STRESS INDEX
DETECTING LUNG STRESS
"Wouldn’t it be nice to be able to detect lung stress & reduce lung injury?!"

AND… find Optimal PEEP
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).

Papazian L. NEJM Sep 2010
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.
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 Puntonieri, 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
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.

**Stress Index will guide you in preventing this potentially harmful scenario.**
The P-V curve depends on the ventilation volumes previously used and the patient’s status and is therefore hard to interpret.
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

Biochemical injury (biotrauma)
- Epithelium/interstitium
  - cytokines, complement, PGs, LTs, ROS, proteases
- neutrophils

Biophysical injury
- shear
- overdistension
- cyclic stretch
- Δ intrathoracic pressure

Distal Organ Dysfunction
- ↑alveolar-capillary permeability
- ↓cardiac output
- ↓organ perfusion

DEATH

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.
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**

\[ \Delta P = a \cdot \Delta t^b + c \]

![Graph showing the relationship between flow and pressure with different values of b]

Ranieri VM et al  Anesthesiology 2000
\[ \Delta P = a \cdot \Delta t^b + c \]

- \( h = 0.70 \)
- \( b = 1.01 \)
- \( b = 1.32 \)

Ranieri VM et al  Anesthesiology 2000
STRESS INDEX – COLLAPSE AND OPENING DURING TIDAL RECRUITMENT

End Inspiration

SI = 1.05
before RM

SI = 1.02
after RM

SI = 0.77

End Expiration

SI = 1.41

SI = 0.77

End Inspiration

S Grasso CCM 2004
STRESS INDEX – OVERDISTENSION

SI = 0.77

End Expiration

SI = 1.41

End Inspiration

S Grasso CCM 2004
STRESS INDEX – LUNG REST/LUNG RECRUITMENT

\[ SI = 1.05 \]
before RM

\[ SI = 1.02 \]
after RM

\[ SI = 0.77 \]

\[ SI = 1.41 \]

LUNG REST
Low PEEP

LUNG RECRUITMENT
High PEEP

End Expiration

End Inspiration

S Grasso CCM 2004
ALVEOLAR DYNAMICS

SI = 1.0

SI > 1.0

SI < 1.0

STRESS INDEX APPLICATION – LUNG REST STRATEGY

Base line ventilation

VT = 6 ml/kg PBW
PEEP = 5 cmH$_2$O

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

Stress Index will be 0.9-1.1.
- 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 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