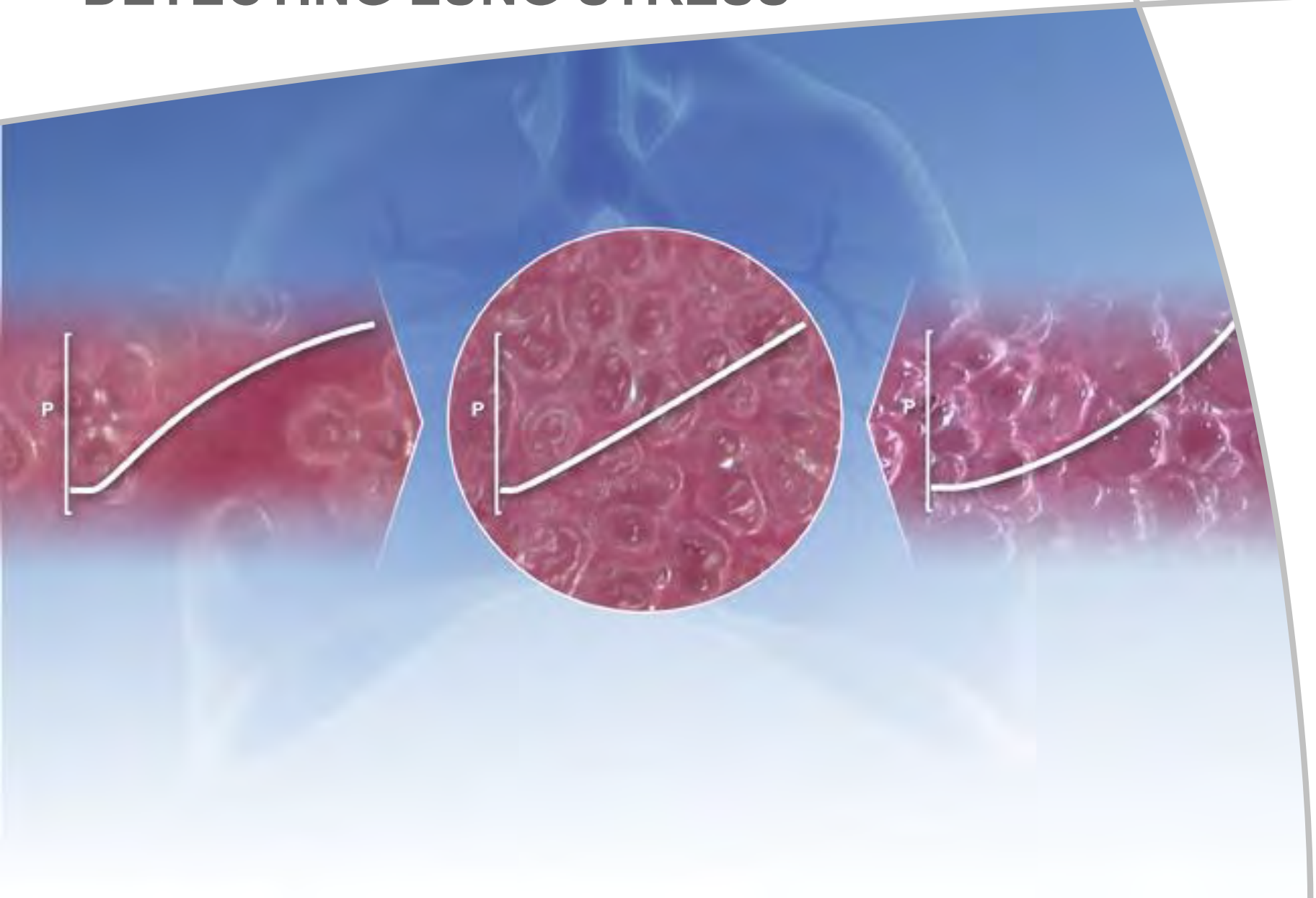
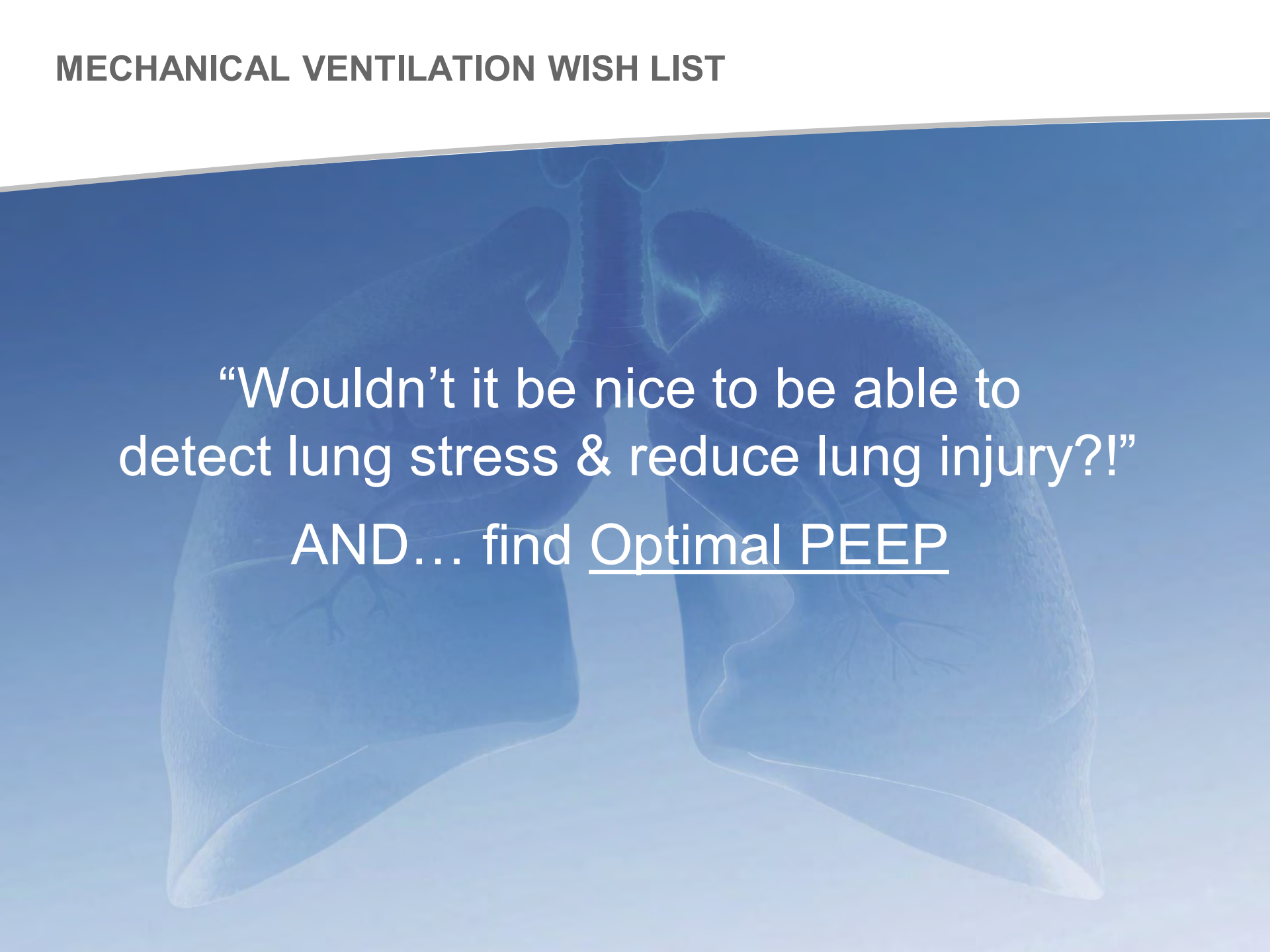
STRESS INDEX
DETECTING LUNG STRESS



MECHANICAL VENTILATION WISH LIST



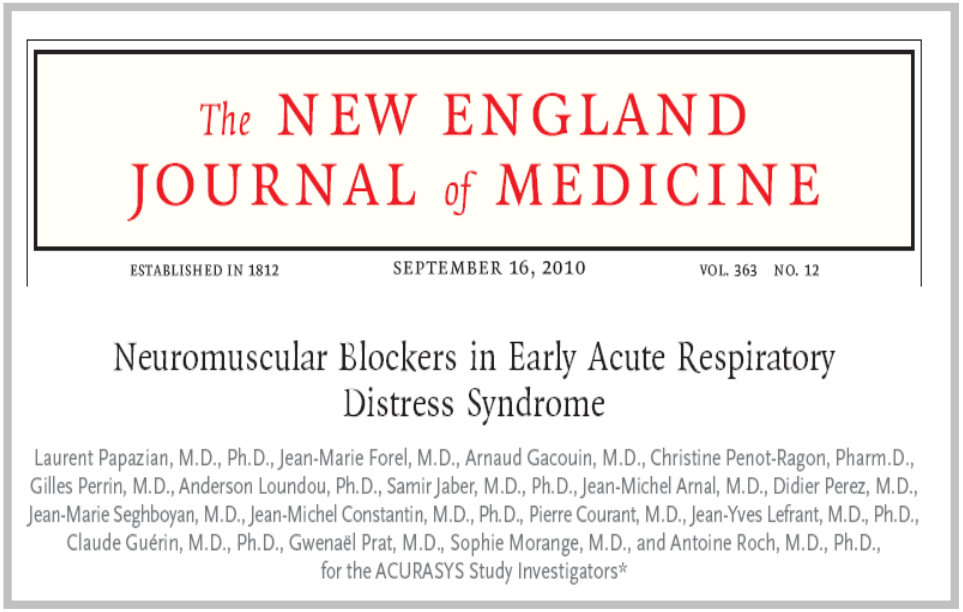
"Wouldn't it be nice to be able to detect lung stress & reduce lung injury?!"

AND… find Optimal PEEP

REDUCING MORTALITY AND MORBIDITY IN ALI / ARDS

- CMV using deep sedation, muscle relaxation and a lung protective strategy in the first two days of ARDS has been shown to decrease mortality and organ failure.

- Lung stress and strain are primary causes of Ventilator-Induced Lung Injury (VILI).



The NEW ENGLAND JOURNAL of MEDICINE

ESTABLISHED IN 1812 SEPTEMBER 16, 2010 VOL. 363 NO. 12

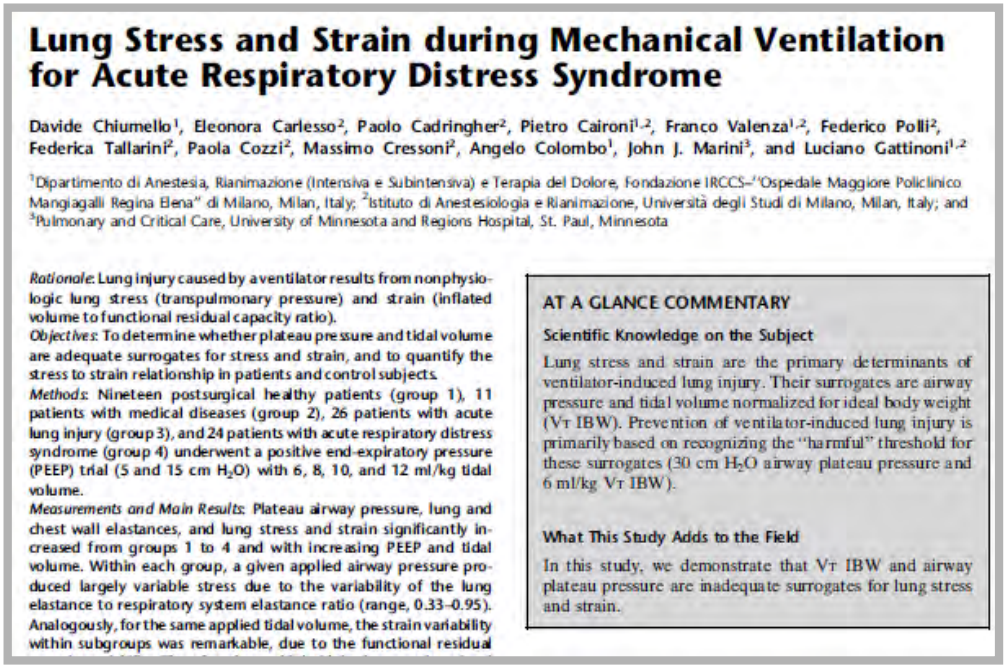
Neuromuscular Blockers in Early Acute Respiratory Distress Syndrome

Laurent Papazian, M.D., Ph.D., Jean-Marie Forel, M.D., Arnaud Gacouin, M.D., Christine Penot-Ragon, Pharm.D., Gilles Perrin, M.D., Anderson Loundou, Ph.D., Samir Jaber, M.D., Ph.D., Jean-Michel Arnal, M.D., Didier Perez, M.D., Jean-Marie Seghboyan, M.D., Jean-Michel Constantin, M.D., Ph.D., Pierre Courant, M.D., Jean-Yves Lefrant, M.D., Ph.D., Claude Guérin, M.D., Ph.D., Gwenaël Prat, M.D., Sophie Morange, M.D., and Antoine Roch, M.D., Ph.D., for the ACURASYS Study Investigators*

Papazian L. NEJM Sep 2010

CAN LUNG INJURY BE RESTRICTED?

- Mortality and complications remain high within intensive care.
- CMV should be administered for a limited time.
- An inflammatory process may occur together with hyperinflation even when using “safe” tidal volumes.
- Normal areas of the lung are at risk.



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]

[1]Dipartimento di Anestesia, Rianimazione (Intensiva e Subintensiva) e Terapia del Dolore, Fondazione IRCCS–“Ospedale Maggiore Policlinico Mangiagalli Regina Elena” di Milano, Milan, Italy; [2]Istituto di Anestesiologia e Rianimazione, Università degli Studi di Milano, Milan, Italy; and [3]Pulmonary and Critical Care, University of Minnesota and Regions Hospital, St. Paul, Minnesota

Rationale: Lung injury caused by a ventilator results from nonphysiologic lung stress (transpulmonary pressure) and strain (inflated volume to functional residual capacity ratio).
Objectives: To determine whether plateau pressure and tidal volume are adequate surrogates for stress and strain, and to quantify the stress to strain relationship in patients and control subjects.
Methods: Nineteen postsurgical healthy patients (group 1), 11 patients with medical diseases (group 2), 26 patients with acute lung injury (group 3), and 24 patients with acute respiratory distress syndrome (group 4) underwent a positive end-expiratory pressure (PEEP) trial (5 and 15 cm H_2O) with 6, 8, 10, and 12 ml/kg tidal volume.
Measurements and Main Results: Plateau airway pressure, lung and chest wall elastances, and lung stress and strain significantly increased from groups 1 to 4 and with increasing PEEP and tidal volume. Within each group, a given applied airway pressure produced largely variable stress due to the variability of the lung elastance to respiratory system elastance ratio (range, 0.33–0.95). Analogously, for the same applied tidal volume, the strain variability within subgroups was remarkable, due to the functional residual

AT A GLANCE COMMENTARY

Scientific Knowledge on the Subject

Lung stress and strain are the primary determinants of ventilator-induced lung injury. Their surrogates are airway pressure and tidal volume normalized for ideal body weight (Vt IBW). Prevention of ventilator-induced lung injury is primarily based on recognizing the “harmful” threshold for these surrogates (30 cm H_2O airway plateau pressure and 6 ml/kg Vt IBW).

What This Study Adds to the Field

In this study, we demonstrate that Vt IBW and airway plateau pressure are inadequate surrogates for lung stress and strain.

Chiumello D, AJRCCM 2008

LUNG INJURY CAUSED BY MECHANICAL VENTILATION

- During low stretch ventilation, the outcome is similar when comparing an “open lung” and a “lung rest” approach.

Pulmonary atelectasis during low stretch ventilation: “Open lung” versus “lung rest” strategy*

Vito Fanelli, MD; Luciana Mascia, MD, PhD; Valeria Puntorieri, MSc; Barbara Assenzio, MSc; Vincenzo Elia, MSc; Giancarlo Fornaro, MD; Erica L. Martin, PhD; Martino Bosco, MD; Luisa Delsedime, MD; Tommaso Fiore, MD; Salvatore Grasso, MD; V. Marco Ranieri, MD

Fanelli V, AJRCCM, 2006

STRESS INDEX – WHAT'S THE EVIDENCE?

- Stress Index (SI) corresponds to CT evidence, SI=1 indicates tidal inflation only for normally aerated alveoli. Grasso S, CCM 2004

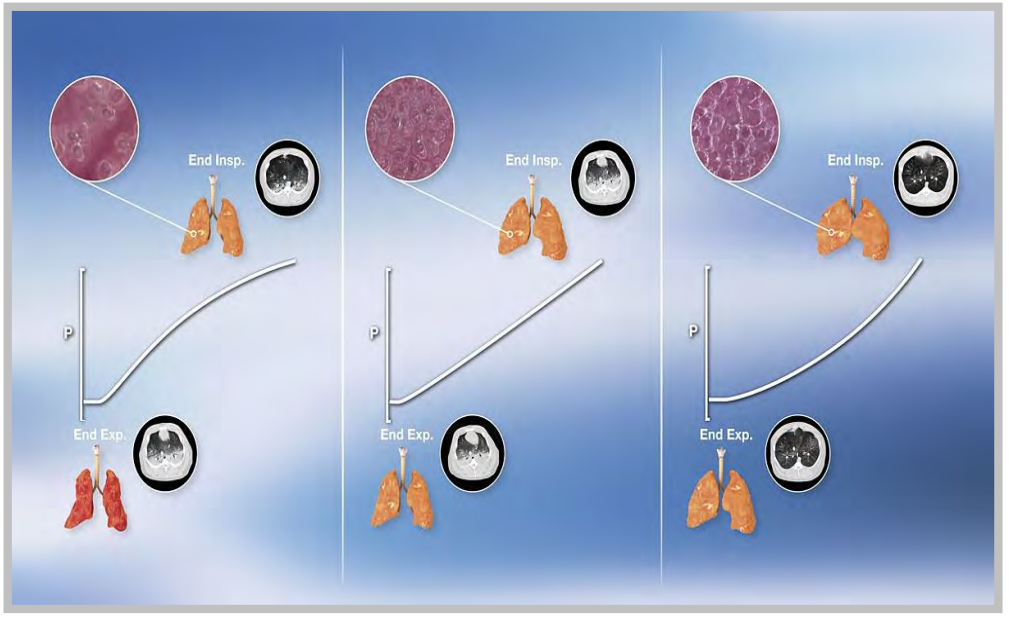
- ARDS patients normally show a small aerated region, which receives most of the tidal volume and is exposed to overdistension and stress due to alveolar wall tension Viera SR, AJRCCM 1999, Gattenoni L AJRCCM 1999

- Using the ARDSnet low tidal volume strategy in ARDS patients, 2/3 show no signs of hyperinflation while 1/3 show signs of hyperinflation. The latter group had higher pulmonary concentrations of inflammatory cytokines Terrangi PP, AJRCCM 2007

- By using ARDSnet for setting VT and titrating PEEP to a Stress Index level of 0.9-1.1, hyperinflation, dead space ventilation and inflammatory cytokines were reduced while improving hemodynamics Grasso S, AJRCCM 2005

STRESS INDEX – A TOOL FOR DETECTING LUNG STRESS

- The dynamics of ALI / ARDS and the uneven gas distribution make identification and detection of injurious ventilatory patterns almost impossible.
- Stress Index provides a tool to monitor the occurrence of **tidal recruitment** and **over-distension**, which are important factors in the mortality and morbidity of severely ill patients.

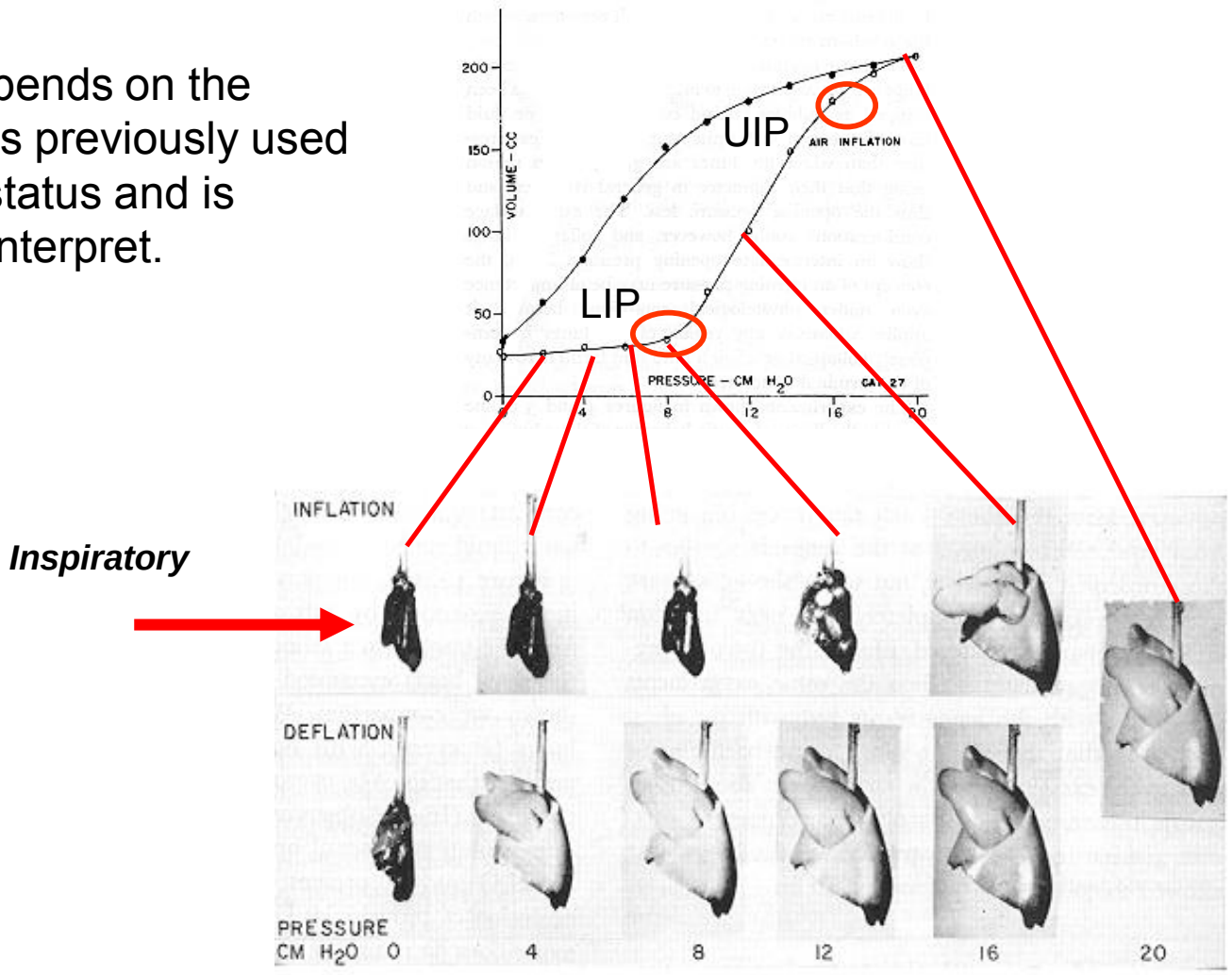


Tidal recruitment Normal Overdistension

Stress Index will guide you in preventing this potentially harmful scenario.

Pressure - Volume Curve

- The P-V curve depends on the ventilation volumes previously used and the patient's status and is therefore hard to interpret.

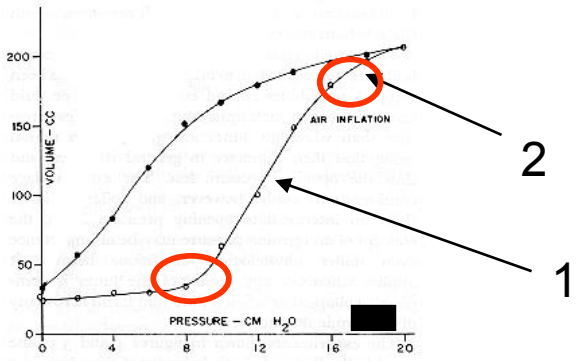


Inspiratory

Handbook of physiology

PROBLEMS WITH P-V CURVE INTERPRETATION

- Alveolar reopening continues on the linear portion of the P-V curve far above LIP (1)
- UIP may indicate that recruitment has ended during inflation (2)
- Regional overinflation is marked if recruitment continues above UIP (2)

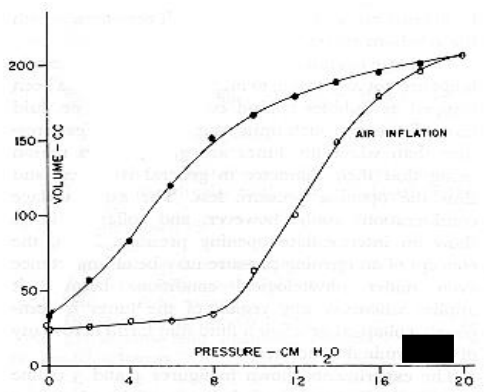


Hickling AJRCCM 1998

LIP – VERIFICATION BY CT

Presence of LIP

- A LIP on the P-V curve simply indicates a homogeneously injured lung and the need for recruitment.



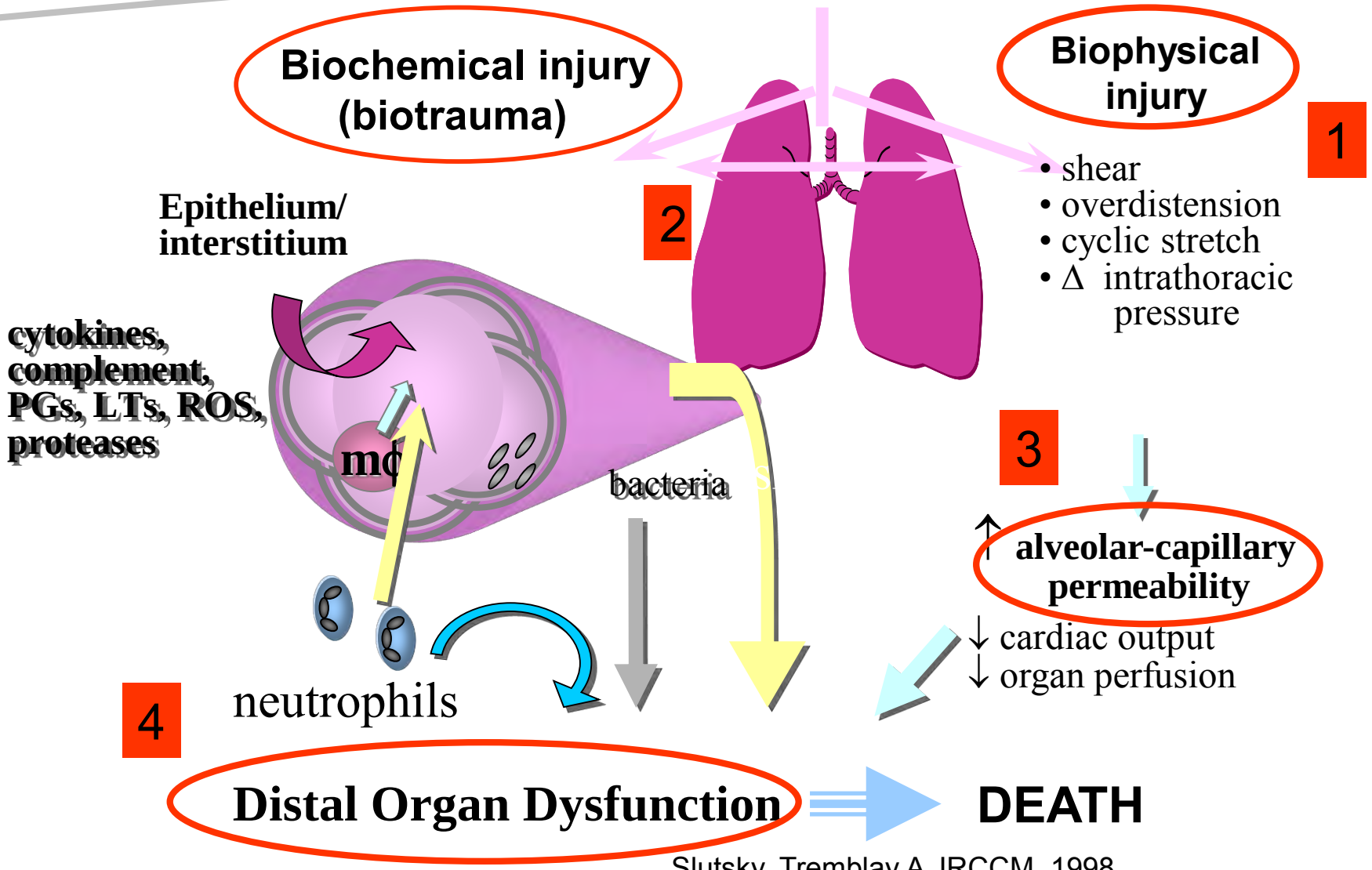
Absence of LIP

- Normally aerated and non-aerated areas coexist. PEEP induces both recruitment and overdistension.

LIP gives no indication for setting an optimal PEEP level.

Viera. AJRCCM 1999

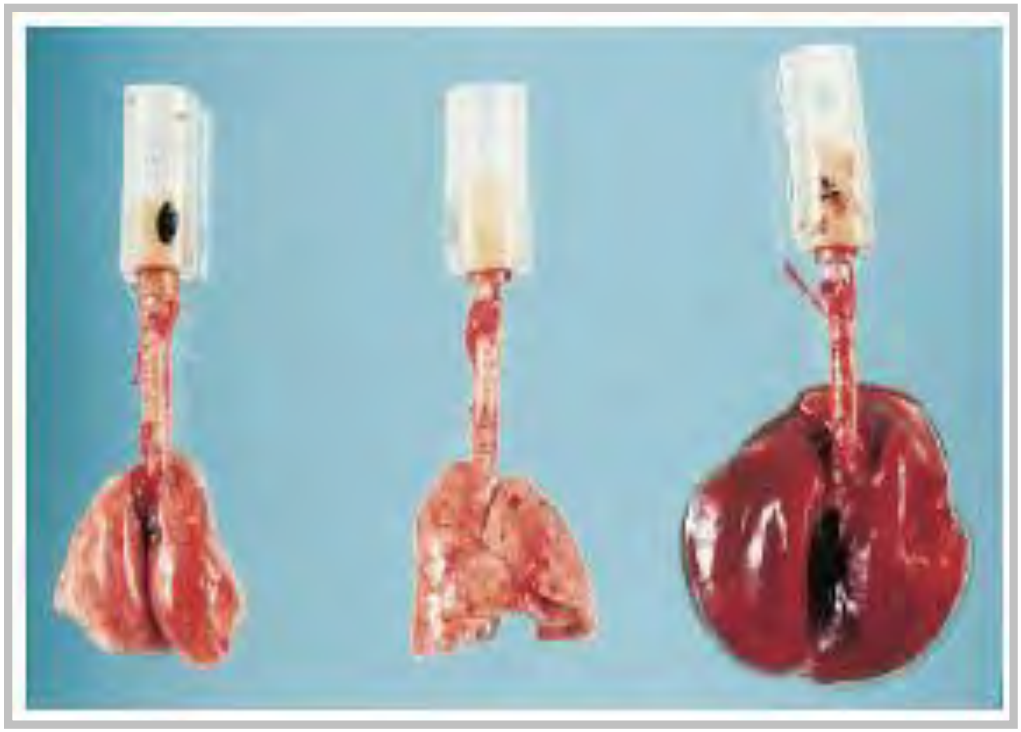
BIOPHYSICAL AND BIOCHEMICAL INJURY IN MECHANICAL VENTILATION



Slutsky, Tremblay A JRCCM. 1998

VENTILATOR INDUCED LUNG INJURY (VILI)

- Normal lung areas are most vulnerable due to high compliance.
- PEEP, VT and time are factors that cause lung injury.
- Blood components infiltrate lung tissue due to VILI.

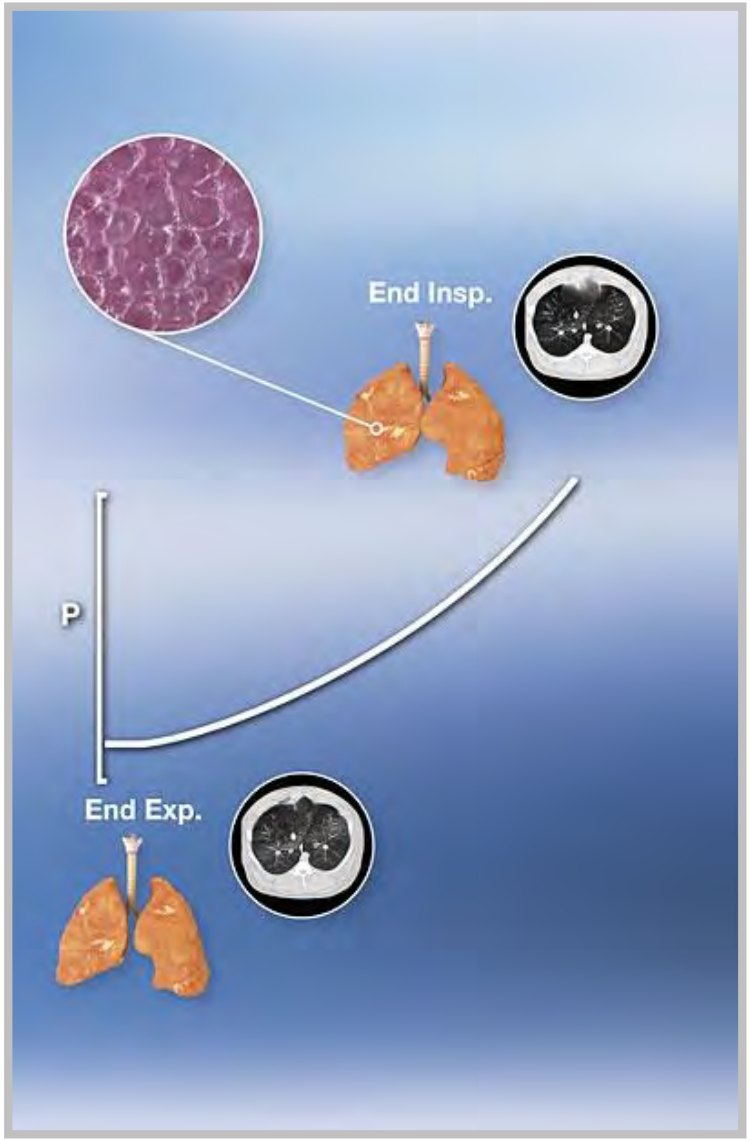


Normal lung 5 min 20 min

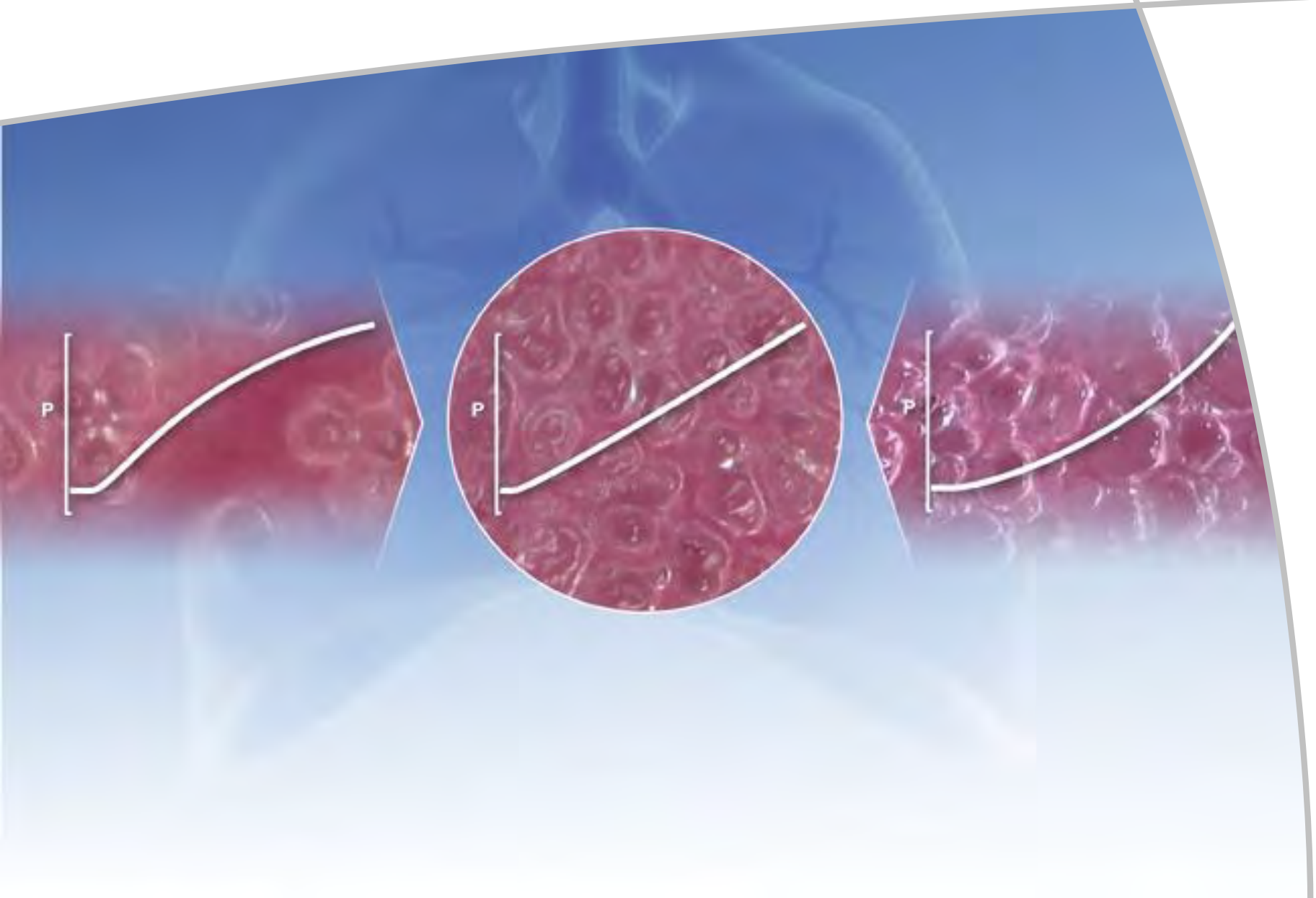
Dreyfuss, Am Rev Respir Dis:132:880-884

CAN LUNG INJURY BE RESTRICTED?

- An inflammatory process may occur together with hyperinflation even when using “safe” tidal volumes.
- Normal areas of the lung could be at risk.
- CMV may cause or aggravate lung injury.
- A Stress Index below 0.9 and over 1.1 indicates a ventilatory strategy at risk.

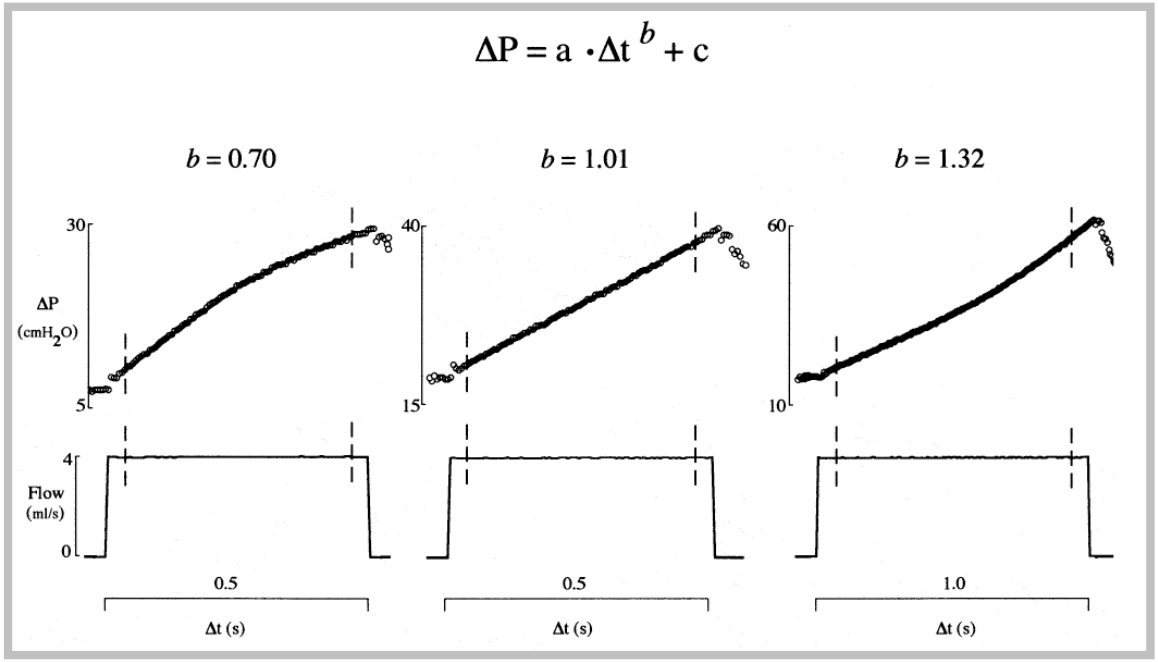


STRESS INDEX PRINCIPLES



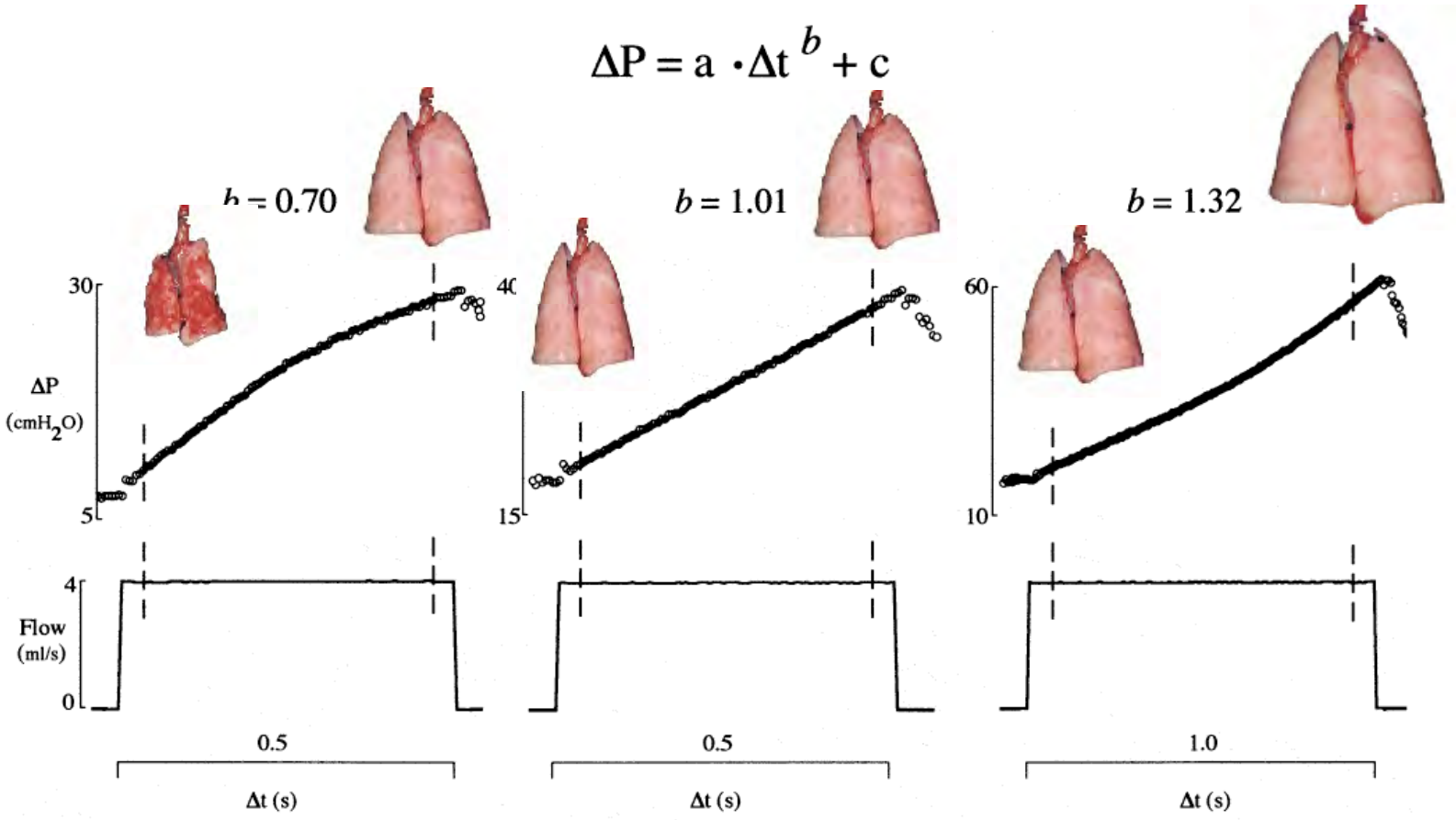
STRESS INDEX PRINCIPLES

- During inspiration with constant flow (i.e. Volume Control):
  - resistance is constant
  - all changes to the shape of the pressure-time curve depend on changes in compliance during the breath.
- The shape of the curve is described by “b” in the equation below.
- **b = Stress Index**



Ranieri VM et al Anesthesiology 2000

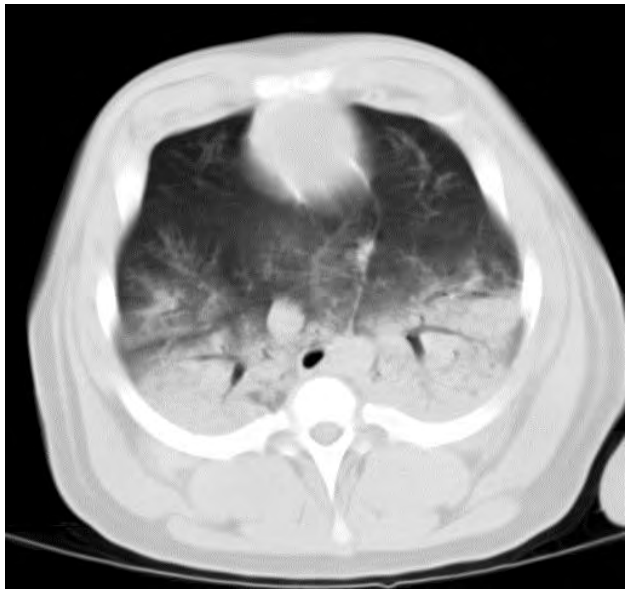
STRESS INDEX PRINCIPLES



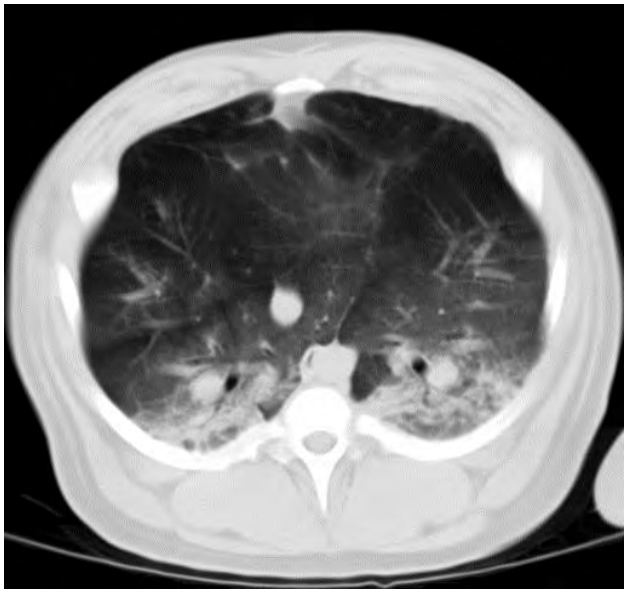
Ranieri VM et al Anesthesiology 2000

STRESS INDEX – COLLAPSE AND OPENING DURING TIDAL RECRUITMENT

SI = 1.02
after RM



SI = 0.77

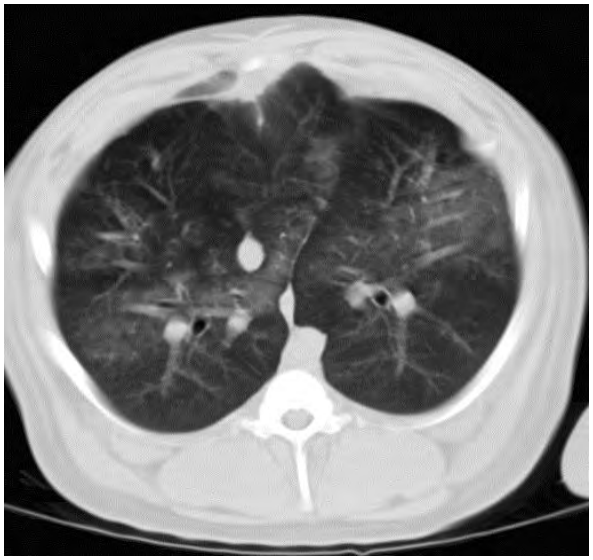


End Expiration

End Inspiration

S Grasso CCM 2004

SI = 0.77



SI = 1.41

End Expiration

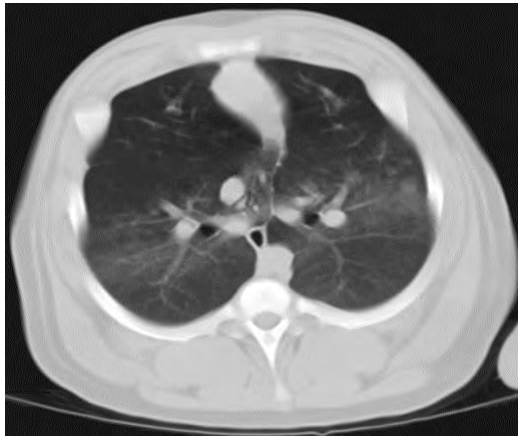
End Inspiration

S Grasso CCM 2004

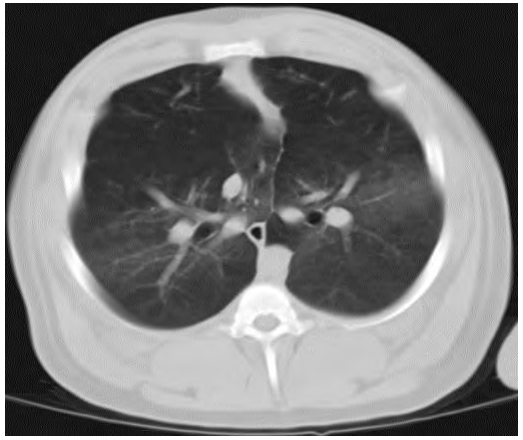
STRESS INDEX – LUNG REST/LUNG RECRUITMENT

SI = 1.05
before RM

LUNG REST
Low PEEP



SI = 1.02
after RM



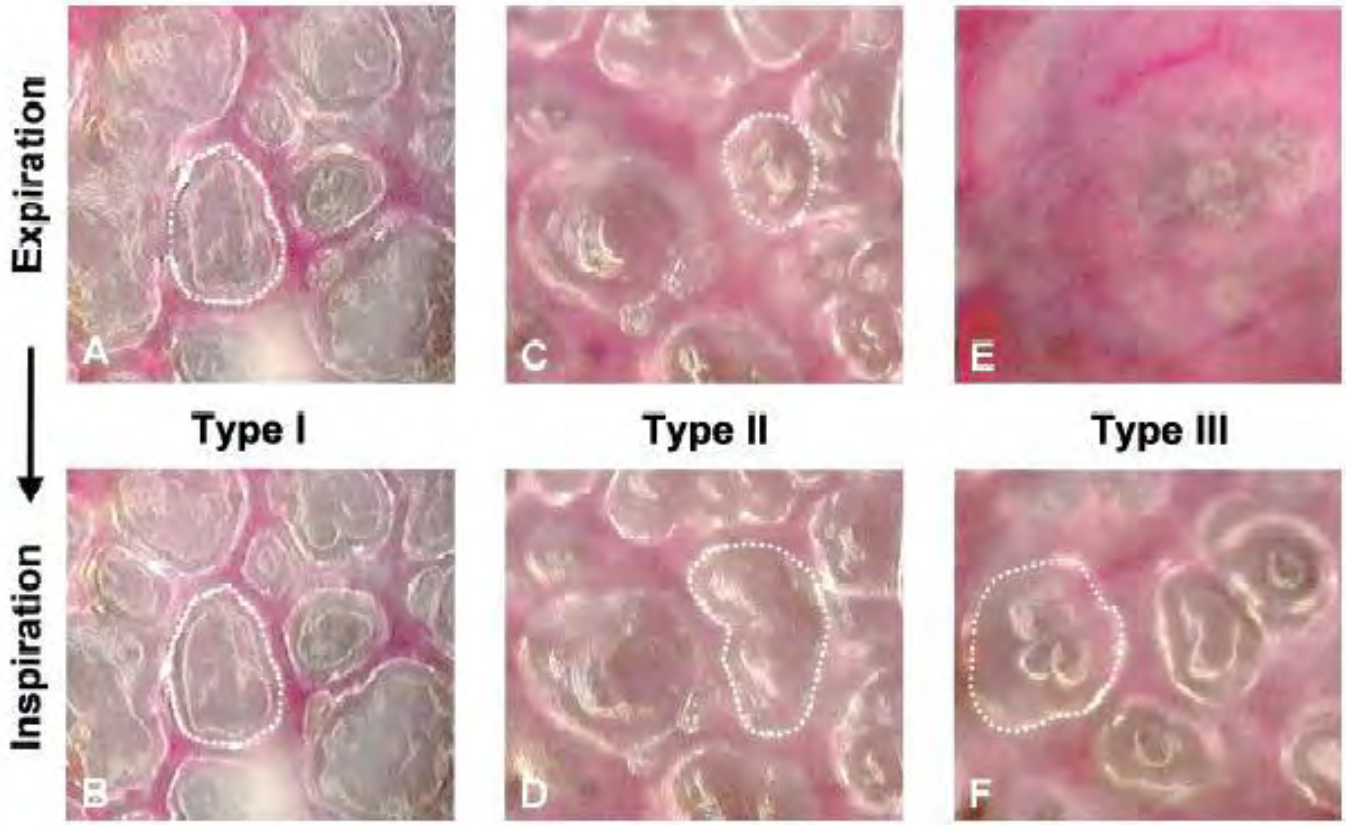
LUNG
RECRUITMENT
High PEEP

End Expiration

End Inspiration

S Grasso CCM 2004

ALVEOLAR DYNAMICS



SI = 1.0 SI > 1.0 SI < 1.0

Nieman et al. CCM 2001, Vol. 29(5):1049-1056

STRESS INDEX APPLICATION – LUNG REST STRATEGY

Base line ventilation

VT= 6 ml/kg PBW

PEEP = 5 cmH_2O

Measure SI during low VT ventilation

Adjust PEEP to achieve a Stress Index of 1.1 > SI > 0.9

1.1 > *Stress Index* > 0.9

Leave PEEP unchanged

SI<0.9

Increase PEEP until 1.1 > *Stress Index* > 0.9

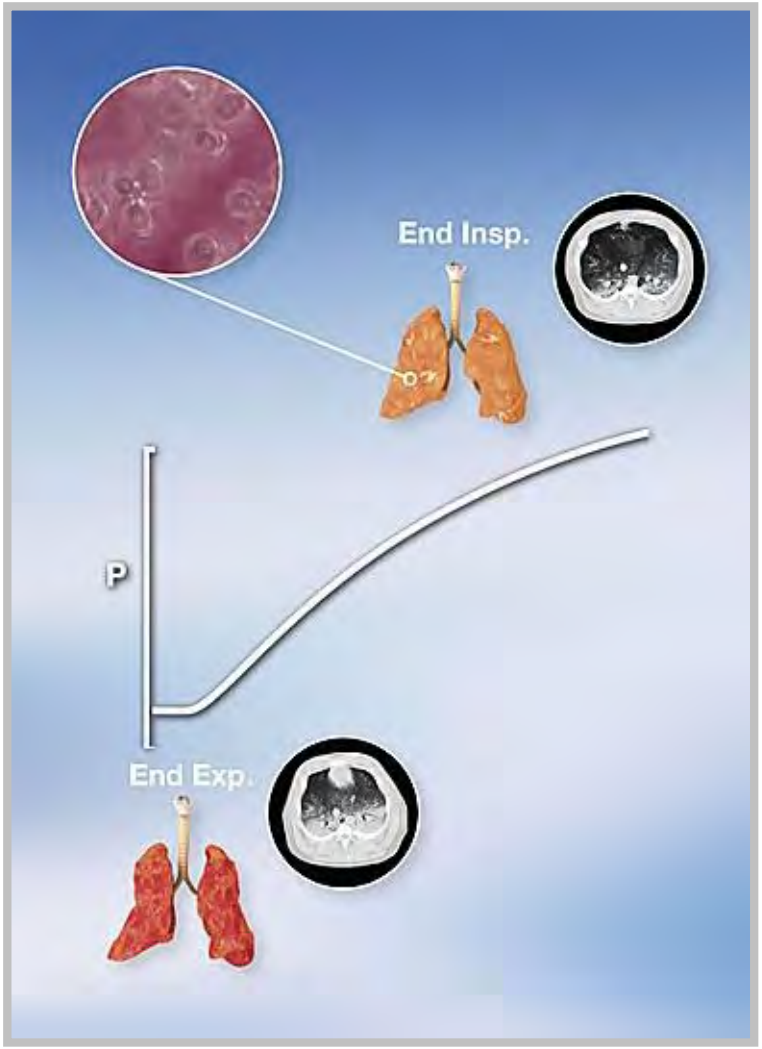
SI>1.1

Decrease PEEP until 1.1 > Stress Index > 0.9

S Grasso CCM 2004

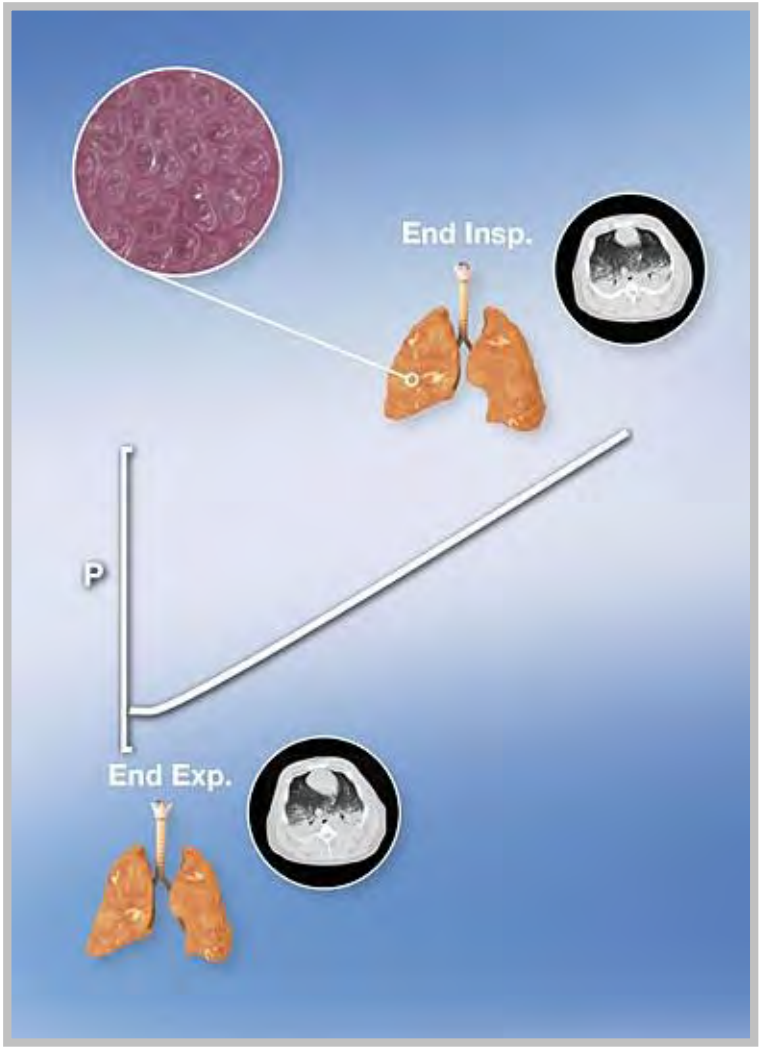
SERVO-i WITH STRESS INDEX – TIDAL RECRUITMENT

- Stress Index will detect tidal recruitment, i.e. alternating opening and closing of lung tissue.
- The pressure-time curve will display downward concavity, reflecting increased compliance.
- Stress Index will be below 0.9.



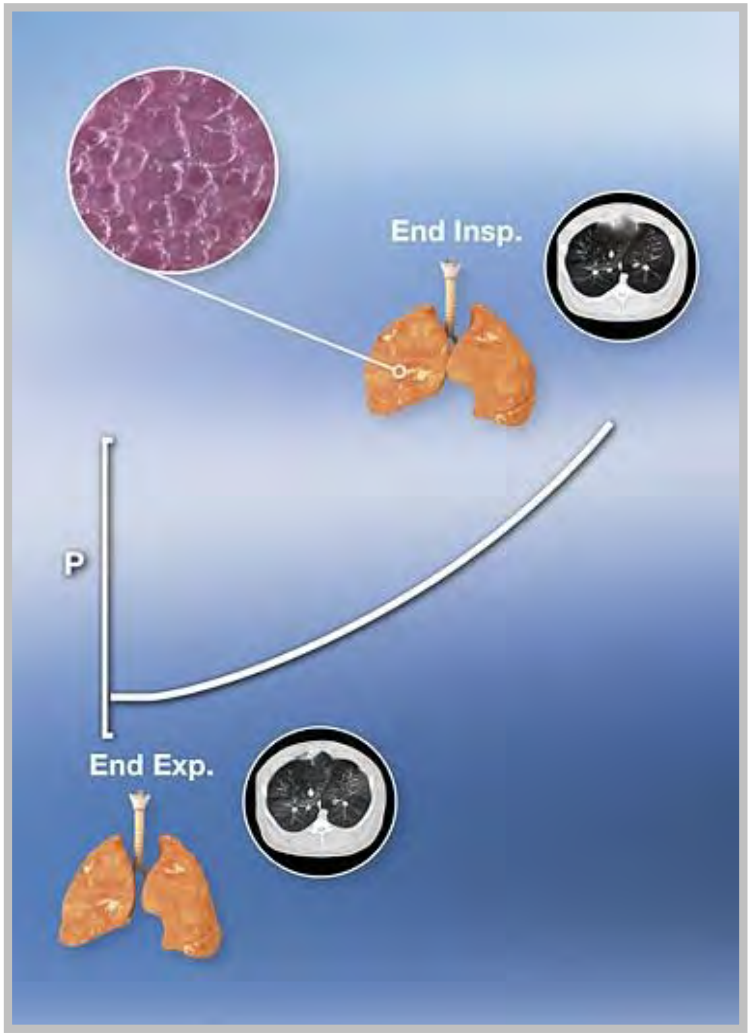
SERVO-i WITH STRESS INDEX – NORMAL LUNG

- In a normal lung, the pressure-time curve will be linear, reflecting constant compliance.
- Stress Index will be 0.9-1.1.



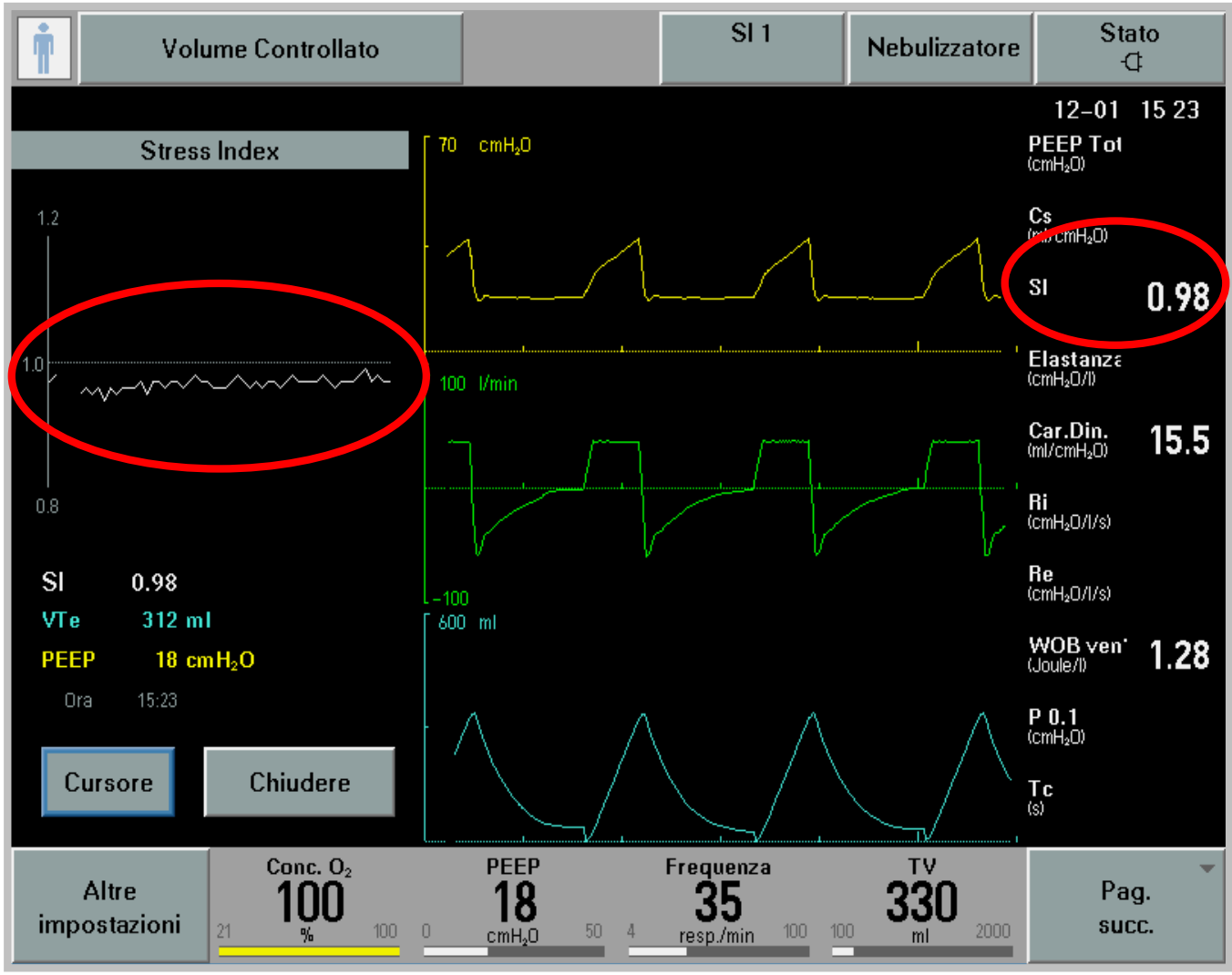
SERVO-i WITH STRESS INDEX – OVERDISTENSION

- Stress Index detects overdistension.
- The pressure-time curve will display upward concavity, reflecting decreased compliance.
- Stress Index will be higher than 1.1.



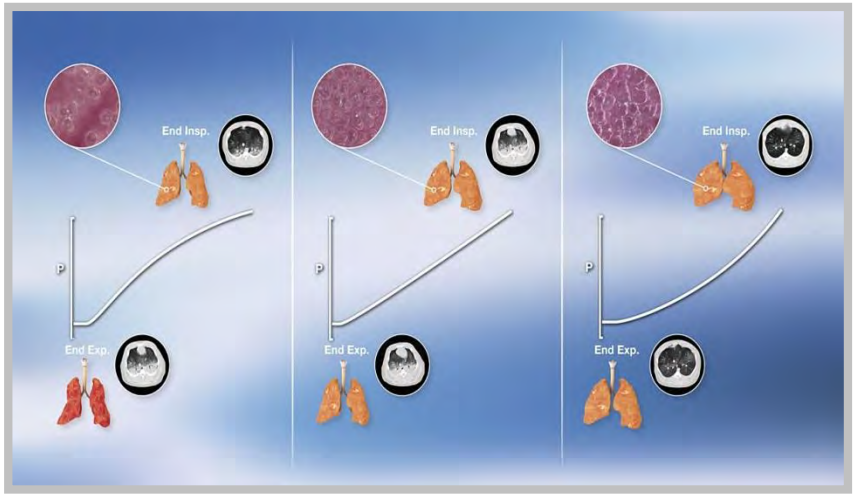
SERVO-i WITH STRESS INDEX – DETECTING LUNG STRESS

- Stress Index detects:
  - Over distension
  - Tidal Recruitment.



STRESS INDEX – LUNG PROTECTIVE VENTILATION

- Stress Index detects lung stress during
  - lung recruitment strategies
  - lung rest strategies.



Stress index guides clinicians in avoiding lung stress and protecting the lung.

STRESS INDEX
DETECTING LUNG STRESS