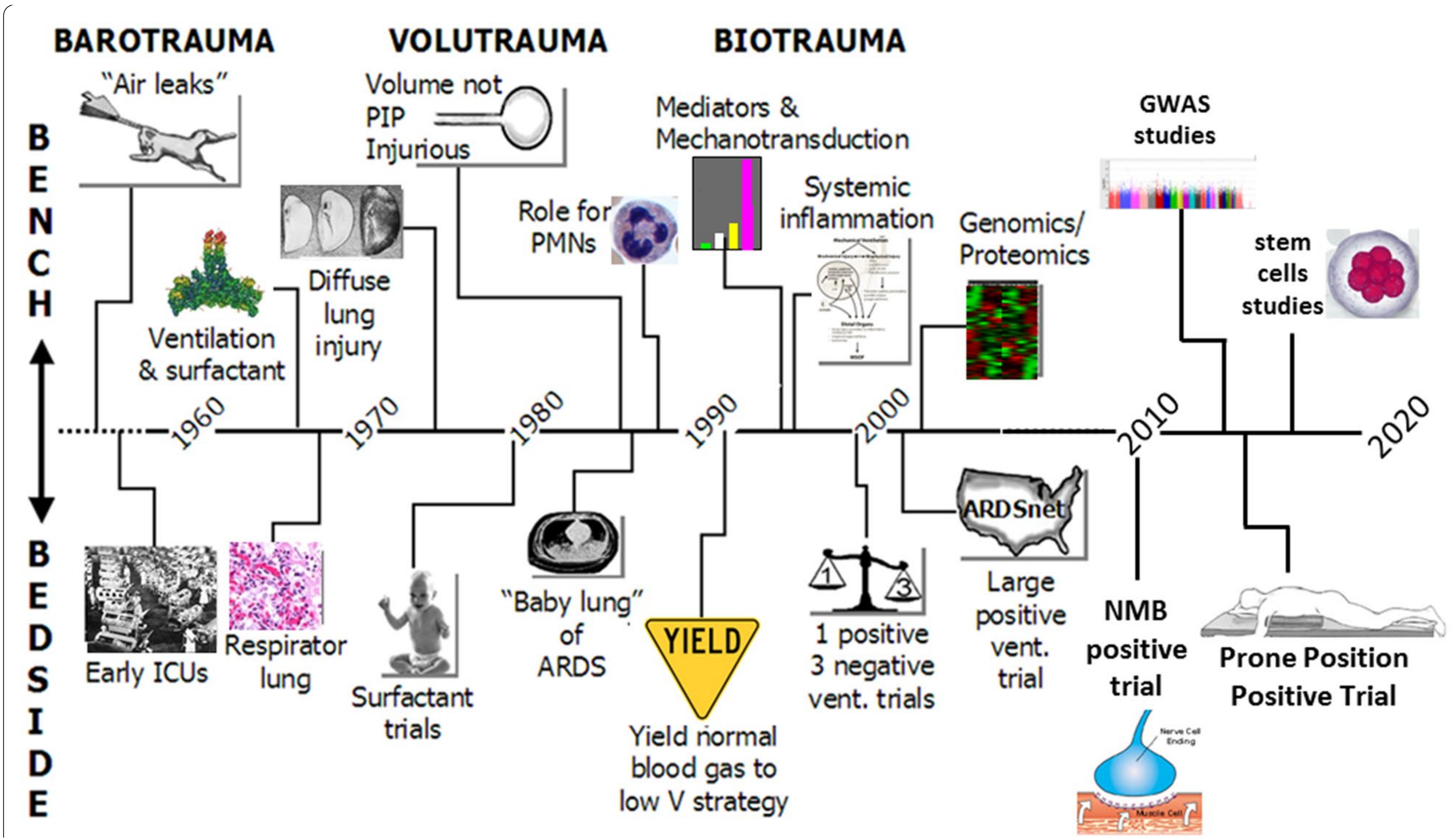


Mortality in ARDS



JAMA Jan 25, 1995-Vol 273, No. 4

Advances in ARDS



Intensive Care Med March 14, 2016

ARDS - Causes of death

16% from irreversible respiratory failure

74% ** from sepsis and multiple organ failure

Am Rev Respir Dis. 1985 Sep;132(3):485-9.

CHEST

ARDS - A Postmortem Study

- Of 9184 ITU admissions
  - 4.1% met clinical criteria of ARDS (45% died)
- At PM **only 50%** of clinical ARDS **actually had ARDS**!
  - 25% - Bronchopneumonia without ARDS
  - 12.5% - Invasive Aspergillosis
    - Only 1/4 had positive sputum
- Lung Weight ~ 1850 gm (N ~ 800 gm)
- Unexpected autopsy finding in 23%

Treatment goals

- **Treat primary condition**
- **Avoid further harm:**
  - Volutrauma
  - Barotrauma
  - Biotrauma
  - Recruitment/de-recruitment
  - Fluid overload

Only really effective treatment is to **avoid further harm !!**

Clinical Case

49 yr old female

Acute respiratory distress following H1N1 flu

Ventilated for 8 days with high Fi02

Tidal volumes ~ 500 mL

No improvement in deteriorating 02 sats

Called Leicester ECMO center for transfer

Refused!

Why?

Ventilator Induced Lung Injury-“VILI”

Vincent *et al. Critical Care* 2010, **14**:311
http://ccforum.com/content/14/3/311

CRITICAL CARE

VIEWPOINT

Thirty years of critical care medicine

Jean-Louis Vincent*[1], Mervyn Singer[2], John J Marini[3], Rui Moreno[4], Mitchell Levy[5], Michael A Matthay[6], Michael Pinsky[7], Andrew Rhodes[8], Niall D Ferguson[9], Timothy Evans[10], Djillali Annane[11] and Jesse B Hall[12]

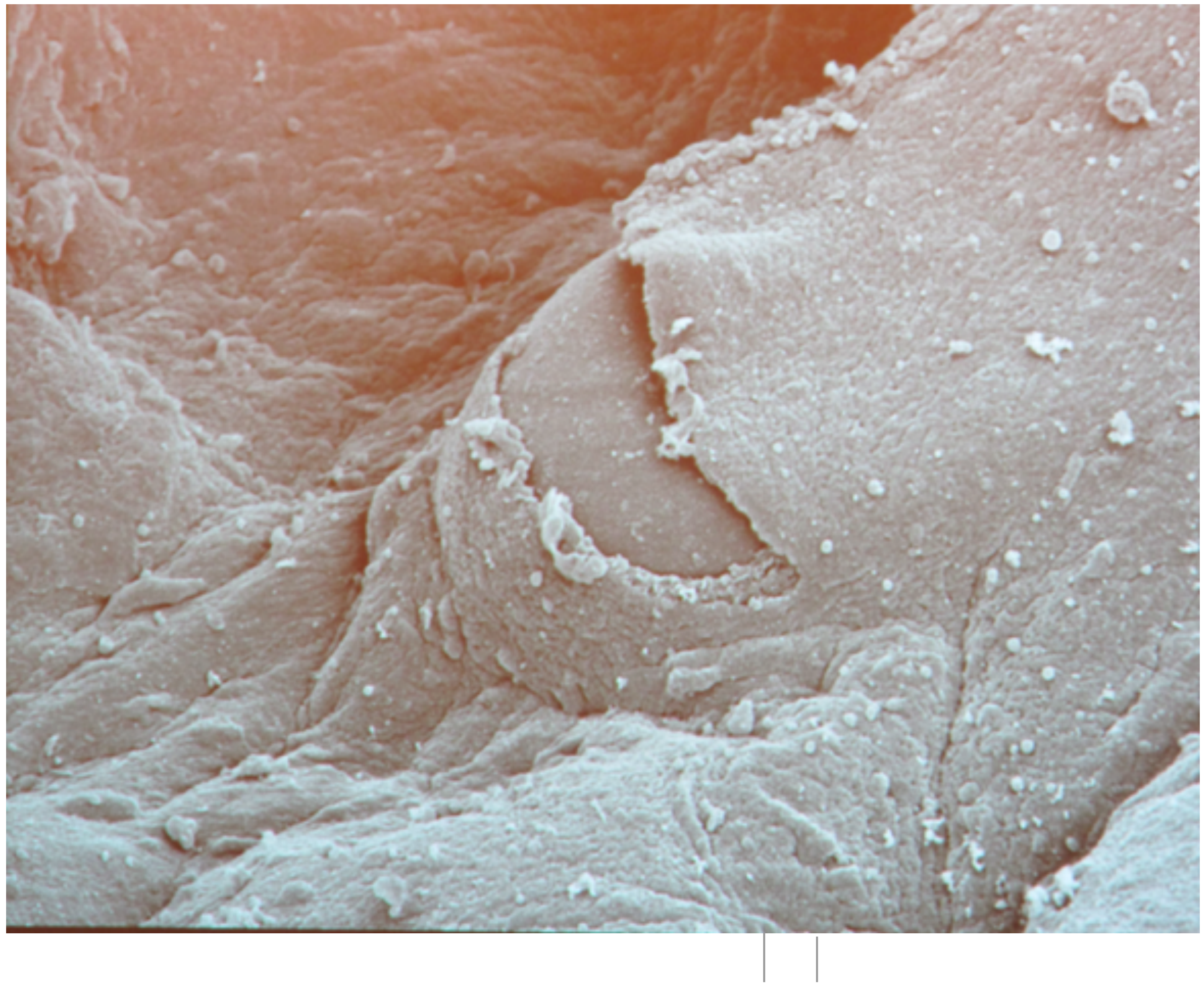
"...we have made major progress in the ventilatory treatment of patients with ARDS over the past 30 years through the recognition and avoidance of iatrogenic ventilator- induced lung injury (VILI) by **limiting tidal volumes** and airway pressures."

Avoid over-stretch of lungs

Control 5 min 20 min

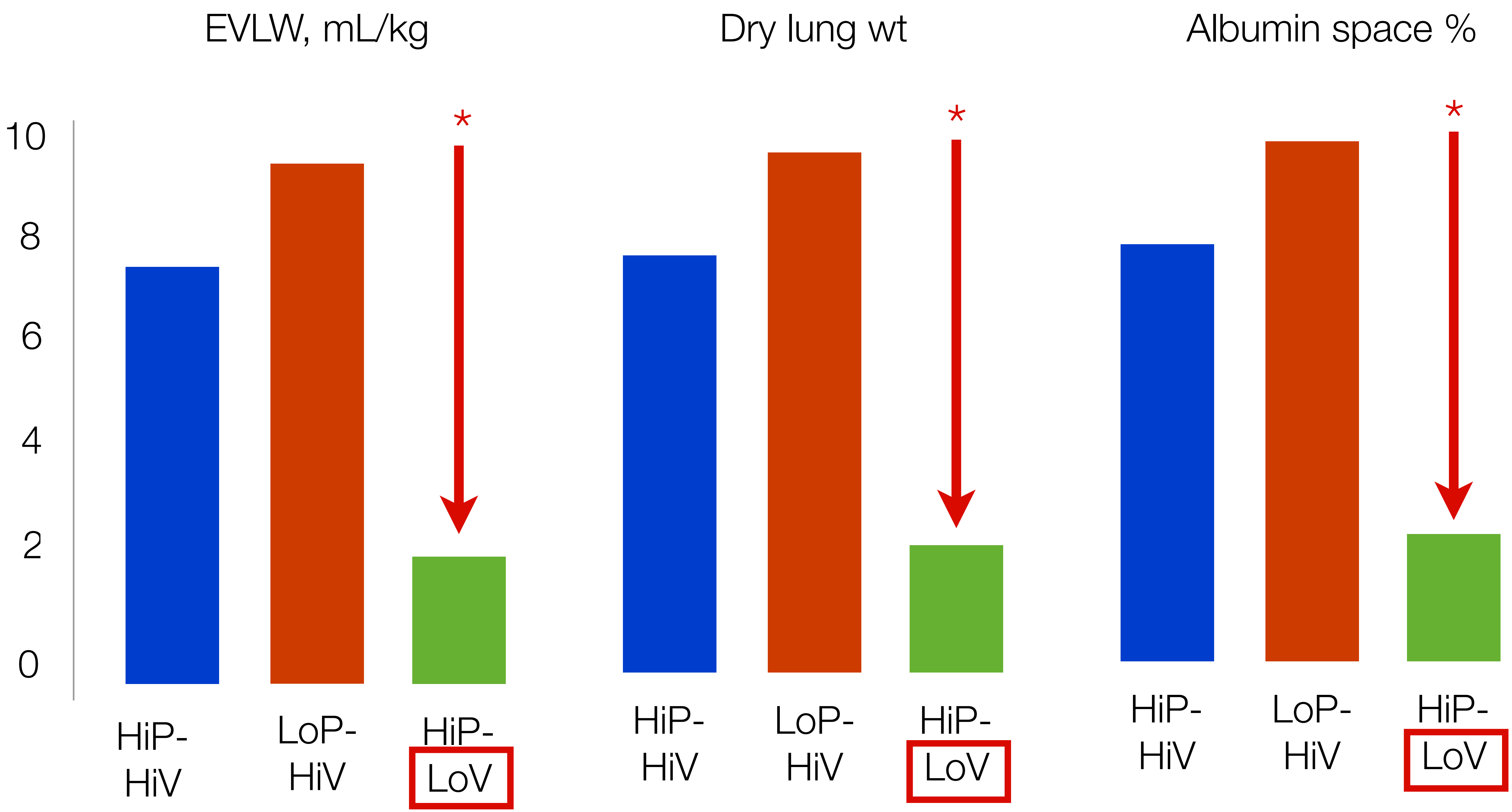
PIP of 45 cm H20

Endothelium and epithelium are injured at high lung volumes and pressures



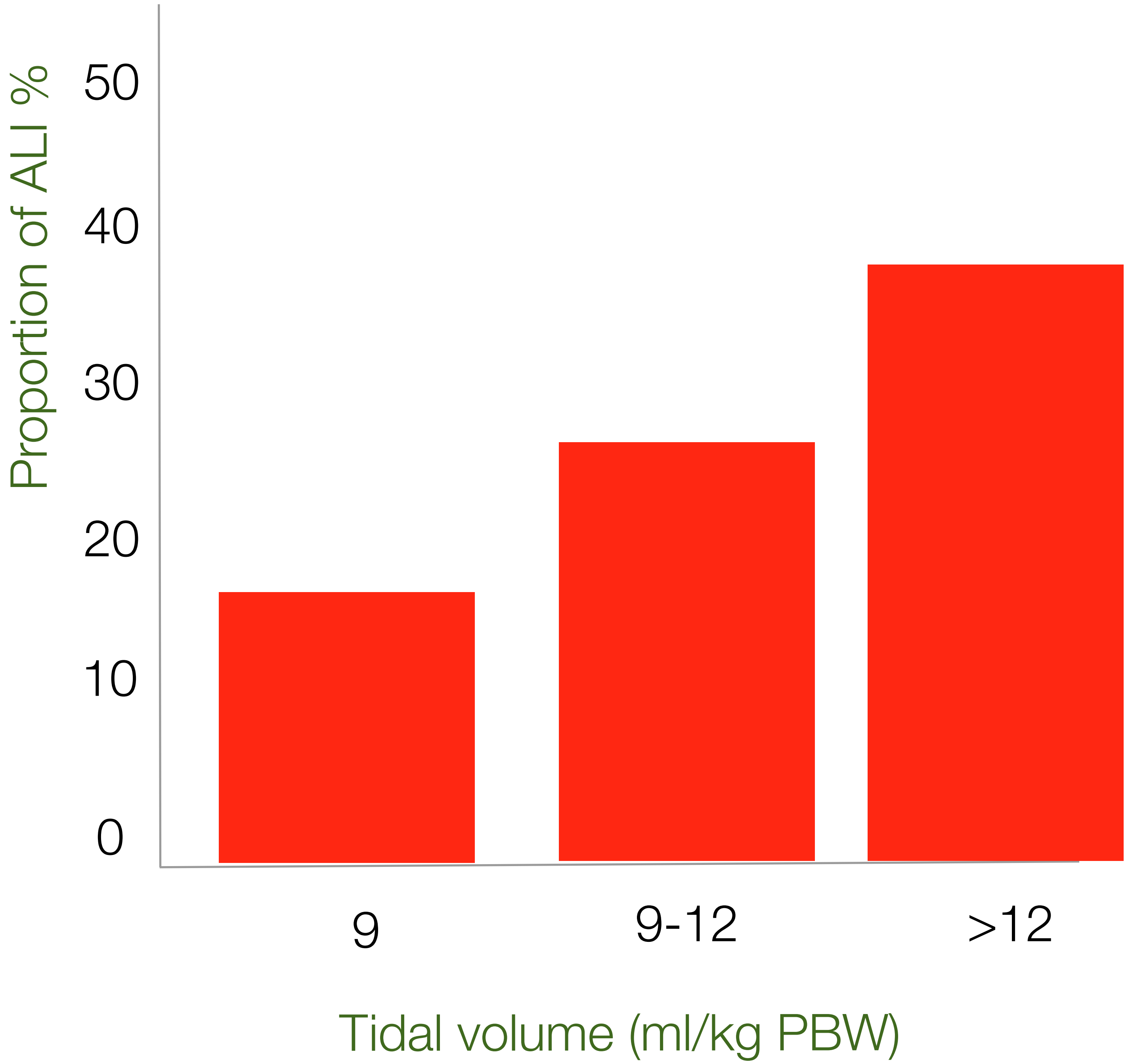
Fu Z et al J Appl Physiol 1992 73: 123-133

VILI - Volutrauma or Barotrauma ?



Dreyfuss D and Saumon G Am Rev Resp D 1988 137; 1159-1164

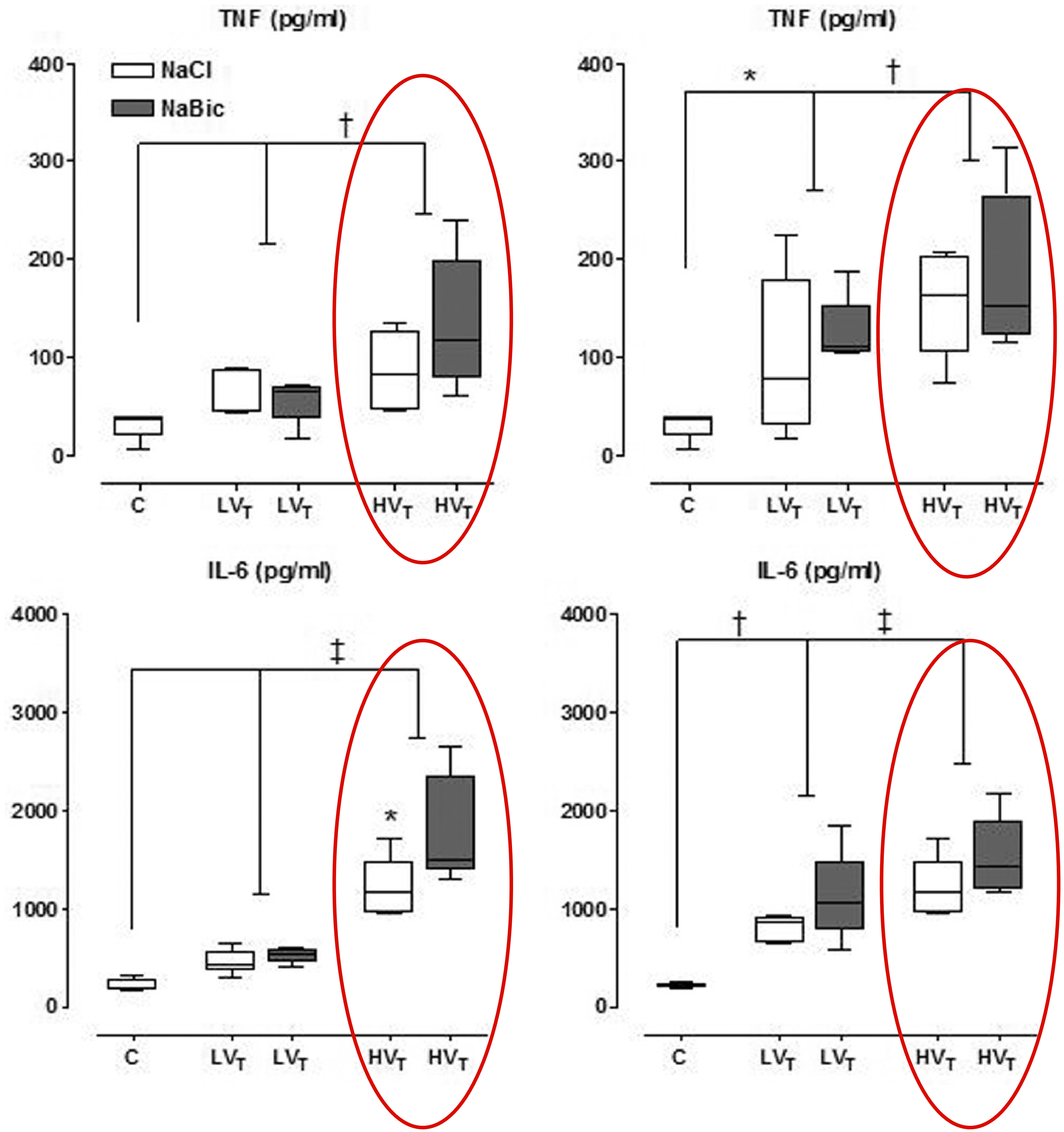
You can induce VILI- in normal lungs!



Gajic O. CCM 2004;32:1817

Systemic effects of volutrauma

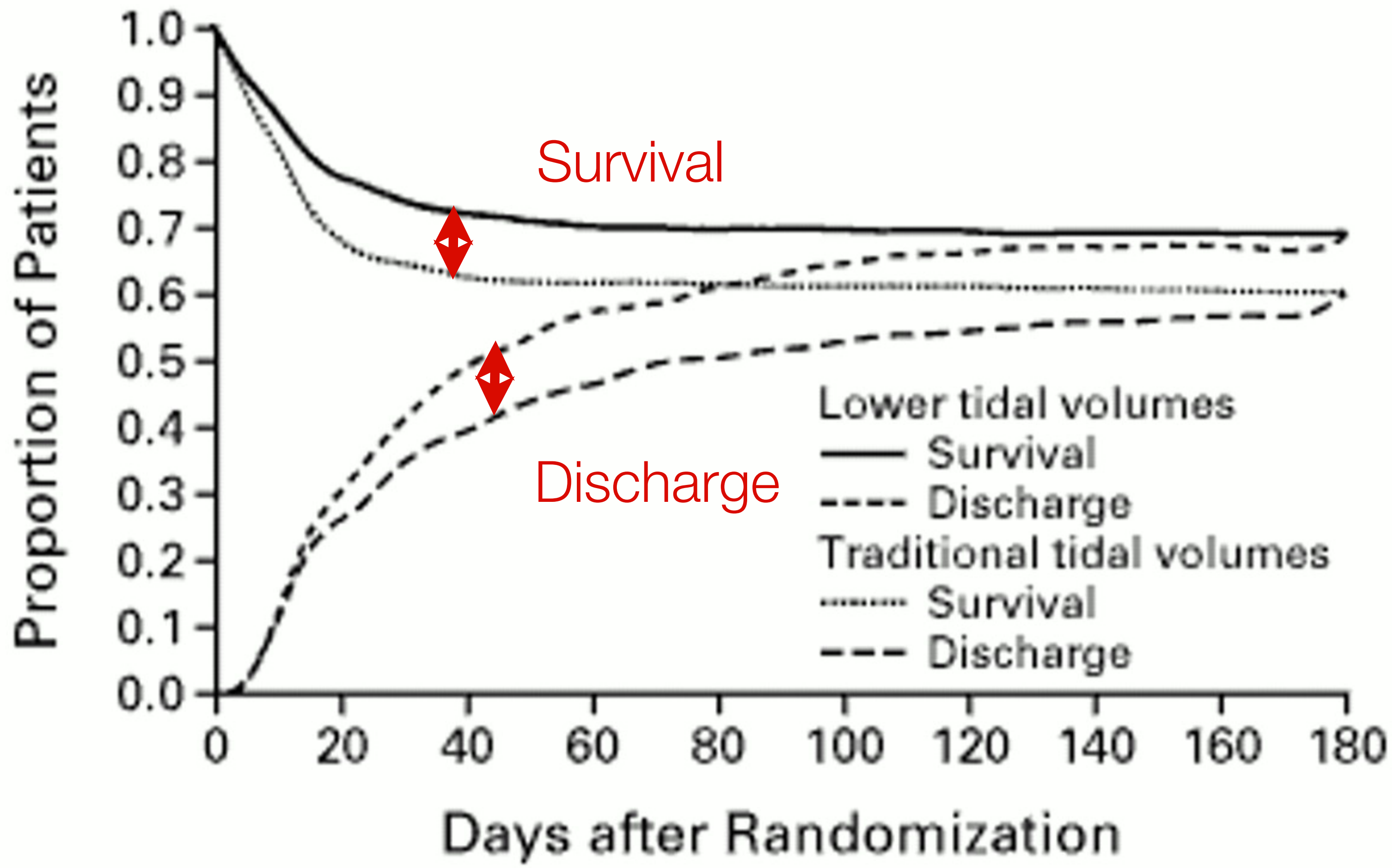
High tidal volumes associated with increased release of cytokines



Bio trauma…i.e., high tidal volumes effect whole body, not just lungs!

Critical Care 2009, 13:R1

Low vs high tidal volumes in ARDS/ALI



Mortality

12 ml/kg pbw
40%

6 ml/kg pbw
30%

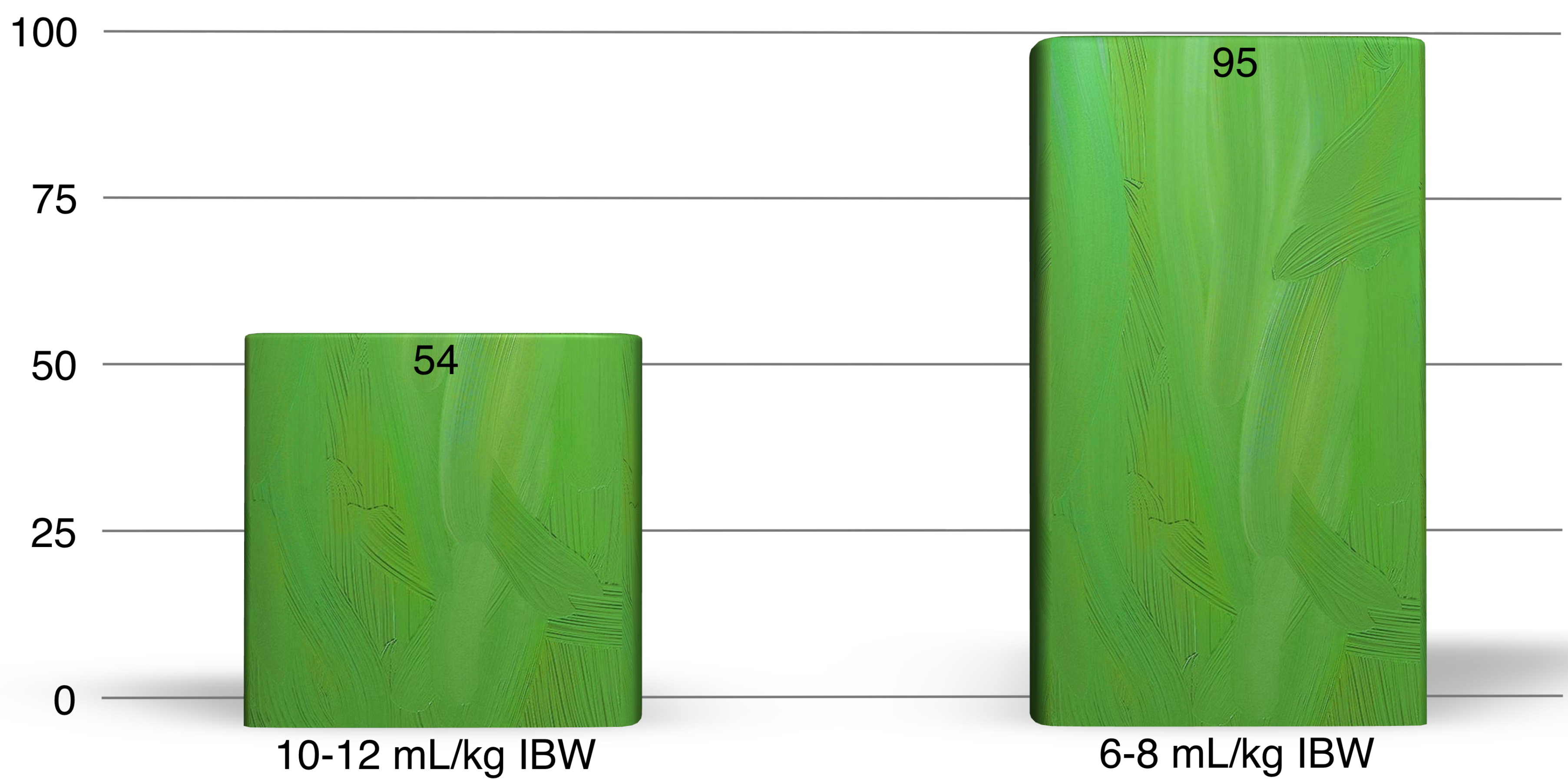
NEJM 2000;342:1301-1308

The NEW ENGLAND JOURNAL of MEDICINE

Effect of a Lung Protective Strategy for Organ Donors on Eligibility and Availability of Lungs for Transplantation

A Randomized Controlled Trial

Lung donor eligibility



JAMA. 2010;304(23):2620-2627

BMJ

Lung protective mechanical ventilation and two year survival in patients with acute lung injury: prospective cohort study

- Survival advantage of using <6.5 ml/kg IBW
- Only 41% used lung protective ventilation
- **64% died** within **two years**
- For **each 1 mL/kg** increase in tidal volume **over** that estimated using predicted body weight, there was an **18% relative increase** in the risk of **mortality** at two years

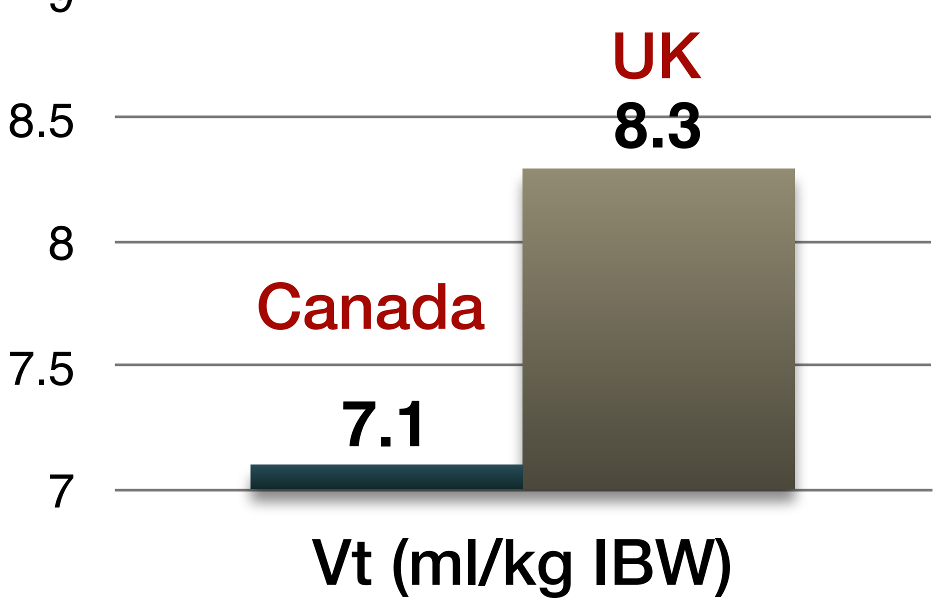
BMJ 2012;344: 5 April 2012

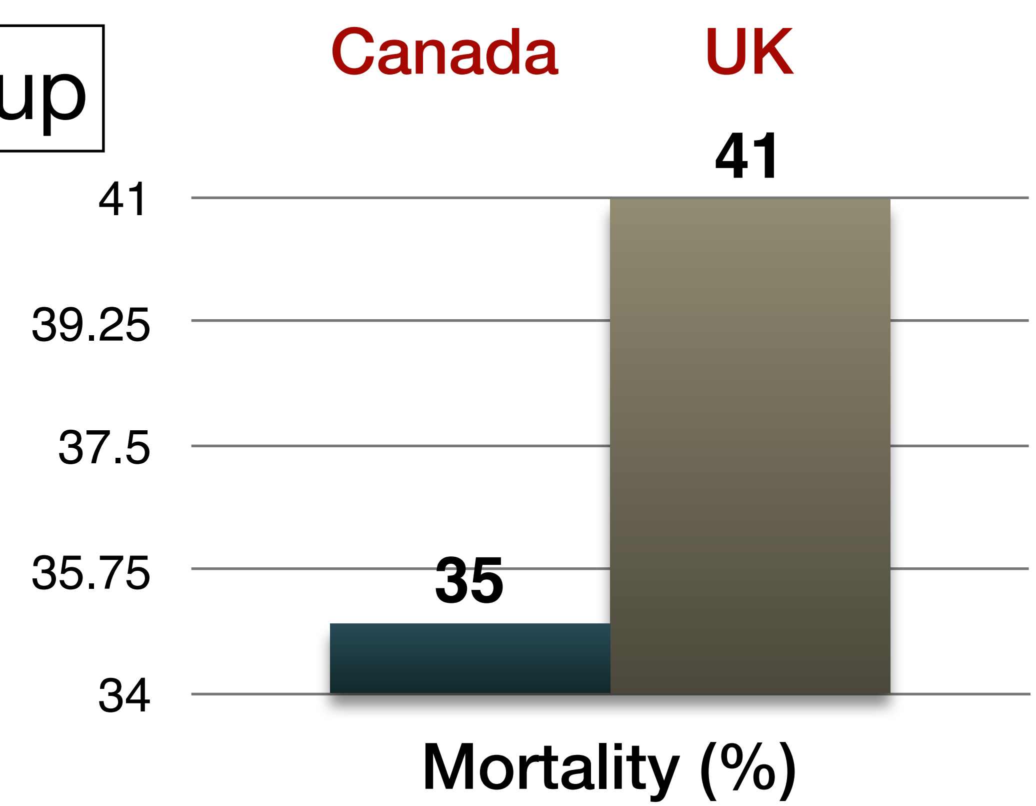
The NEW ENGLAND JOURNAL of MEDICINE

ORIGINAL ARTICLE

High-Frequency Oscillation for Acute Respiratory Distress Syndrome

Control group





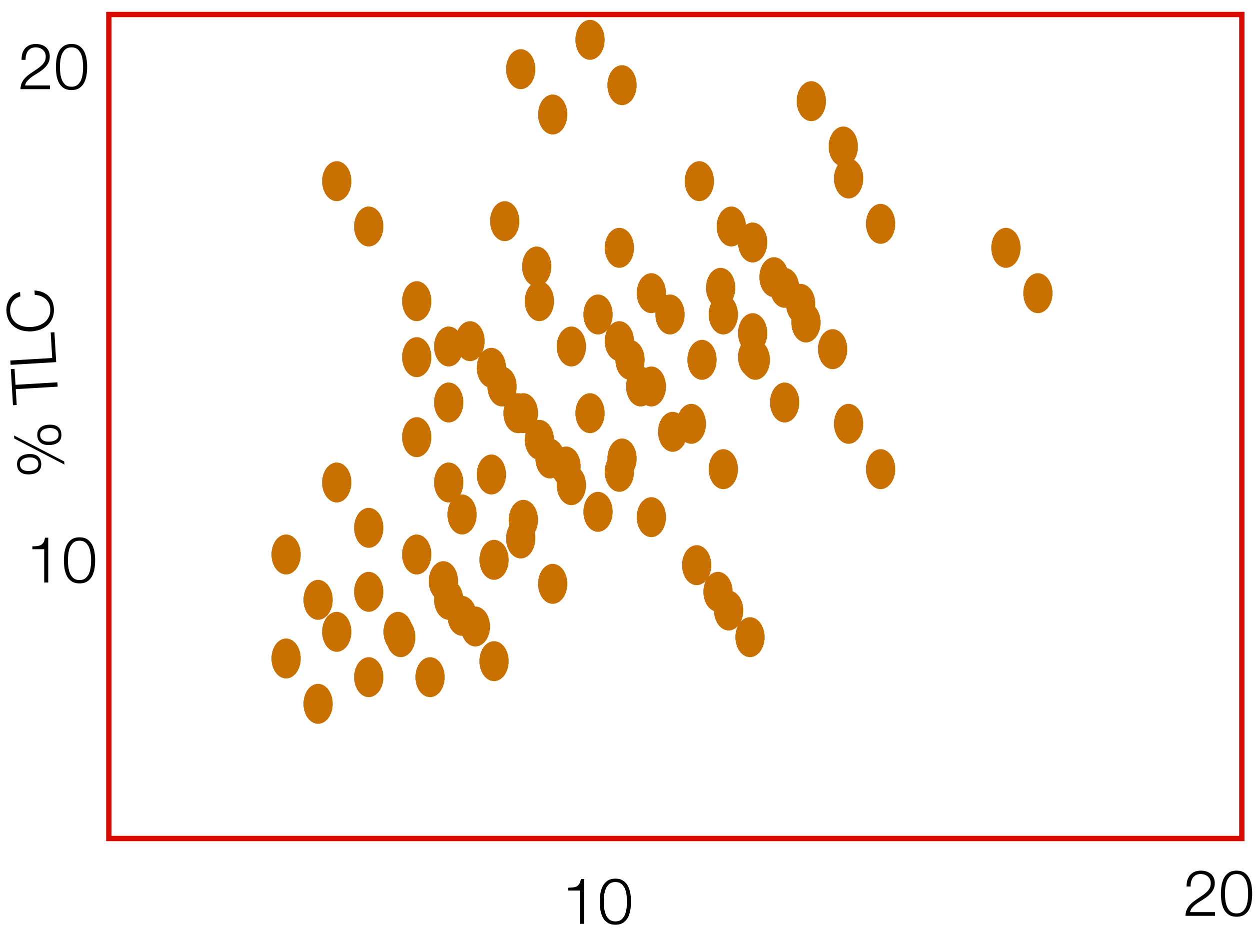
- Needham showed that Vt less than 6.5 ml/kg IBW had survival advantage

  (UK control ventilated with >8.3 **+/- 3.5** !!!)

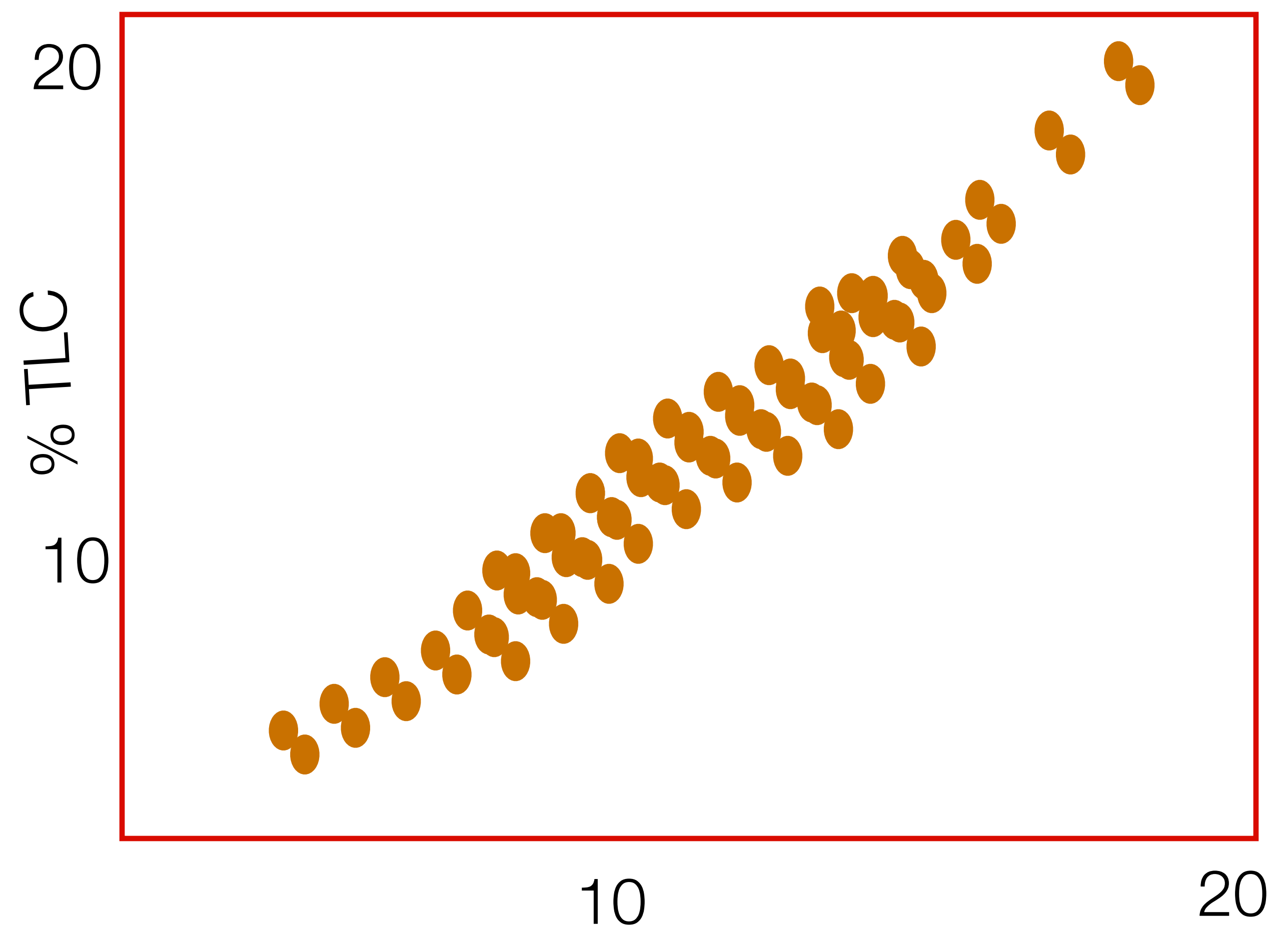
- Given the SD of **3.5** in OSCAR (UK)
  - >34% ventilated with Vt 8.3 to 12 ml/kg IBW
  - ~ 14% ventilated with between 12 to 15.5 ml/kg IBW !

N Engl J Med January 22, 2013.

Predicted or actual body weight of 332 ventilated patients plotted against total lung capacity (%TLC).



Vt mL/kg **actual** body weight



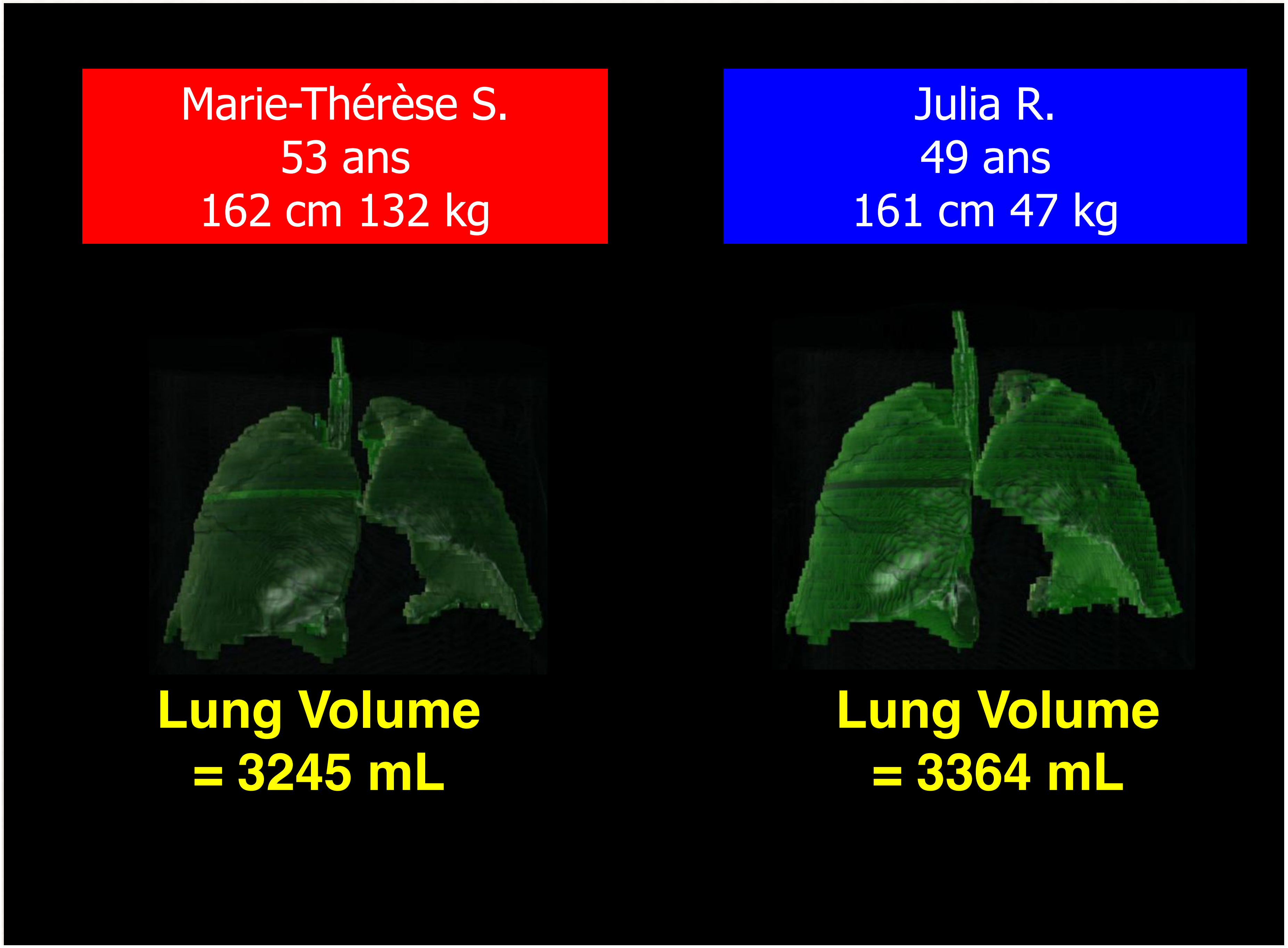
Vt mL/kg **predicted** body weight

The correlation between **actual** body **weight** and % TLC is extremely **poor**

Crit Care Med 2004 Vol. 32, No. 9

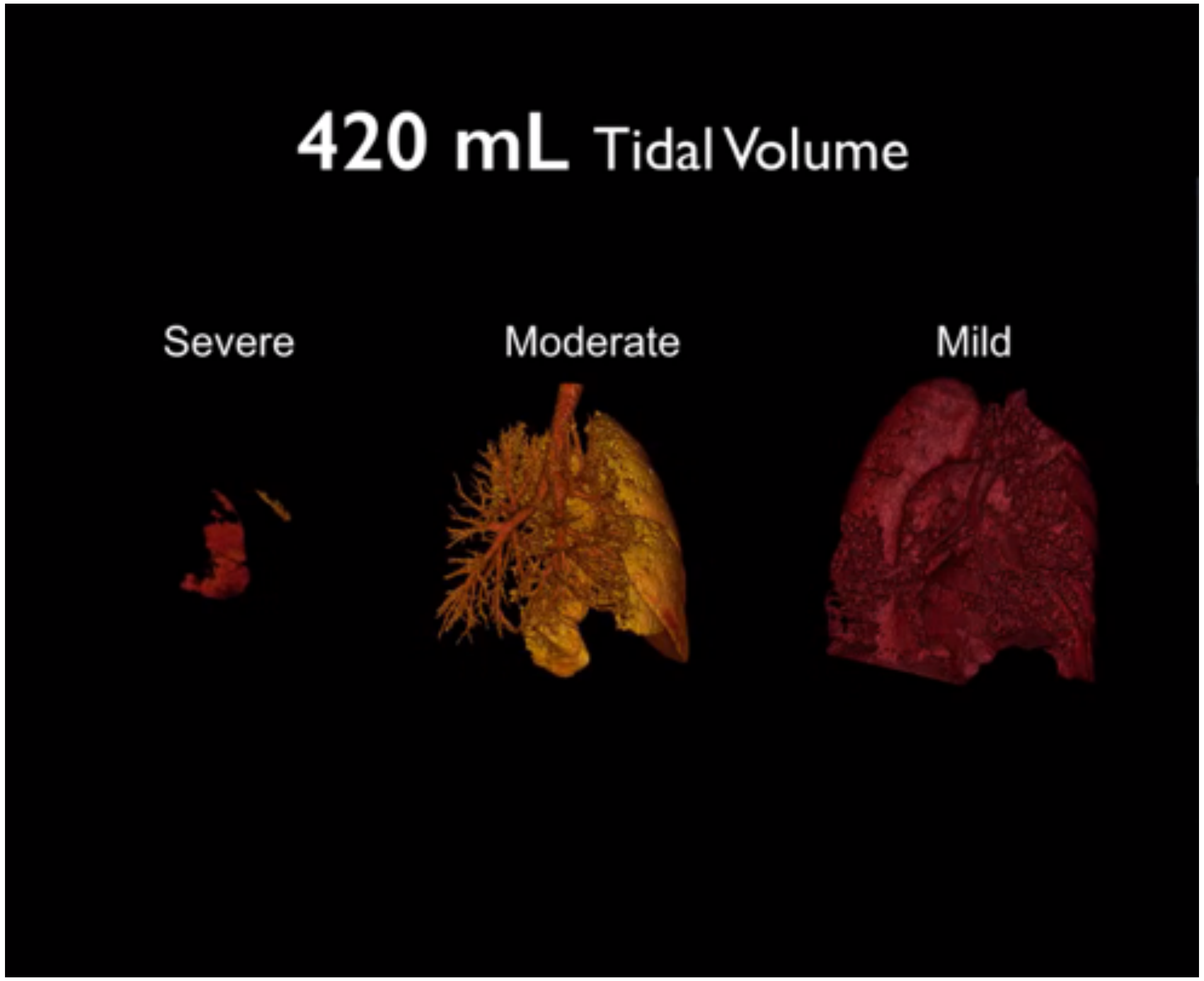
Don't forget protective tidal volumes are based on **ideal** (or predicted) body weight, which are based on **SEX** and **HEIGHT** (NOT weight!!)

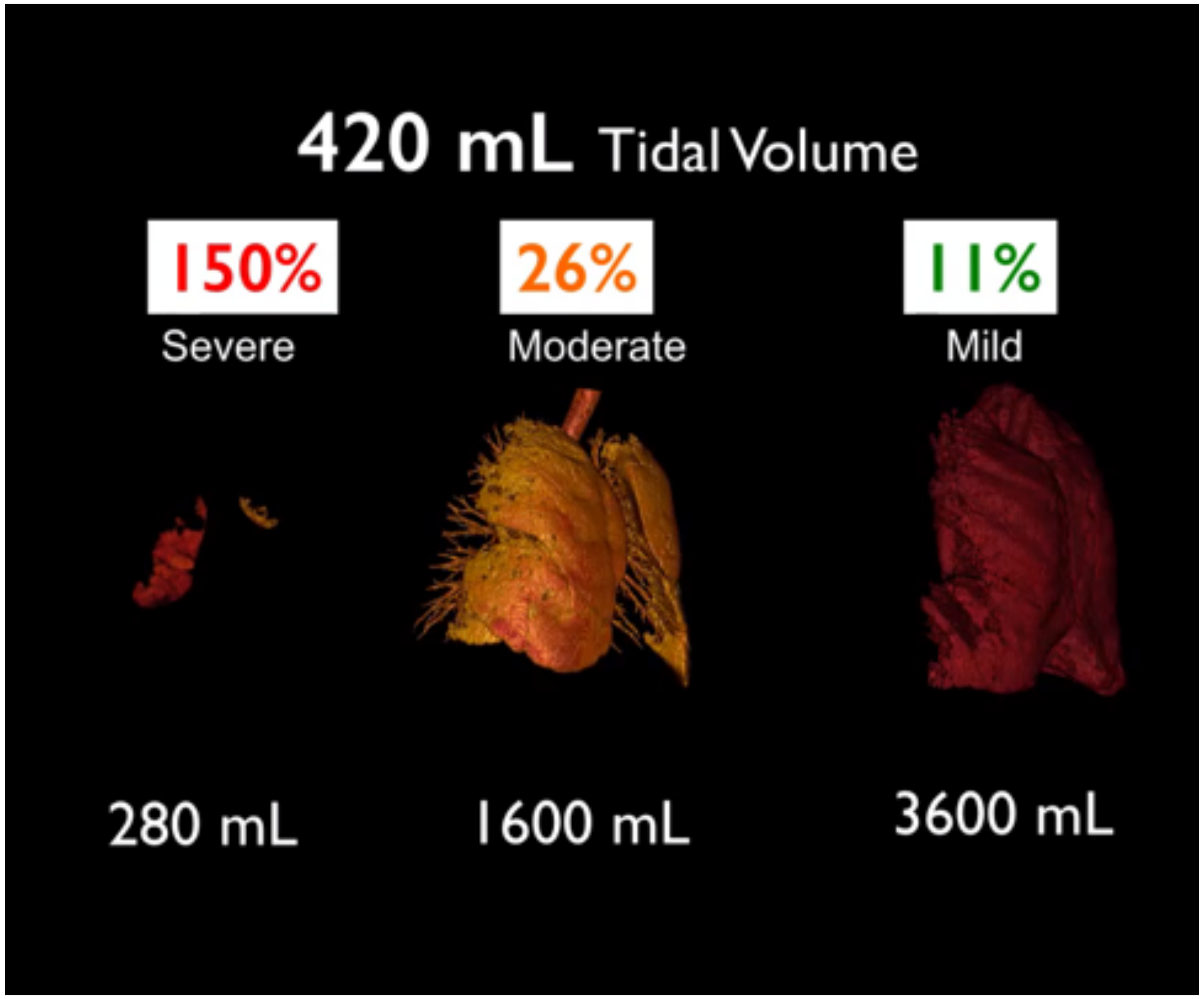
Don't forget protective tidal volumes are based on **ideal** (or predicted) body weight, which are based on **SEX** and **HEIGHT** (NOT weight!!)



6 ml/kg IBW?

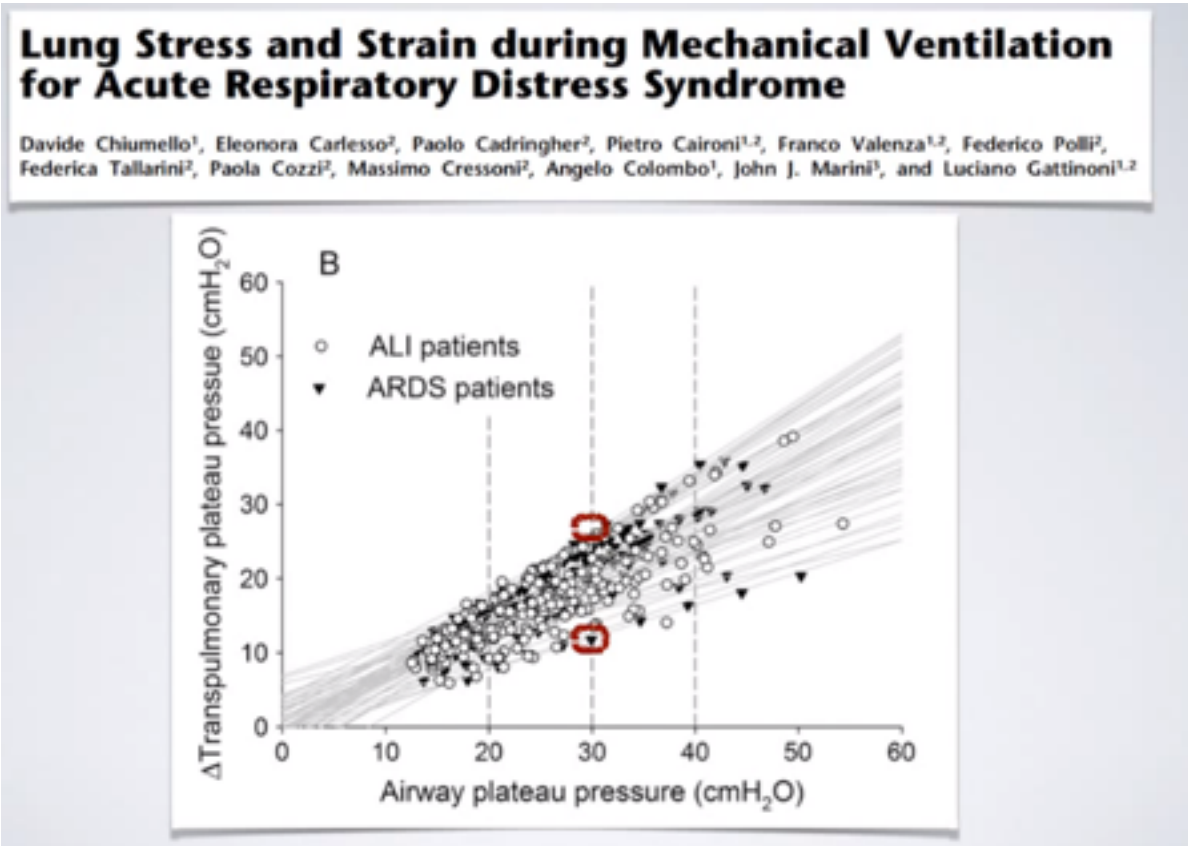
New slide?

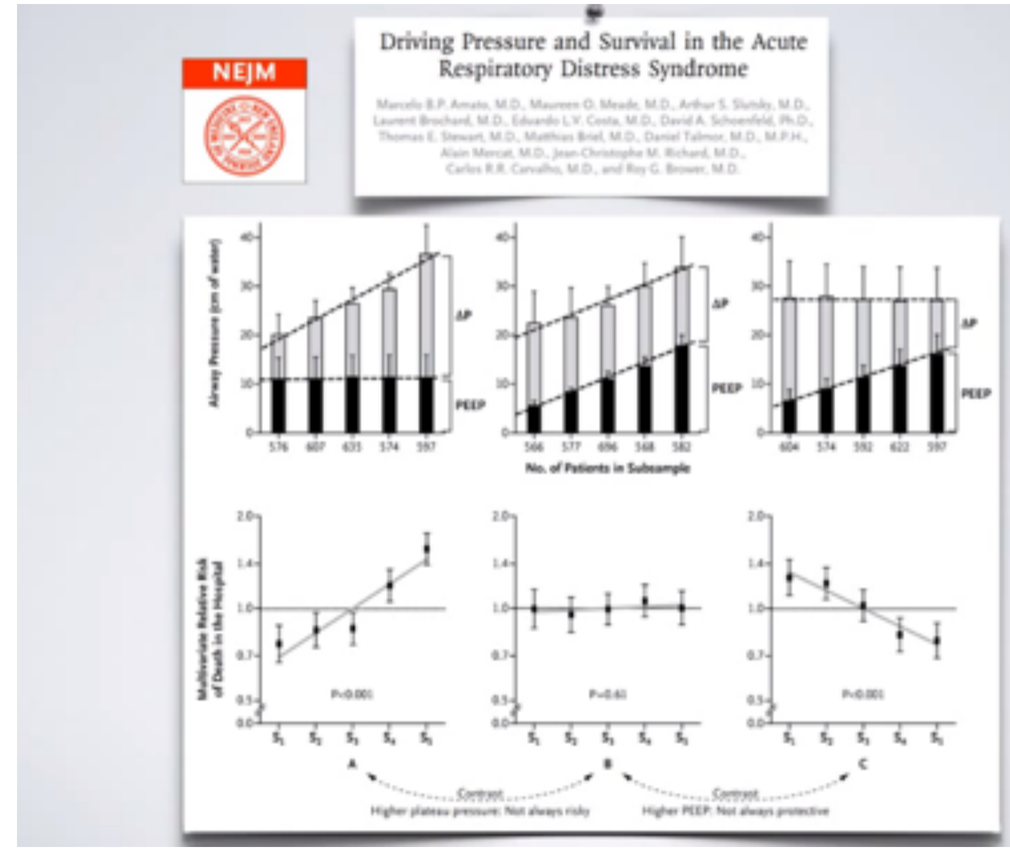


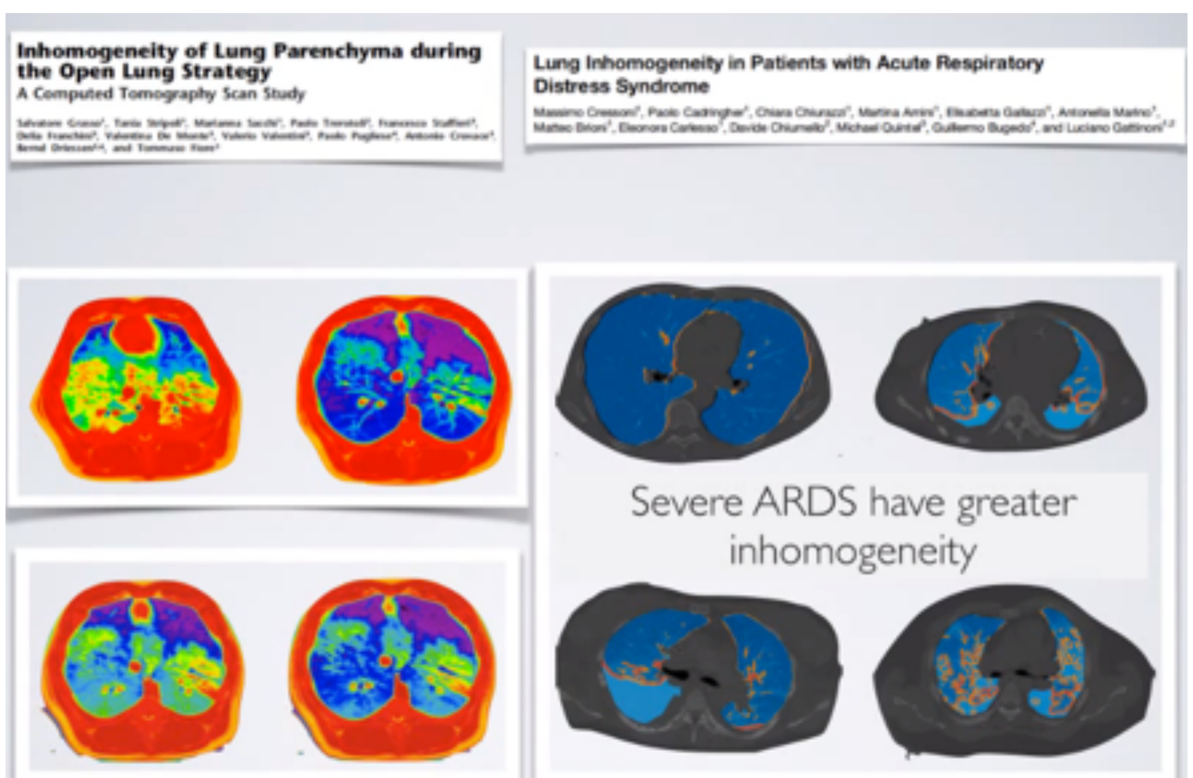


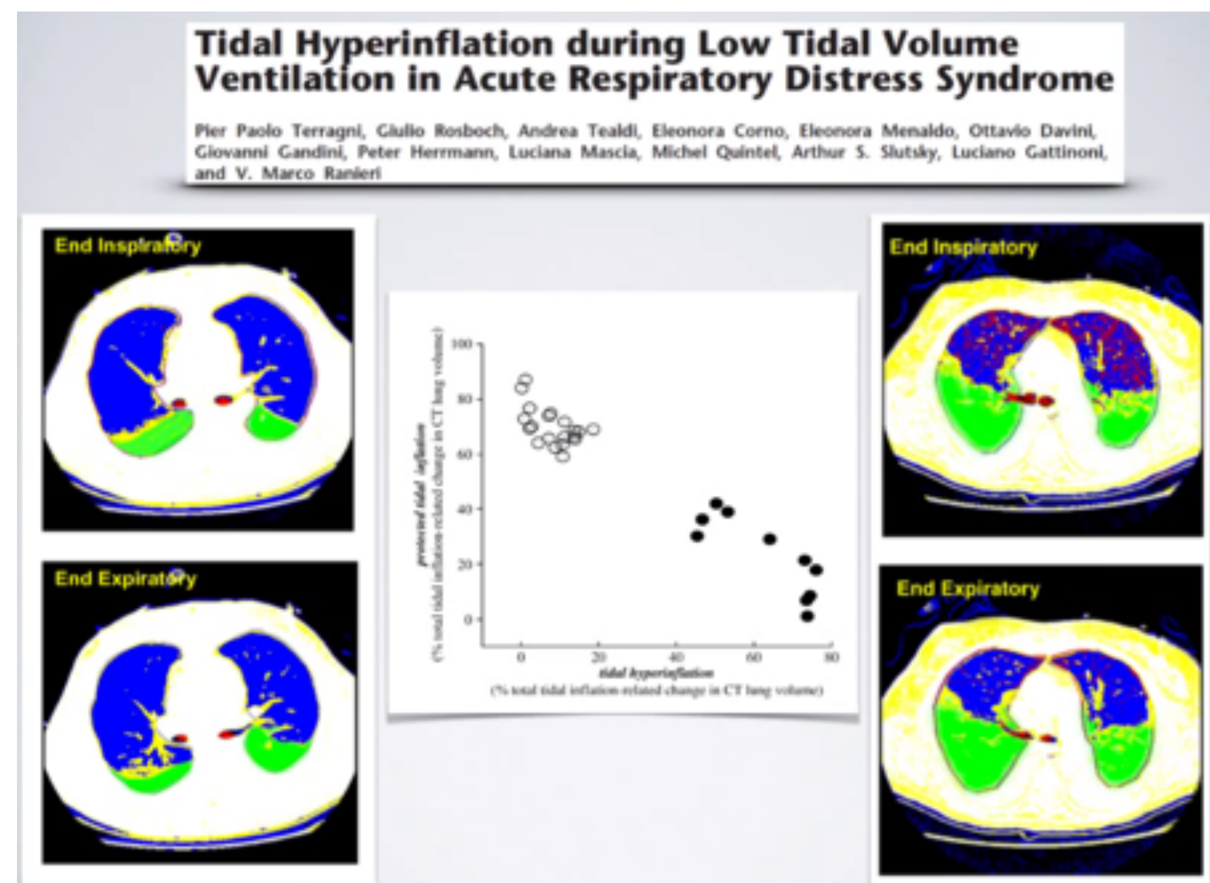
"Baby lung"

New slide?

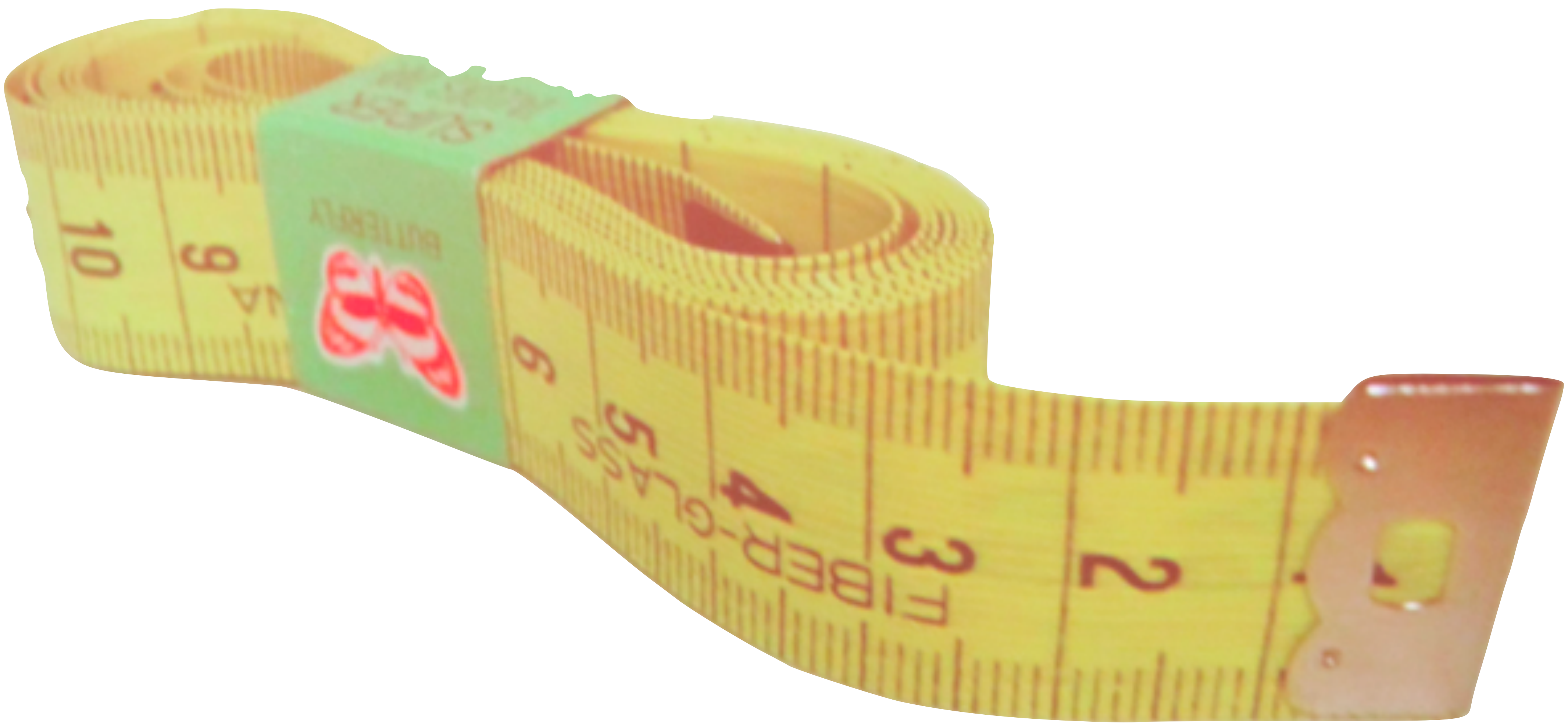

Lung Stress and Strain during Mechanical Ventilation for Acute Respiratory Distress Syndrome
Davide Chiumello[1], Eleonora Carlesso[2], Paolo Cadringher[2], Pietro Caironi[1,2], Franco Valenza[1,2], Federico Polli[2], Federica Tallarini[2], Paola Cozzi[2], Massimo Cressoni[2], Angelo Colombo[1], John J. Marini[3], and Luciano Gattinoni[1,2]
B
ALI patients
ARDS patients
ΔTranspulmonary plateau pressure (cmH2O)
Airway plateau pressure (cmH2O)
0
10
20
30
40
50
60


NEJM
Driving Pressure and Survival in the Acute Respiratory Distress Syndrome
ΔP
PEEP
No. of Patients in Subsample


Inhomogeneity of Lung Parenchyma during the Open Lung Strategy
A Computed Tomography Scan Study
Lung Inhomogeneity in Patients with Acute Respiratory Distress Syndrome
Massimo Cressoni, Paolo Cadringher, Chiara Chiurazzi, Martina Amini, Elisabetta Gallazzi, Antonella Marino, Matteo Brioni, Eleonora Carlesso, Davide Chiumello, Michael Quintel, Guillermo Bugedo, and Luciano Gattinoni
Severe ARDS have greater inhomogeneity


Tidal Hyperinflation during Low Tidal Volume Ventilation in Acute Respiratory Distress Syndrome
Pier Paolo Terragni, Giulio Rosboch, Andrea Tealdi, Eleonora Corno, Eleonora Menaldo, Ottavio Davini, Giovanni Gandini, Peter Herrmann, Luciana Mascia, Michel Quintel, Arthur S. Slutsky, Luciano Gattinoni, and V. Marco Ranieri
End Inspiratory
End Expiratory
End Inspiratory
End Expiratory
tidal hyperinflation

So don’t forget the tape measure!



Ventilatory goals

- Limit tidal volume to **4-8 ml/kg IBW**
  - Accept lower blood gases initially (>90% SaO_2)
  - Permissive hypercapnia (pH >7.20)
  - May need to increase RR
- Plateau pressures **< 30 cmH20**
  - Beware of cause of high pressures
    - Ex. Intra-abdo hypertension
    - Fighting the ventilator
    - May need to measure **TPP**

How low can you go !

CRITICAL CARE MEDICINE

Anesthesiology 2009; 111:826–35

Tidal Volume Lower than 6 ml/kg Enhances Lung Protection

Role of Extracorporeal Carbon Dioxide Removal

Pier Paolo Terragni, M.D., Lorenzo Del Sorbo, M.D.,* Luciana Mascia, M.D., Ph.D.,* Rosario Urbino, M.D.,* Erica L. Martin, Ph.D.,* Alberto Birocco, M.D.,† Chiara Faggiano, M.D.,† Michael Quintel, M.D.,‡ Luciano Gattinoni, M.D.,§ V. Marco Ranieri, M.D.‖*

Maybe we should be interested in driving pressure

The NEW ENGLAND JOURNAL of MEDICINE

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.,

Driving pressure (ΔP) = Tidal volume / Compliance (Respiratory system)

"We found a strong association between ΔP and survival **even though all the ventilator settings that were used were lung-protective**"

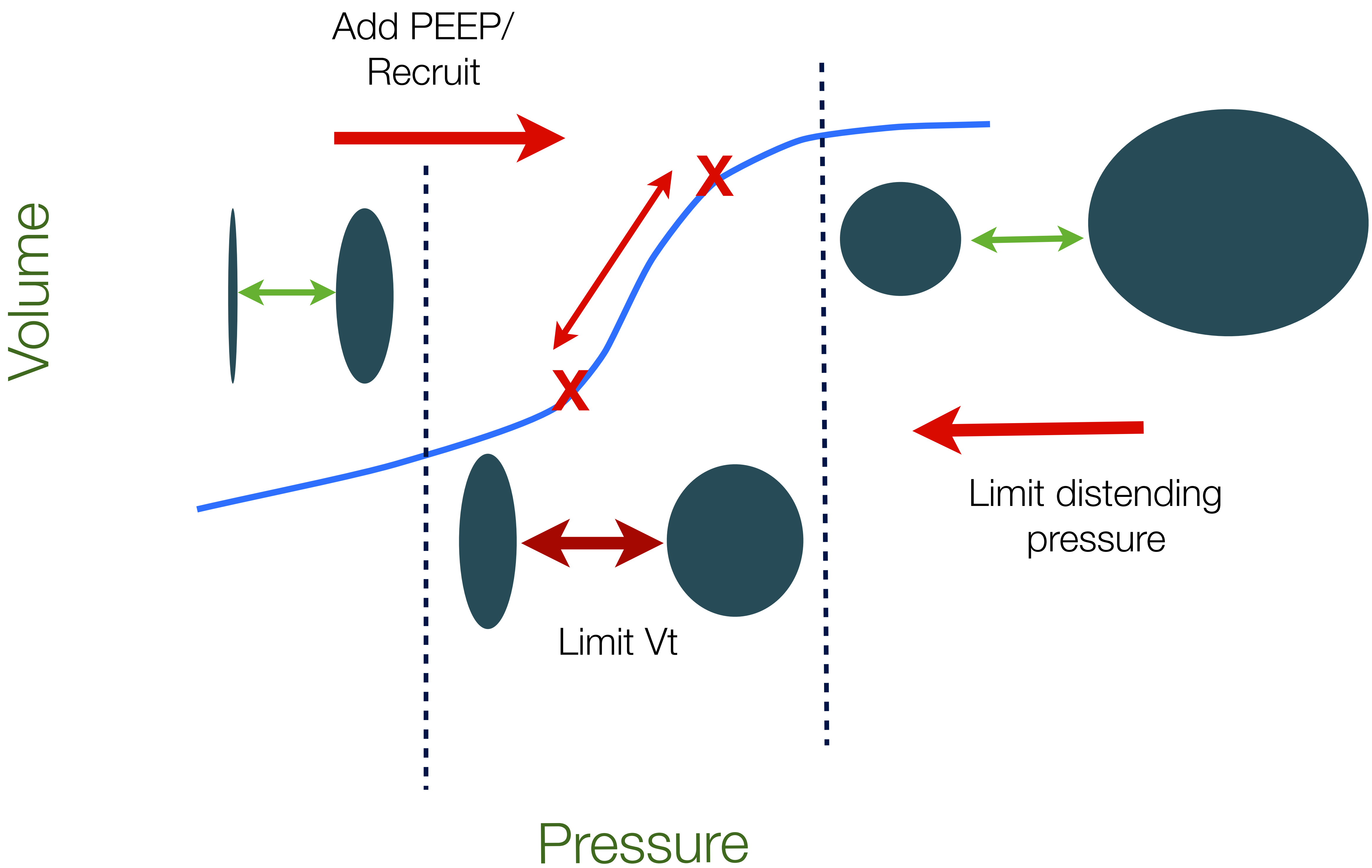
"limiting driving pressure…to scale the **delivered breath to the size of the (baby) lung**…rather than scaling to body size."

N Engl J Med 2015;372:747-55

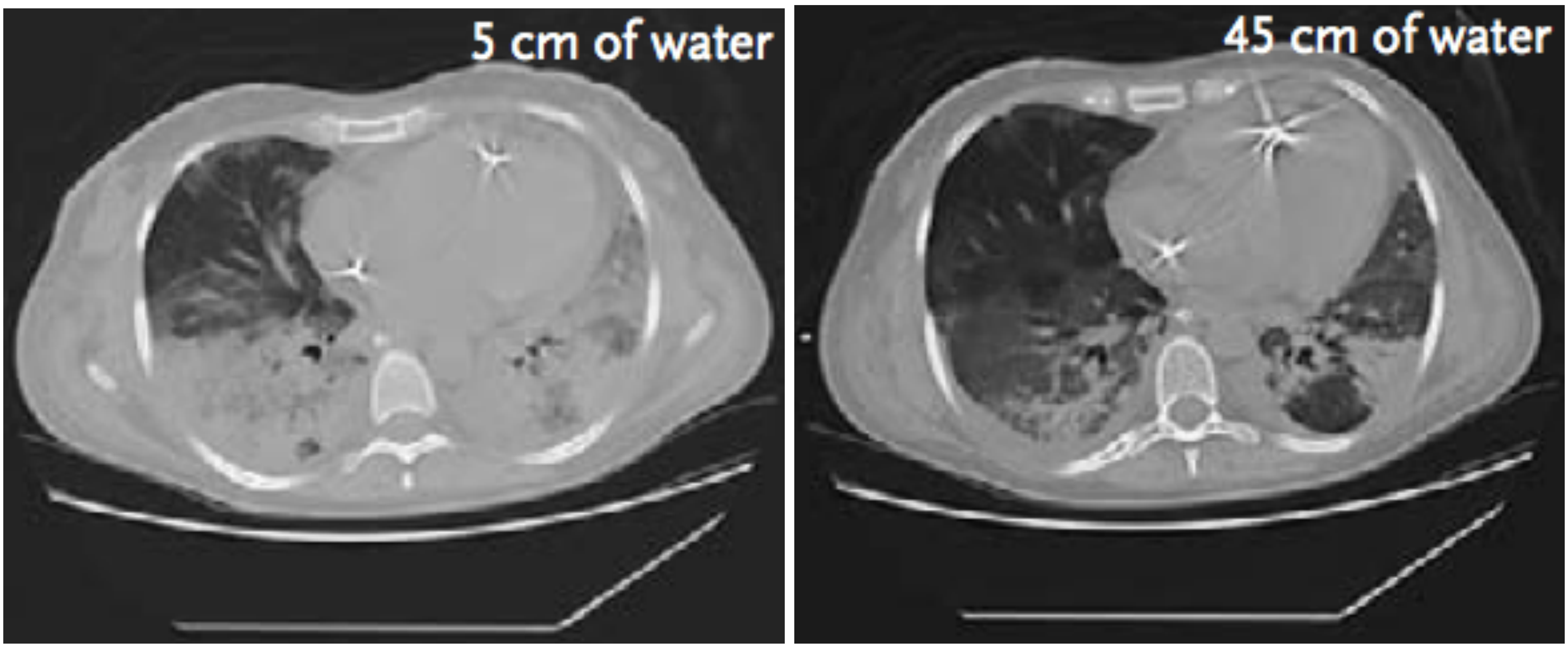
“Lung protective ventilation”

Avoid recruitment/de-recruitment

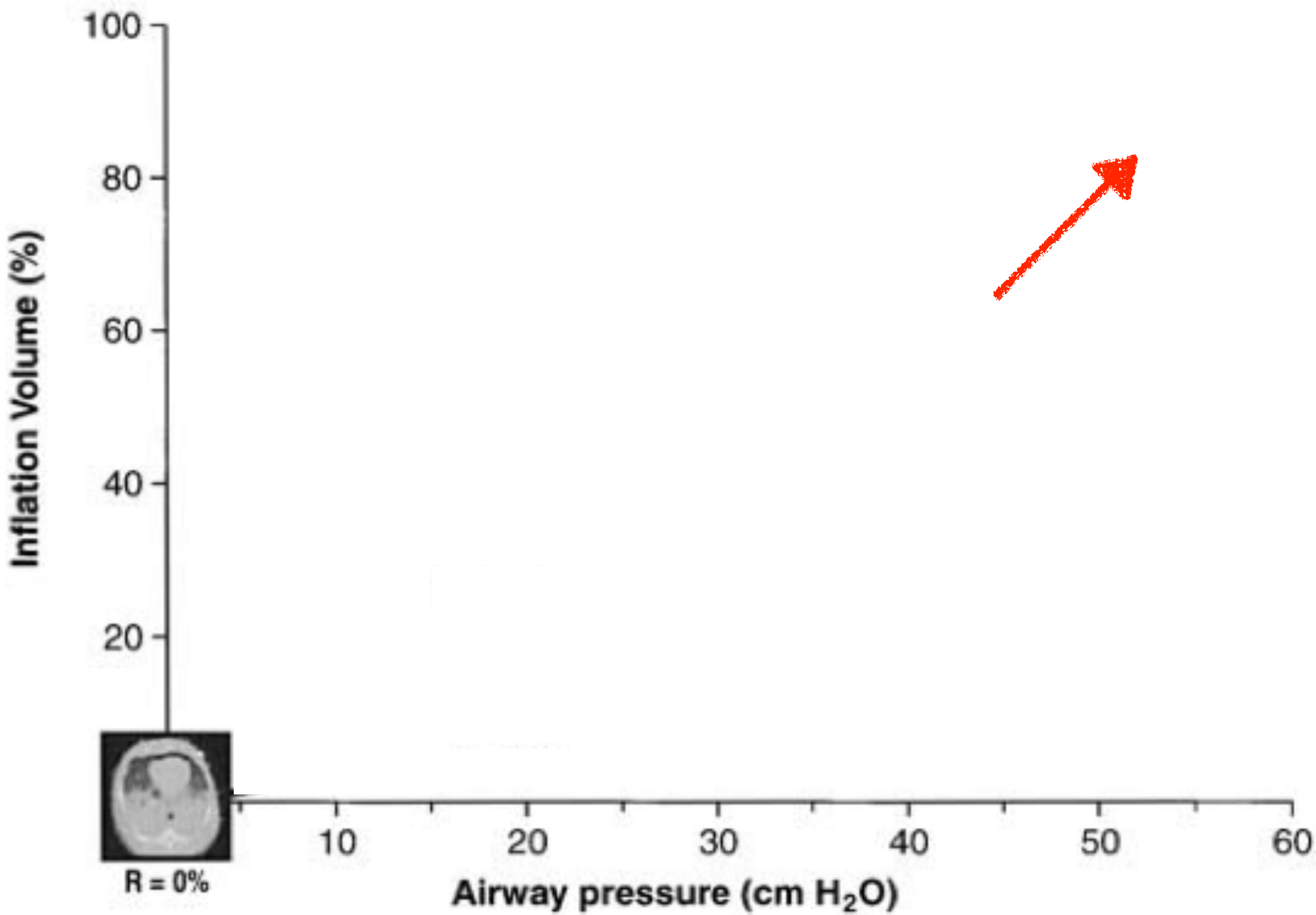
Preventing overdistension and under-recruitment injury



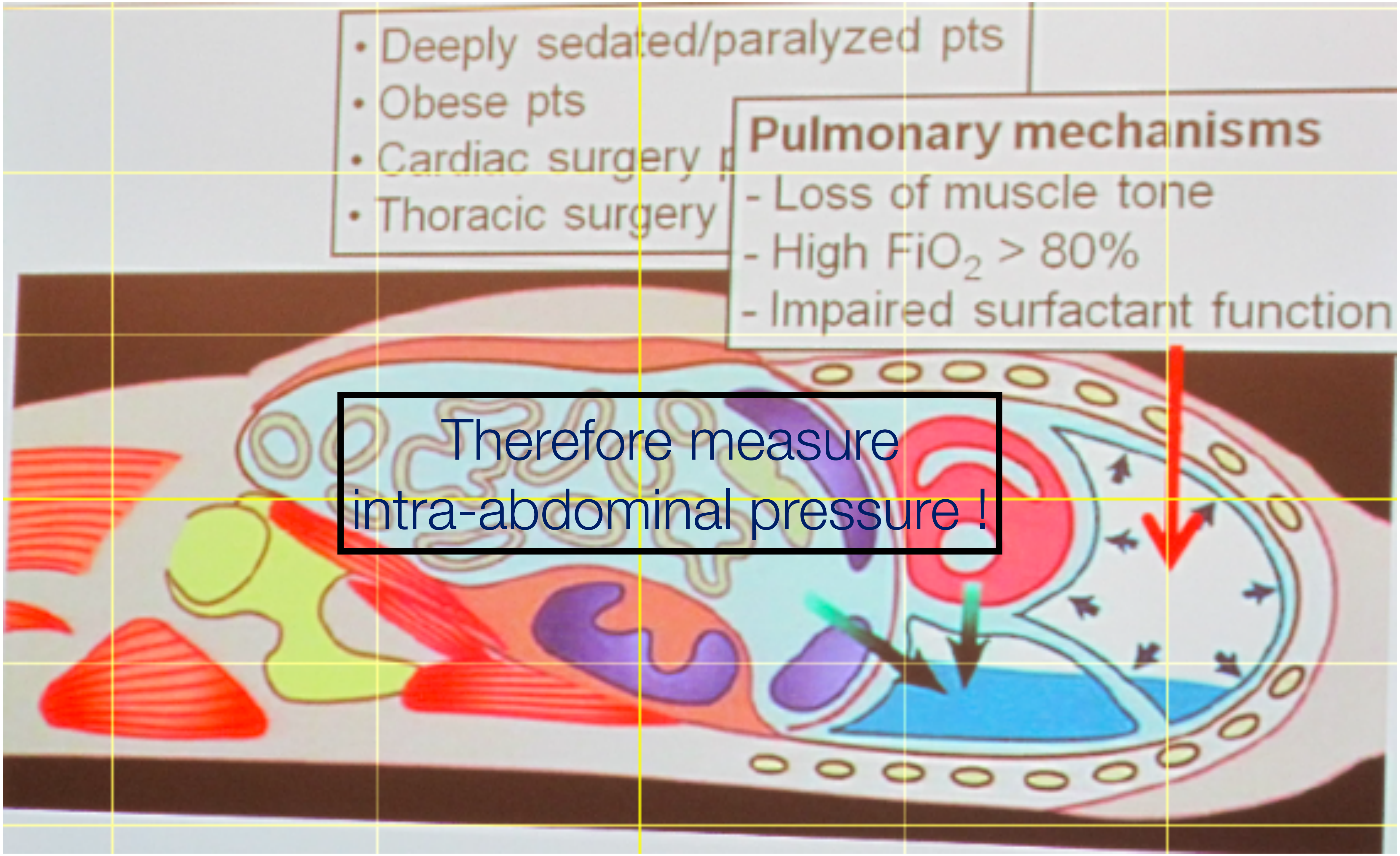
Recruitment manoeuvre and PEEP



Recruitment manoeuvre and PEEP

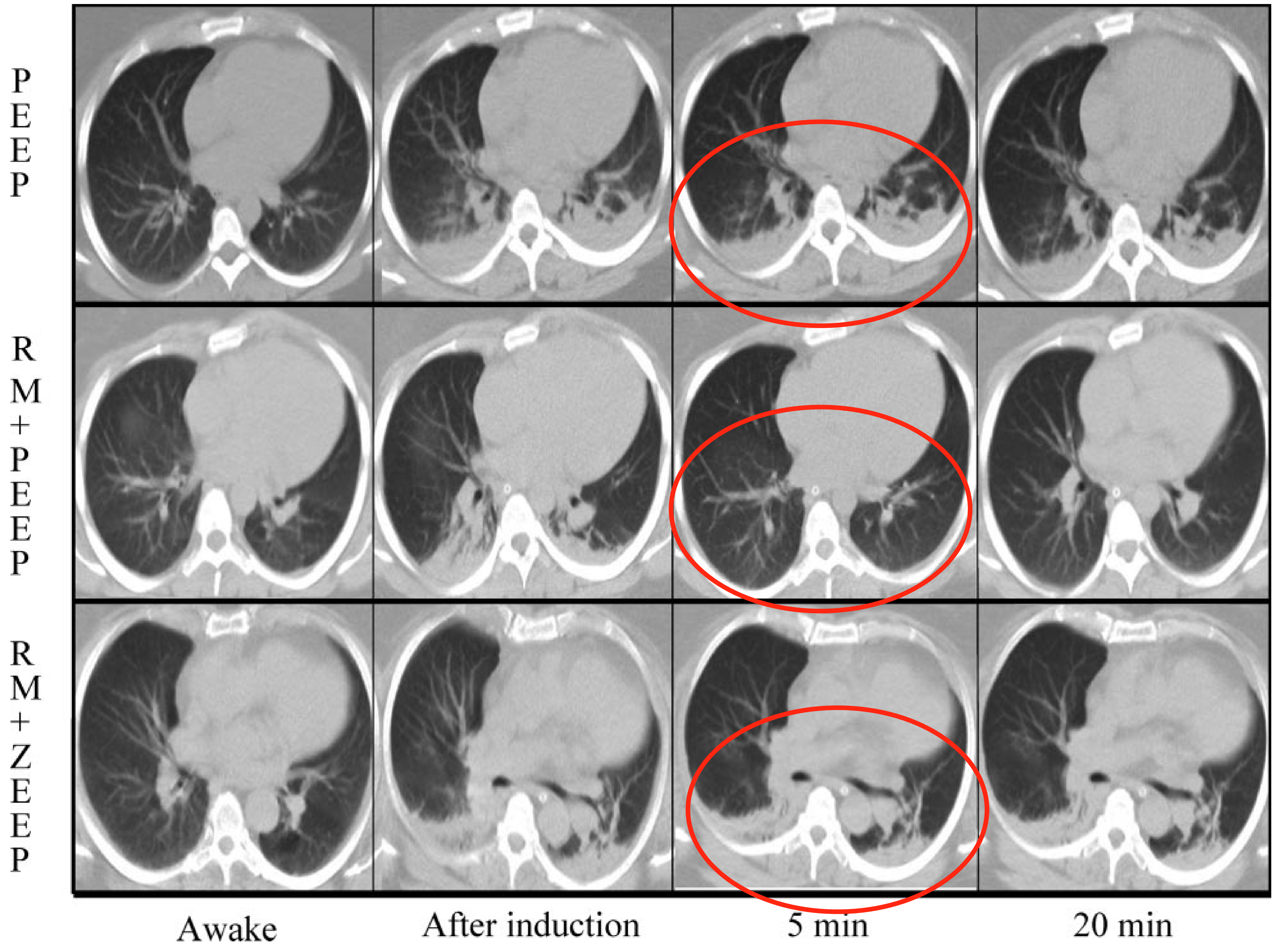


De-recruited lung

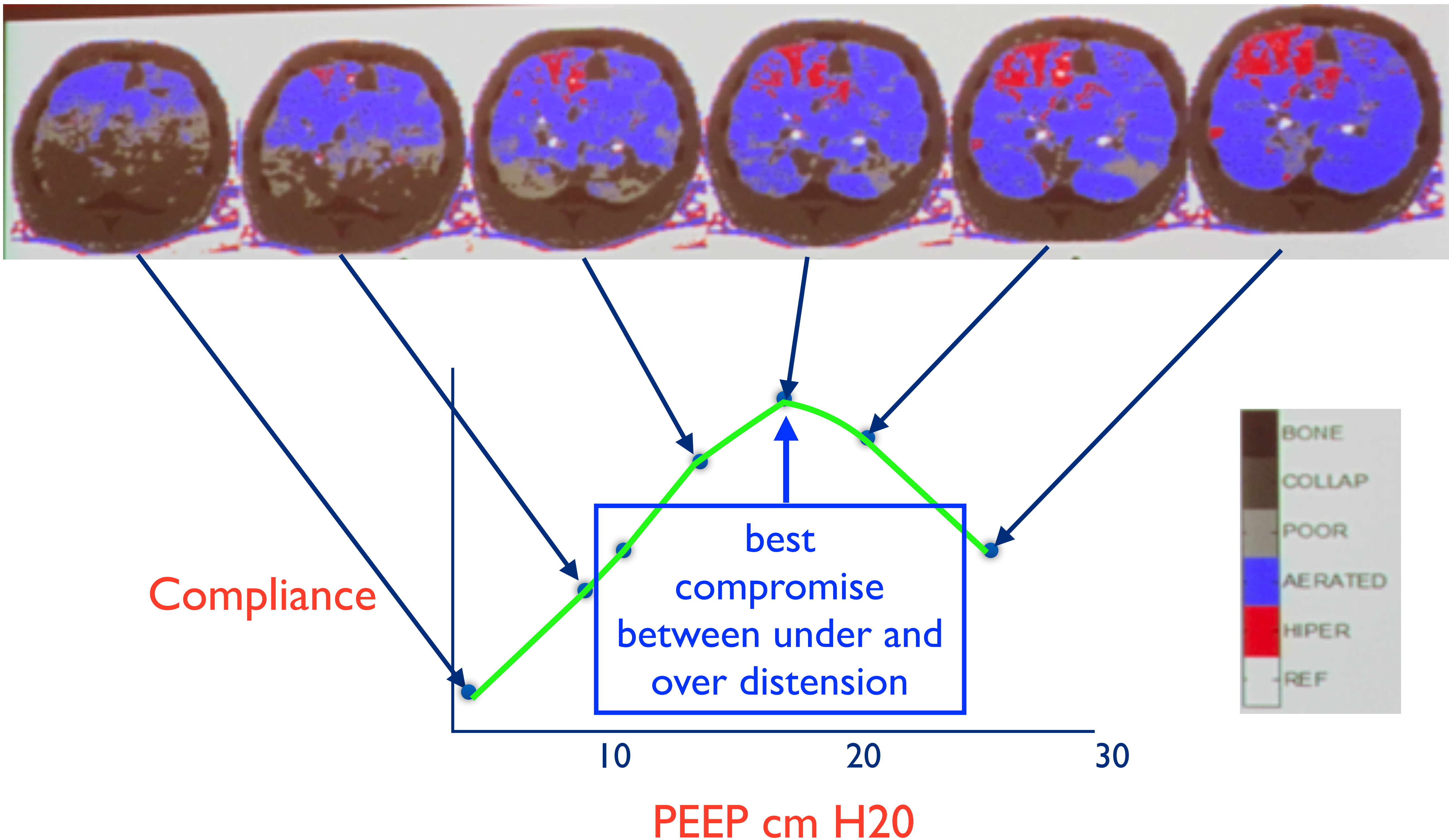


Duggan and Kavanagh Anesthesiology 2005, 102: 838-854

Recruitment manoeuvre and PEEP



Use compliance to titrate PEEP in ARDS



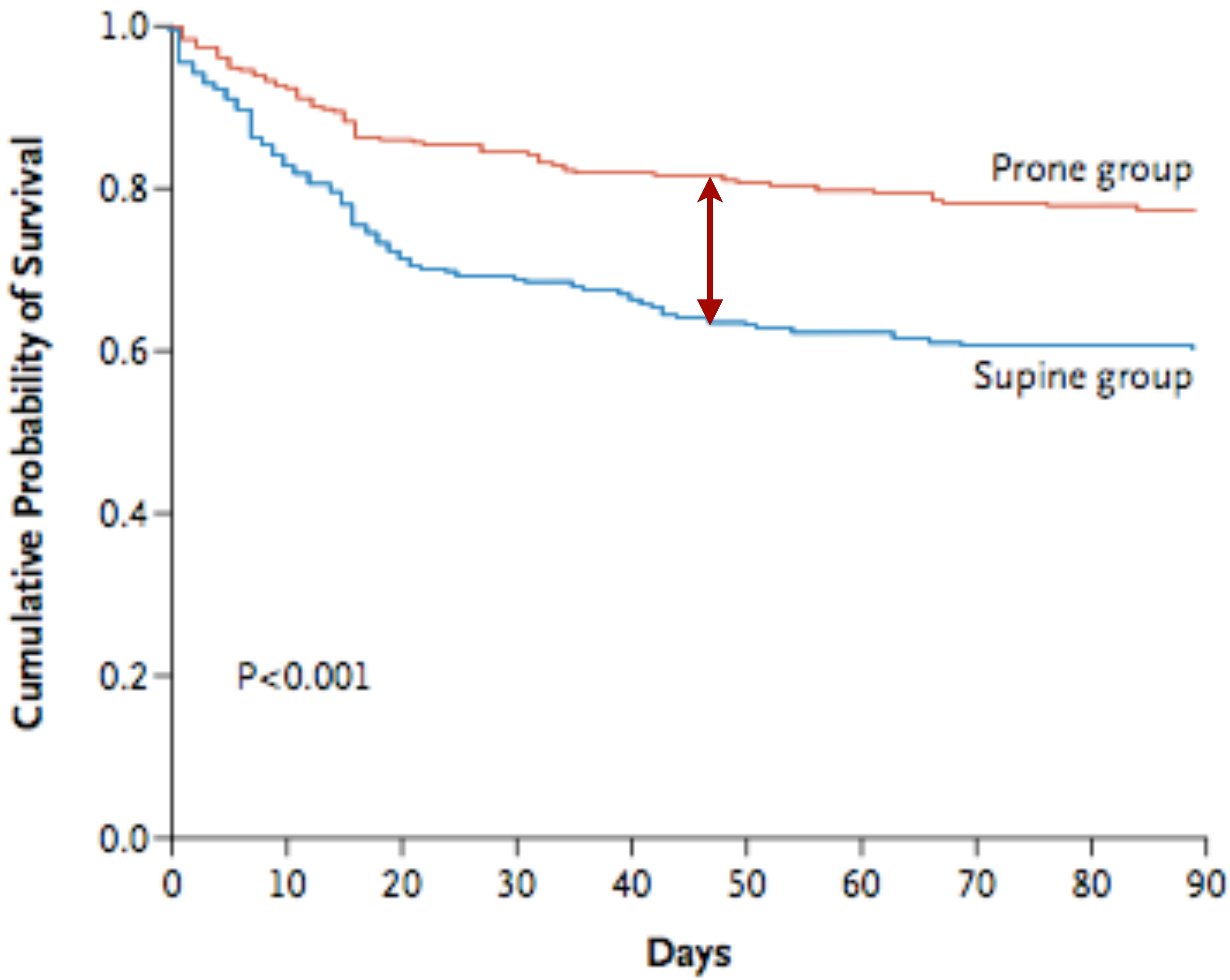
Carvalho AR et al. Intensive care medicine 2008 Dec; 34(12):2291-9

Other considerations

What works

ORIGINAL ARTICLE

Prone Positioning in Severe Acute Respiratory Distress Syndrome

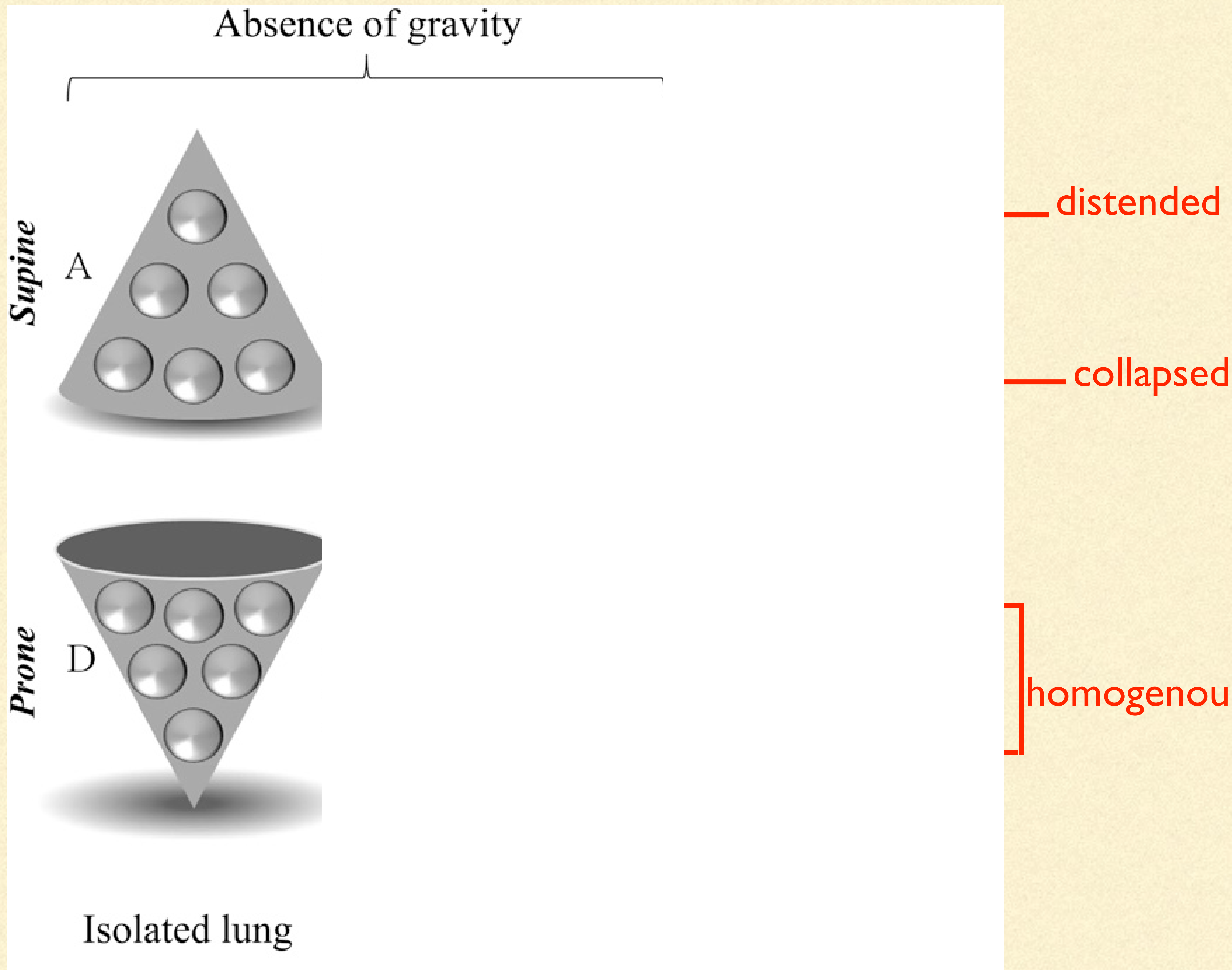


N Engl J Med 2013; 368:2159-2168

HOW DOES PRONING WORK?

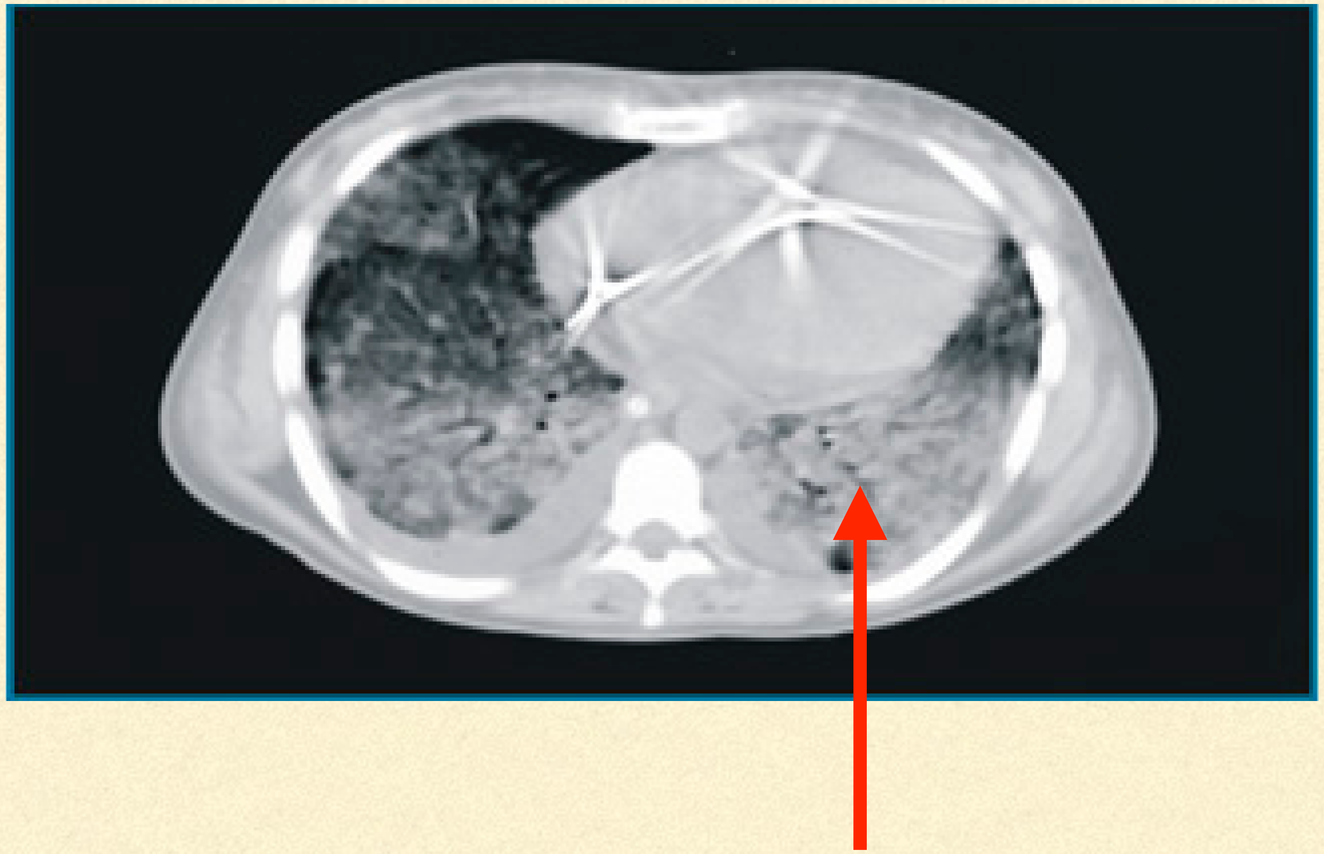
2 forces on alveoli:

- **shape mismatch**
- **gravity**

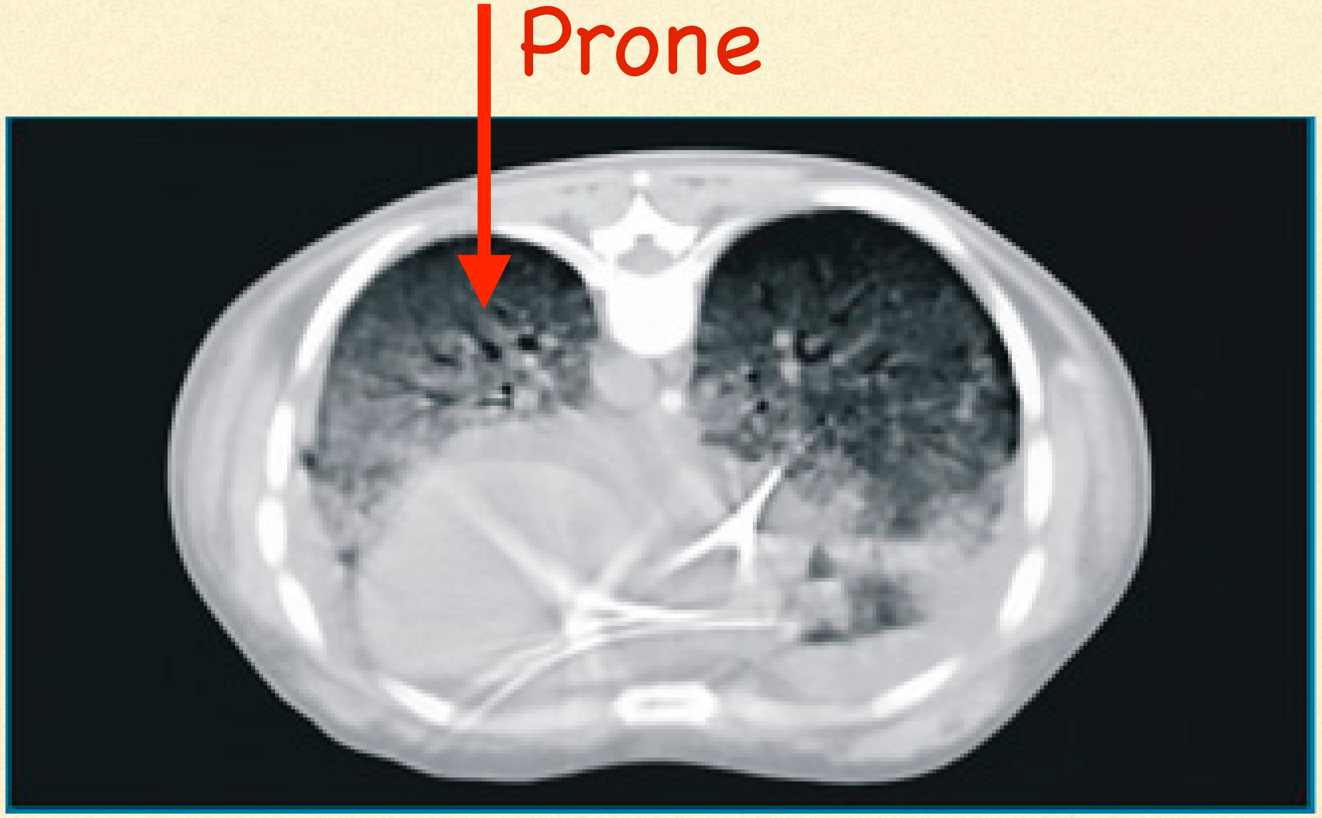


Prone position in ARDS

Supine



Prone



Am J Respir Crit Care Med Vol 188, Iss. 11, pp 1286–1293, Dec 1, 2013

The NEW ENGLAND JOURNAL of MEDICINE
ESTABLISHED IN 1812 SEPTEMBER 16, 2010 VOL. 363 NO. 12

Neuromuscular Blockers in Early Acute Respiratory Distress Syndrome

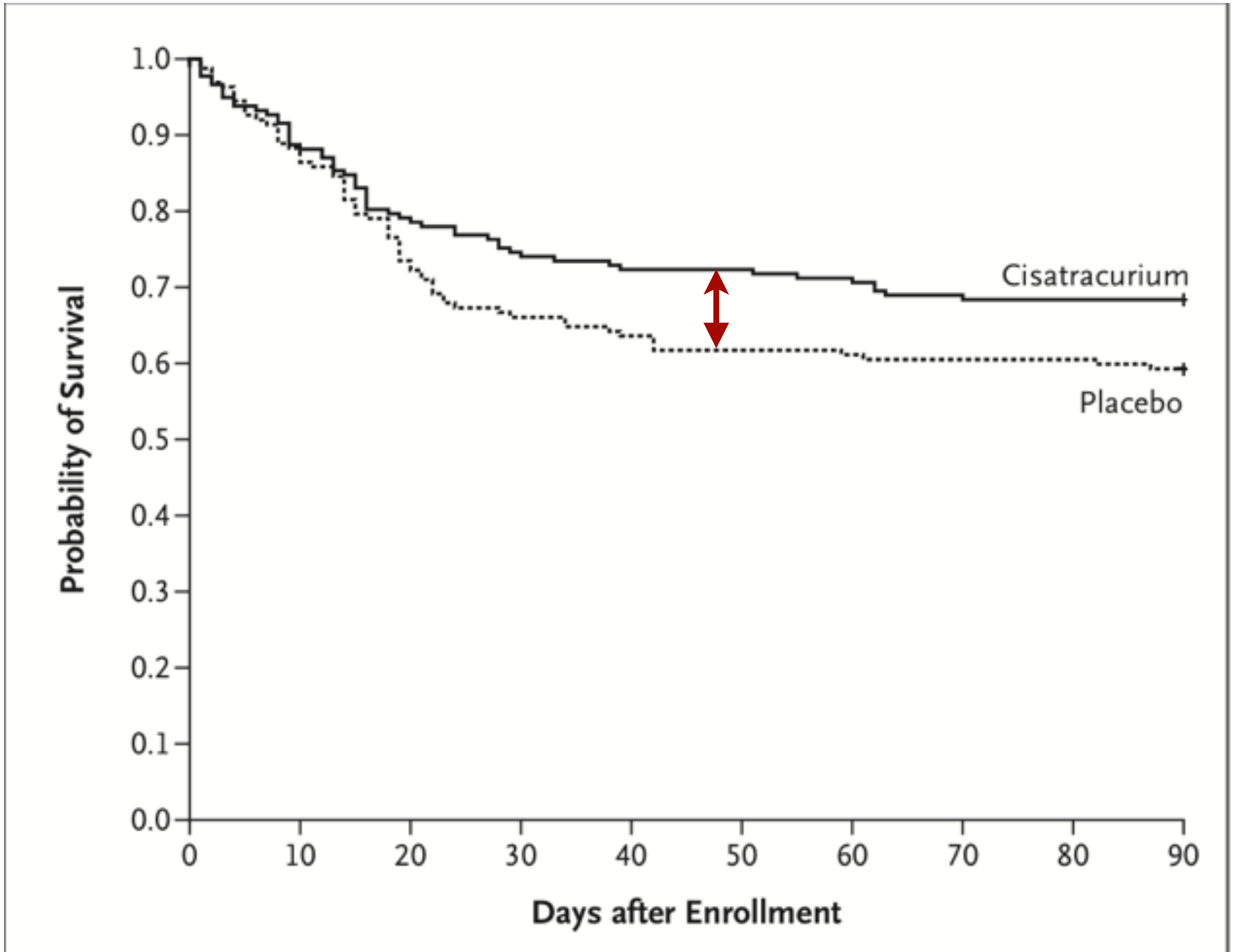
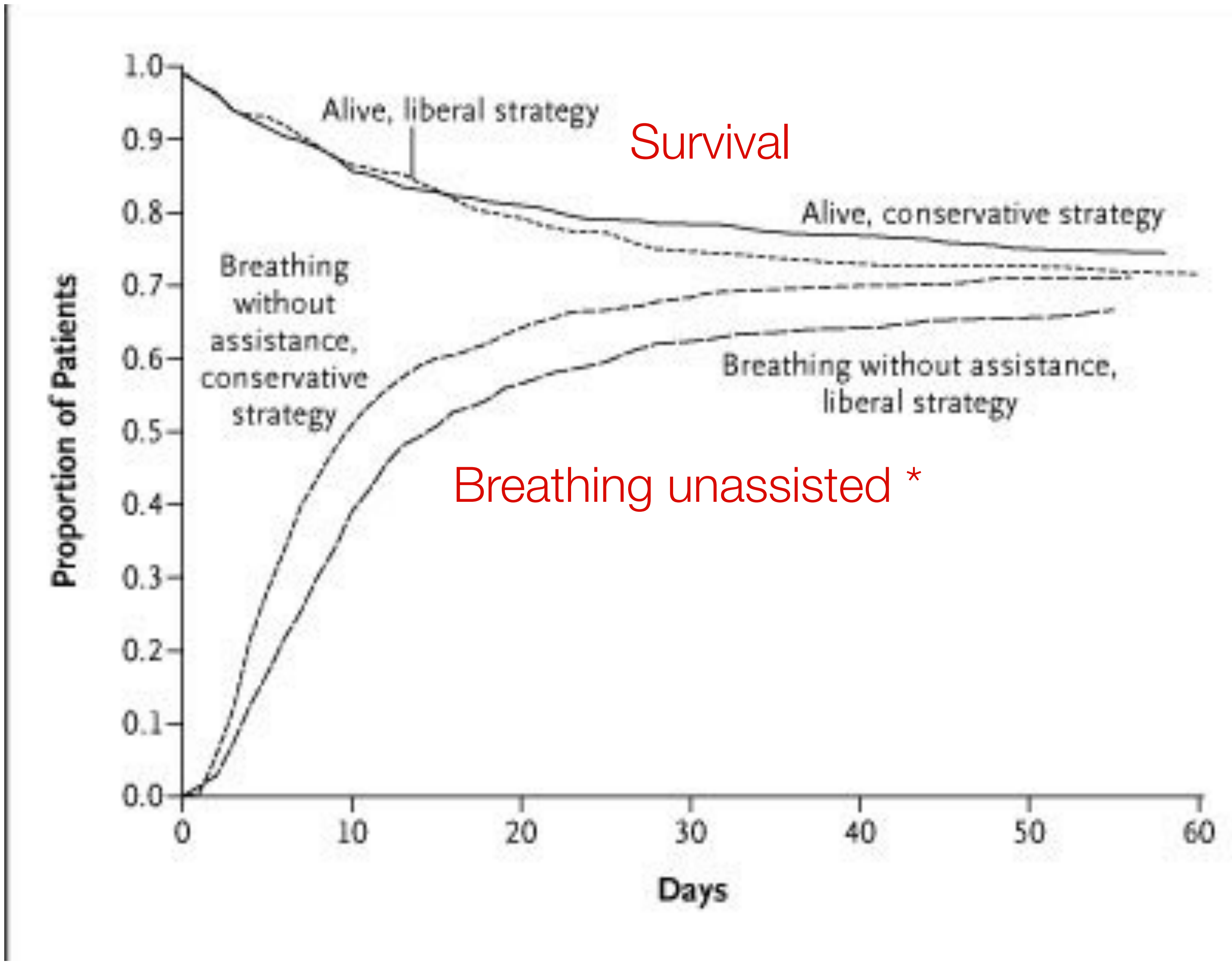


Figure 2. **Probability of Survival through Day 90, According to Study Group.**

N Engl J Med 2010; 363:1107-1106

Fluids in ARDS



Mortality

at 60 days

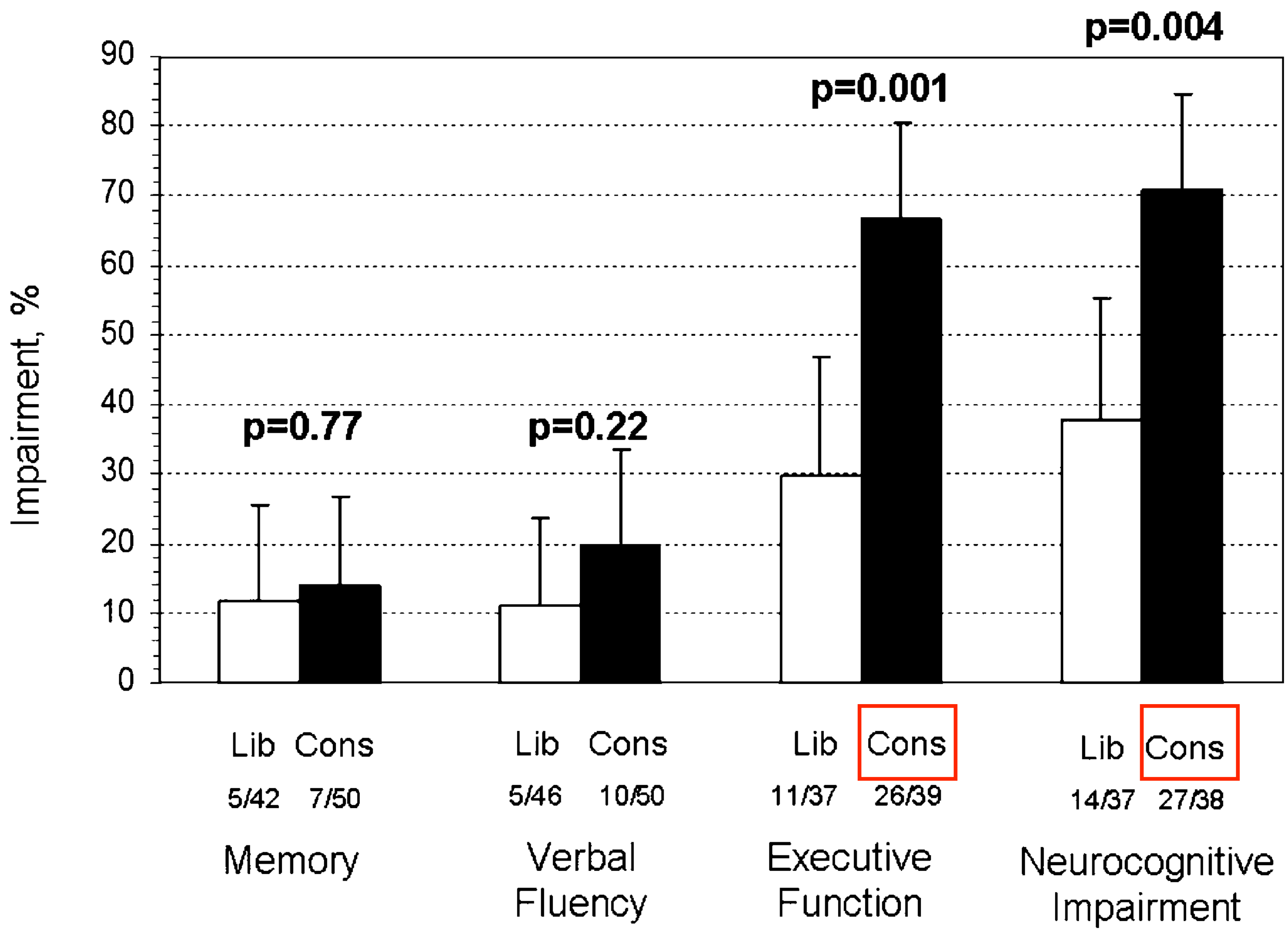
Liberal
28.4%

Conservative
25.5%

"the conservative strategy.....
shortened the duration of mechanical ventilation and intensive care without increasing nonpulmonary-organ failures"

N Engl J Med 354:2564, June 15, 2006

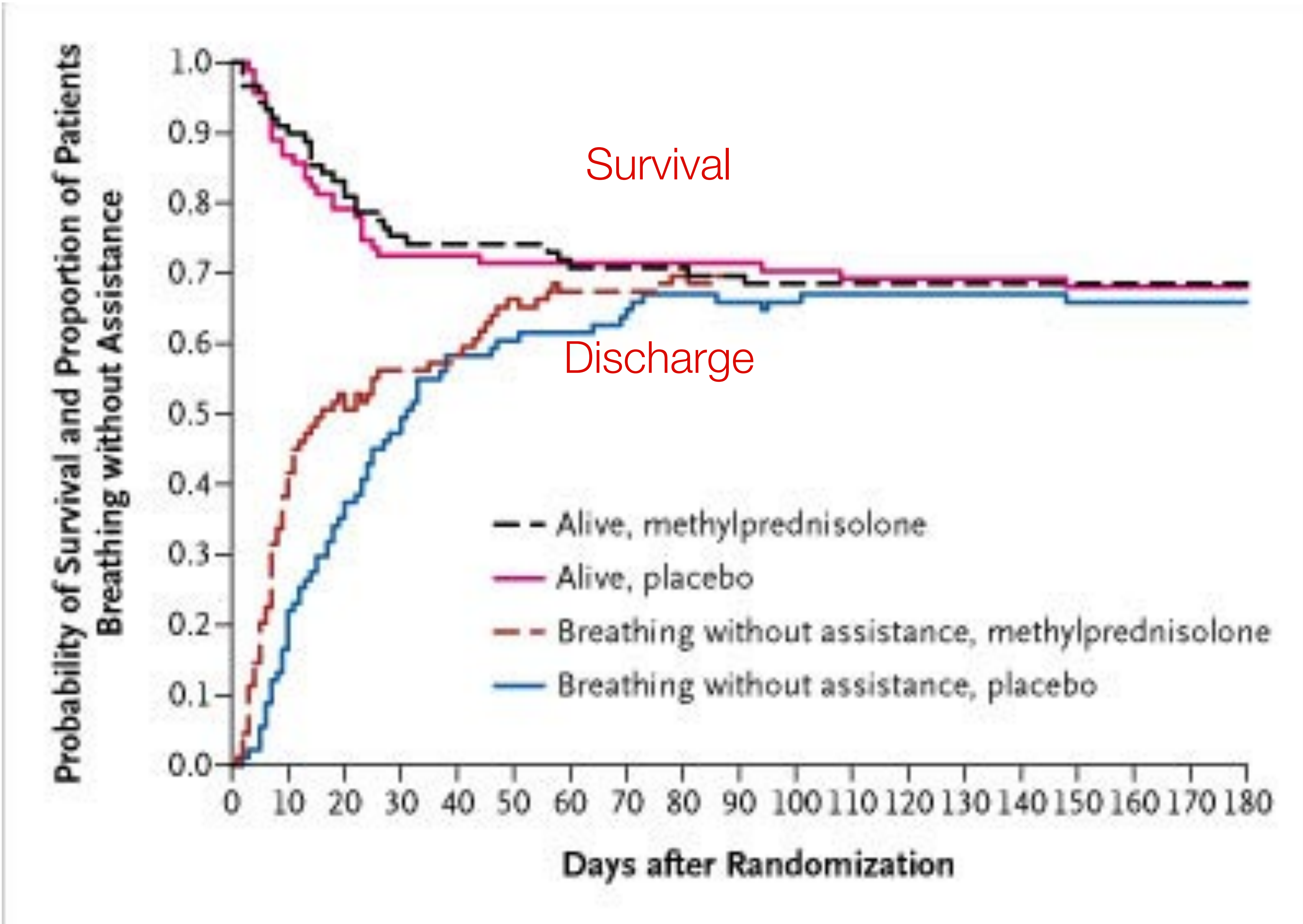
Fluids in ARDS - long term outcomes matter!



Am J Respir Crit Care Med Vol 185, Iss. 12, pp 1307–1315, Jun 15, 2012

What does not work

Steroids in ARDS



Mortality
at 60 days

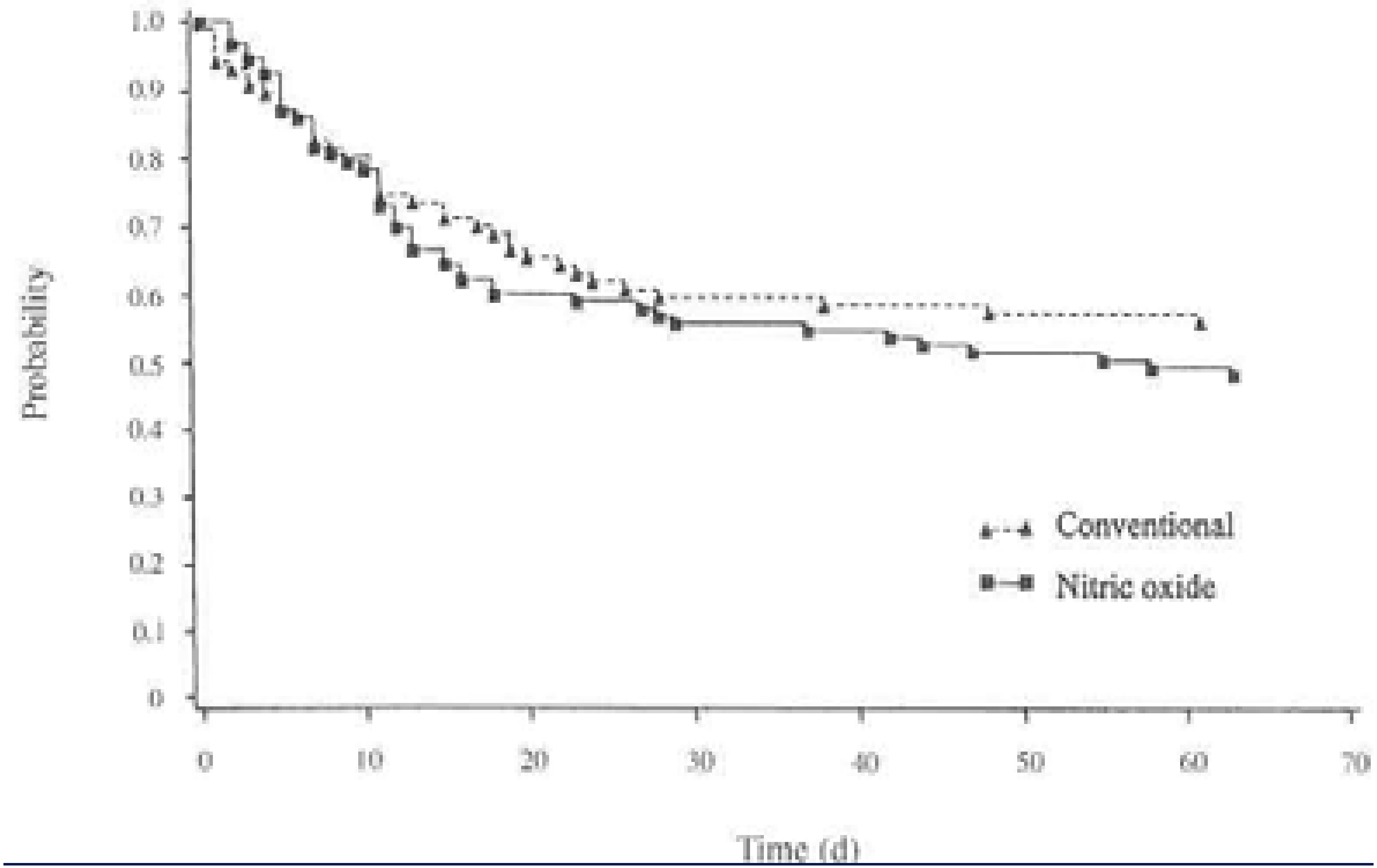
Steroids
29.2%

Placebo
28.6%

"starting methylprednisolone therapy **more than two weeks after** the onset of ARDS may **increase the risk of death**"

N Engl J Med 354:1671, April 20, 2006

Nitric Oxide in ARDS -
No improvement in survival



Lundin S et al Intensive Care Med 1996

Other ventilatory modes

- High Frequency Ventilation
- ECMO
- Nova-Lung - for C02 removal
- APRV - “Airway pressure release ventilation”
- NAVA - “neurologically adjusted ventilator assistance

Probably an “extreme” form of low tidal volumes .
Anecdotal results likely user dependent.

Other ventilatory modes

Rescue modes improve the end-point of oxygenation but **not mortality** (or even makes it worse).

Protective lung ventilation does the opposite (i.e., you have to accept initial worse blood gases worse but **survival better**).

Recruitment/de-recruitment

High Frequency Ventilation

High Frequency Oscillation

EDITORIAL

High-Frequency Oscillatory Ventilation on Shaky Ground

Atul Malhotra, M.D., and Jeffrey M. Drazen, M.D.

ORIGINAL ARTICLE

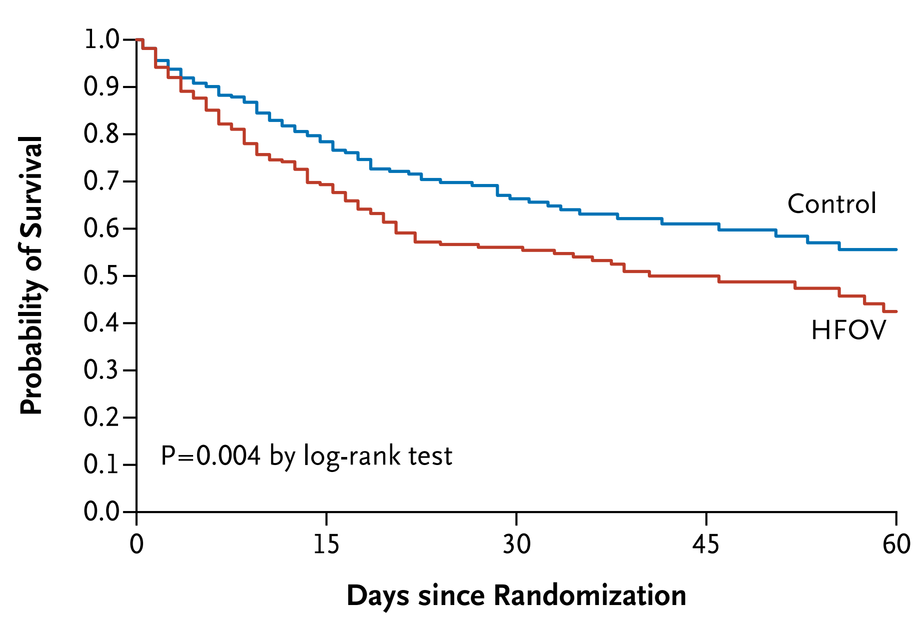
High-Frequency Oscillation for Acute Respiratory Distress Syndrome

Duncan Young, D.M., Sallie Lamb, D.Phil., Sanjoy Shah, M.D., Iain MacKenzie, M.D., William Tunnicliffe, M.Sc., Ranjit Lall, Ph.D., Kathy Rowan, D.Phil., and Brian H. Cuthbertson, M.D., for the OSCAR Study Group*

ORIGINAL ARTICLE

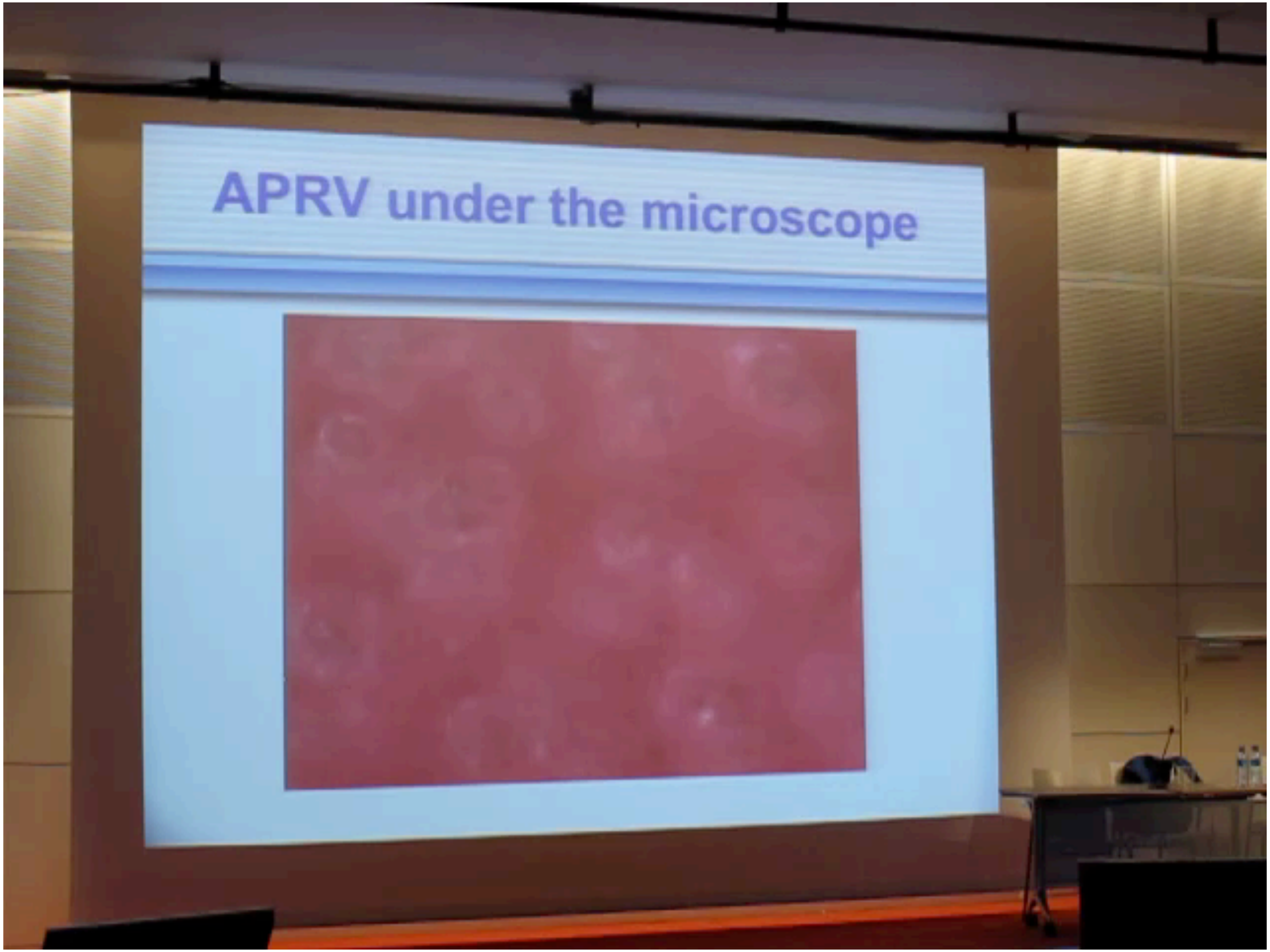
High-Frequency Oscillation in Early Acute Respiratory Distress Syndrome

Niall D. Ferguson, M.D., Deborah J. Cook, M.D., Gordon H. Guyatt, M.D., Sangeeta Mehta, M.D., Lori Hand, R.R.T., Peggy Austin, C.C.R.A., Qi Zhou, Ph.D., Andrea Matte, R.R.T., Stephen D. Walter, Ph.D., Francois Lamontagne, M.D., John T. Granton, M.D., Yaseen M. Arabi, M.D., Alejandro C. Arroliga, M.D., Thomas E. Stewart, M.D., Arthur S. Slutsky, M.D., and Maureen O. Meade, M.D., for the OSCILLATE Trial Investigators and the Canadian Critical Care Trials Group*



N Engl J Med January 22, 2013.

APRV



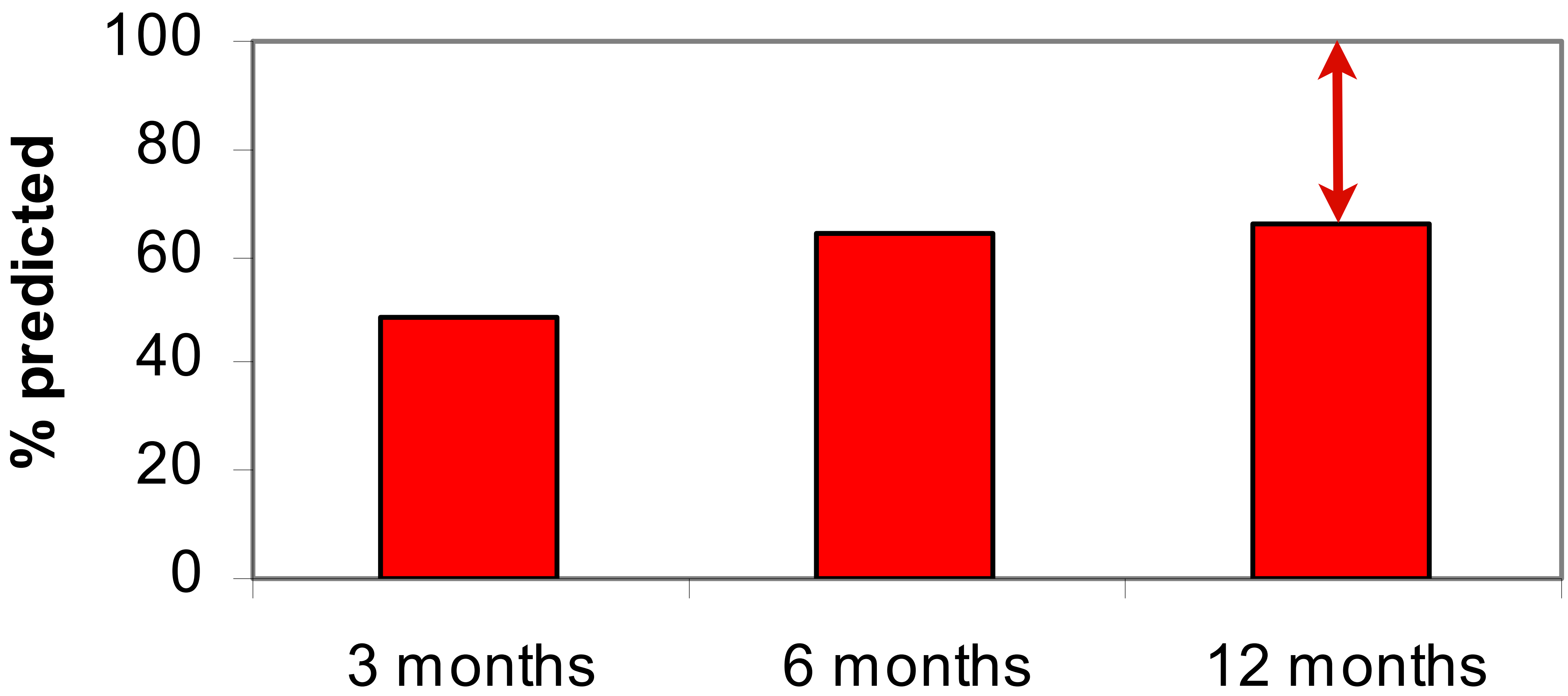
Long term outcomes

With the exception of DLCO, lung function returns to normal

Variable (% predicted)	3 Month	6 Month	12 Month
FVC	72	80	85
FEV 1sec	75	85	86
TLC	92	92	95
Residual vol	107	97	105
DLCO **	63	70	72 *

Herridge M et al NEJM 2003; 348:683-693
Herridge M al NEJM 2011; 364:1293-1304

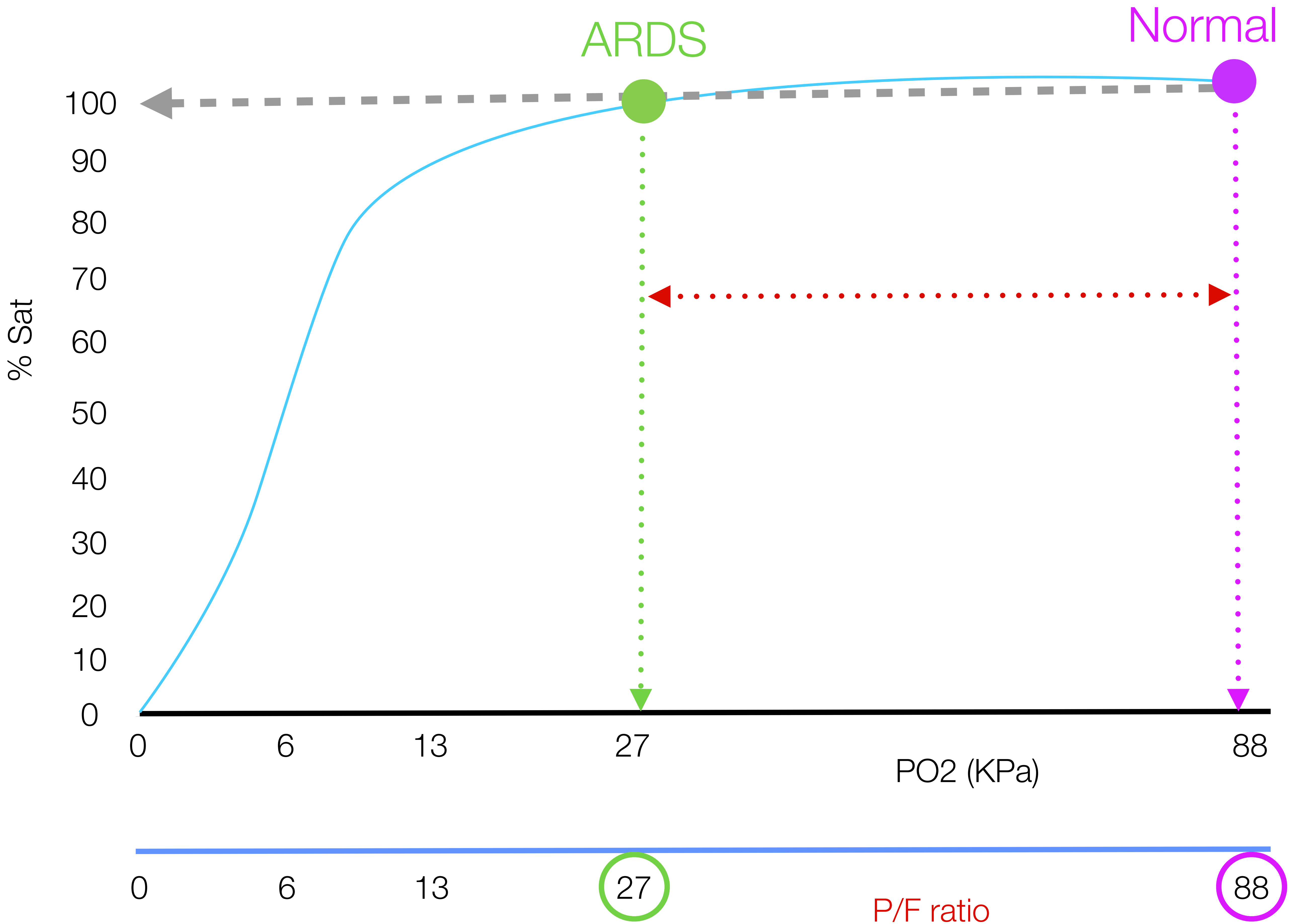
Six minute walk test improved over time but limitations persist



Herridge M et al NEJM 2003; 348:683-693
Herridge M et al NEJM 2011; 364:1293-1304

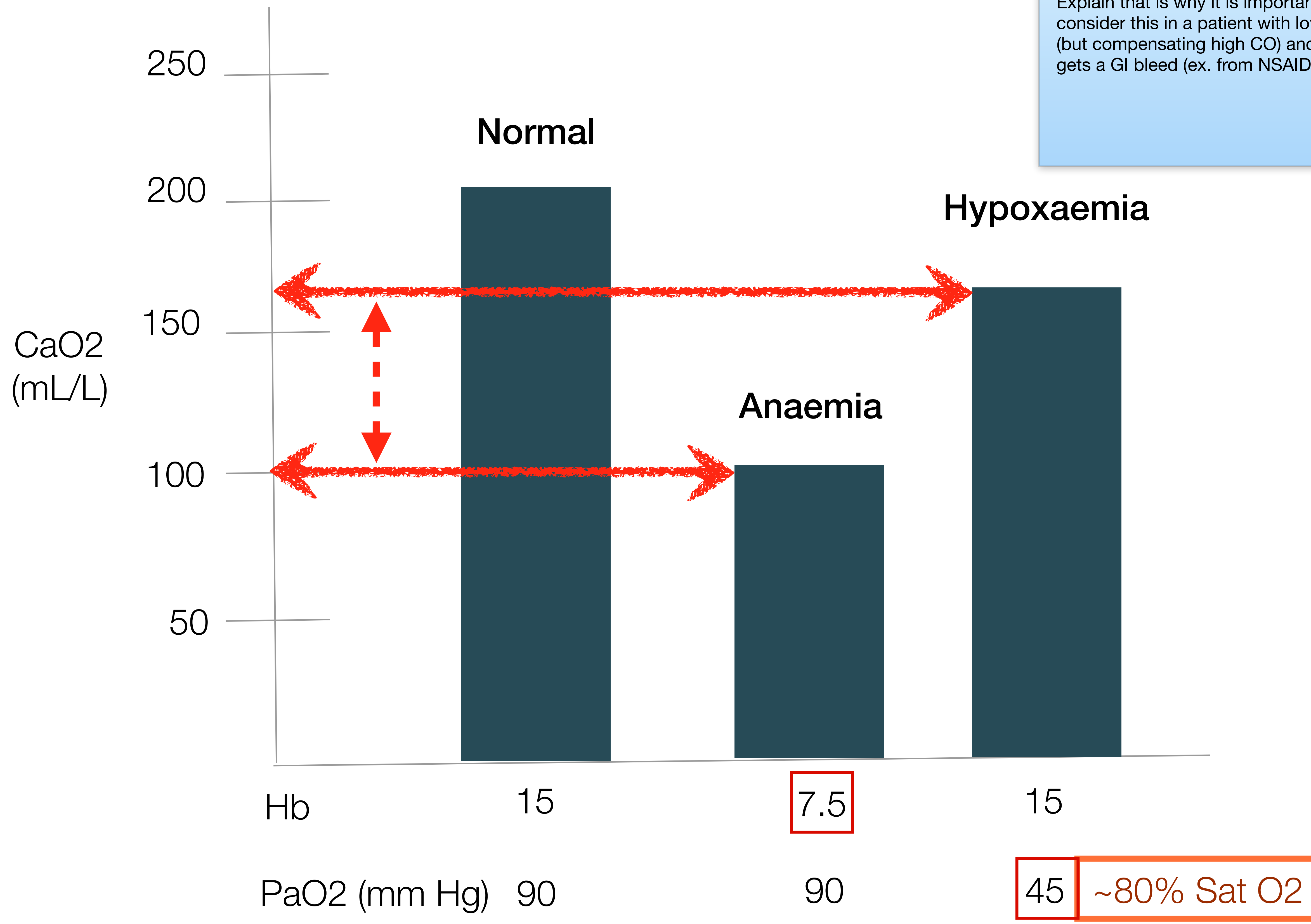
Use P/F ratio to trend efficiency of oxygen transfer

PaO2/FiO2 ratios (= P/F) describes lung efficiency



Effects of a equivalent 50% reduction in Hb and pO2 on **O2 content** in arterial blood

Explain that is why it is important to consider this in a patient with low Hb (but compensating high CO) and then gets a GI bleed (ex. from NSAIDS)

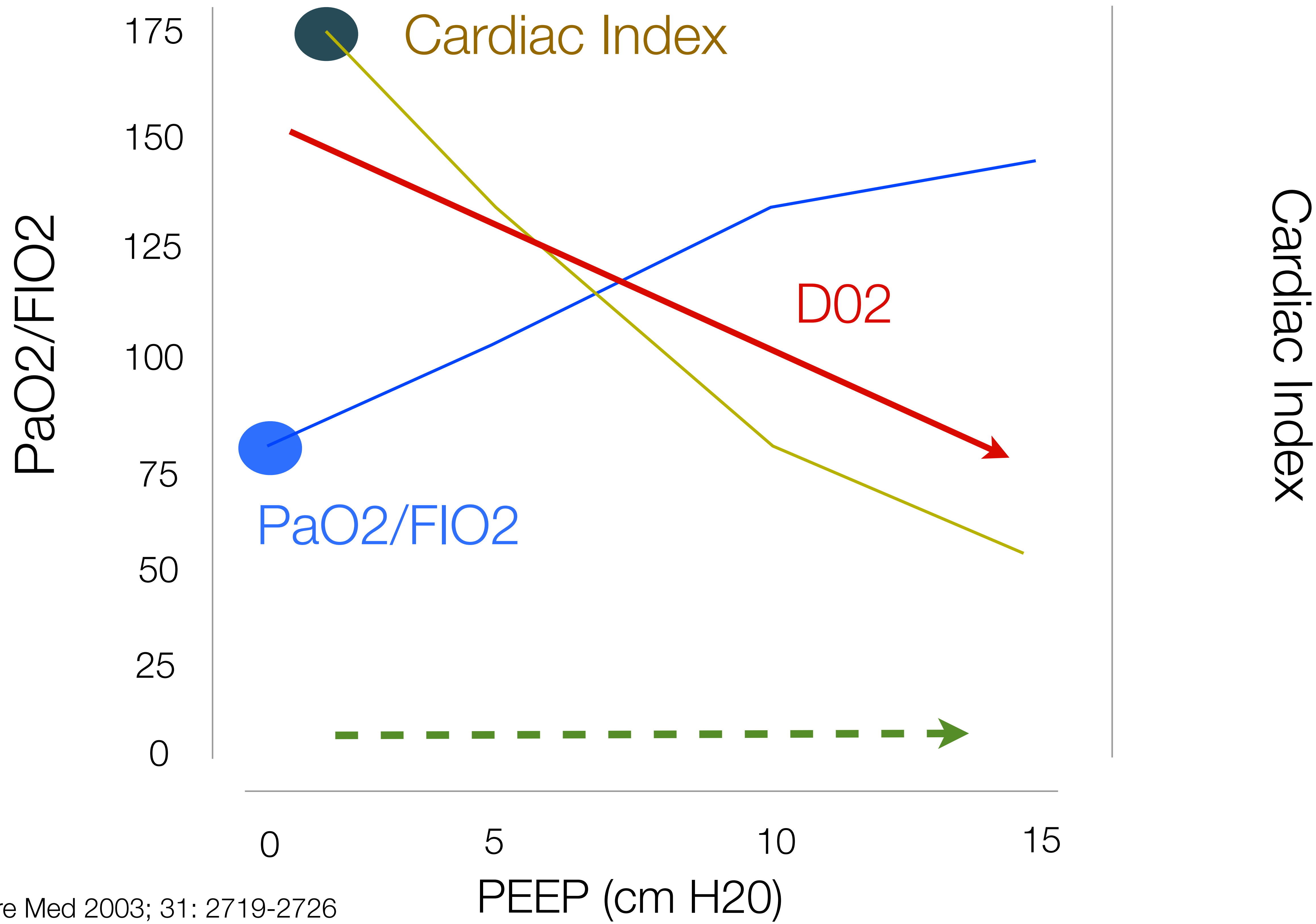


Clinical Case

21 yr old female
Acute respiratory distress following flu-like symptoms (H1N1)
Requires intubation
02 sats continues to drop rapidly from 87% to 78% on 100% 02
Central venous saturation 72%
Attempt at higher PEEP of 25cm H20
Little improvement in 02 sats
But now central venous saturation is 52%

Why?
What does this signify?
What did we do?

Effect of PEEP on lung efficiency vs. cardiac output



Crit Care Med 2003; 31: 2719-2726

Recap

- Mortality is decreasing but still a deadly disease
- We can cause harm to the lungs by
  - overstretching
  - allowing collapse
- Use “low” (i.e., normal tidal volumes)
  - calculate ideal weight using **height and sex**
- Follow efficiency of gas exchange using P/F ratio

Don't forget, we are in the **oxygen delivery** business

Cardiac output x Hb x % Sat O2

???

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http://www.jvsmedicscorner.com

Mallory / Everest2013