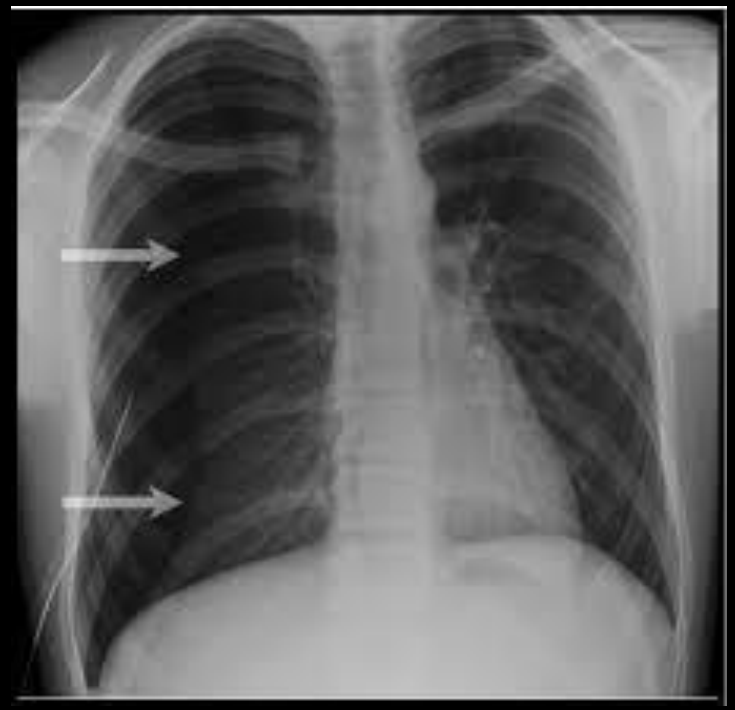
Μελέτη αερισμού των πνευμόνων παρά την κλίνη της Εντατικής. Είναι εφικτή και αξιόπιστη ;

Γ. Γαβριηλίδης
Εντατικολόγος
Μονάδα Εντατικής Θεραπείας
Α’ Πανεπιστημιακή Πνευμονολογική Κλινική
Νοσοκομείο ‘Σωτηρία’

- Μέτρηση του τελο-εκπνευστικού όγκου (EELV) → Strain = Vt/EELV
- Παρακολούθηση της κατανομής του αερισμού κατά τη διάρκεια του αναπνευστικού κύκλου
- Απεικόνιση των πνευμόνων

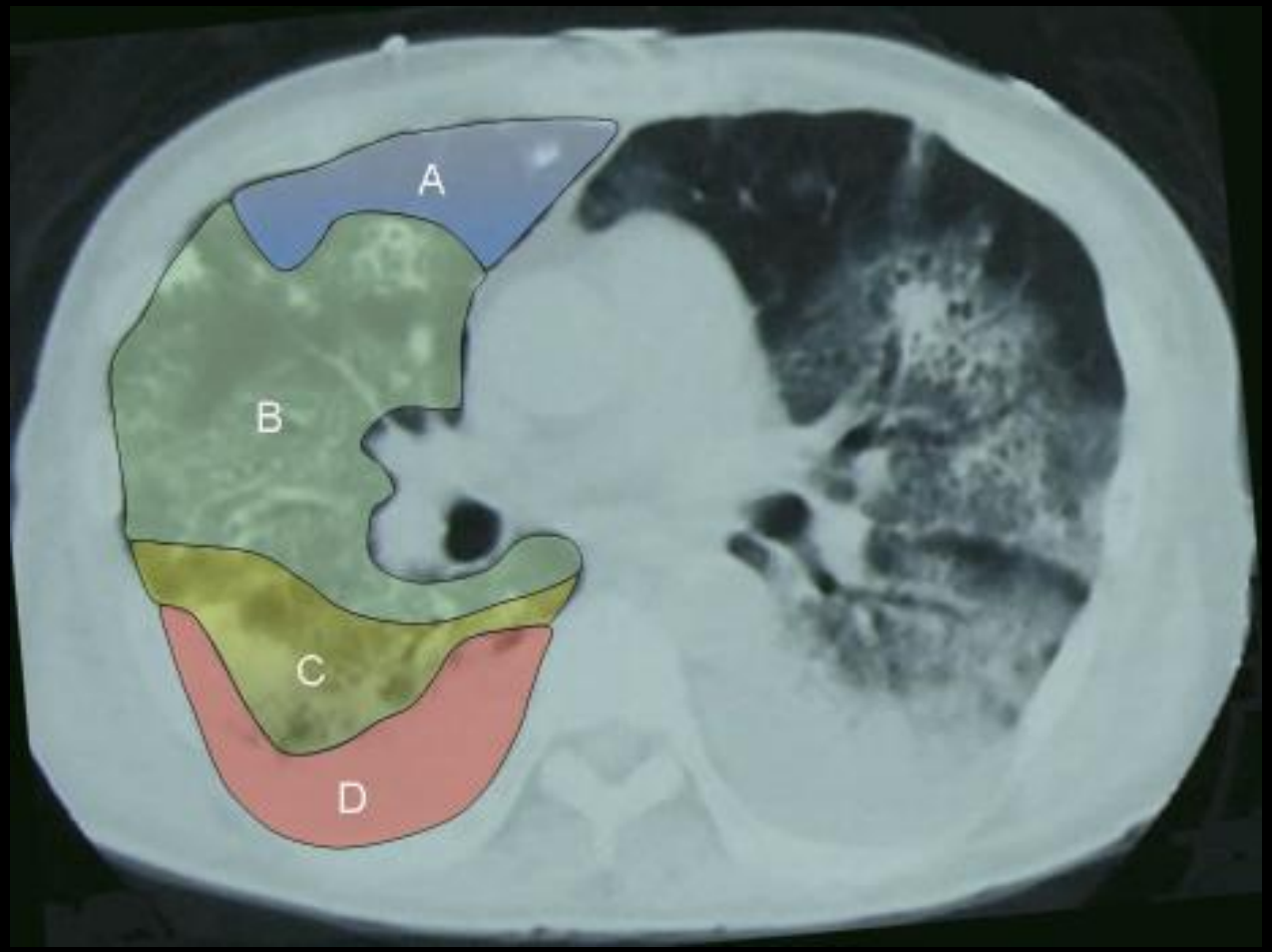
Atelectasis

Pneumothorax



ARDS Lung

A) Hyperinflated
B) Normally aerated
C) Poorly aerated
D) Non-aerated



MultiBreath-Nitrogen Washout technique for the assessment of EELV

Engstrom Carestation (GE)

Είναι αξιόπιστη μέθοδος ;

CRITICAL CARE

Research

Open Access

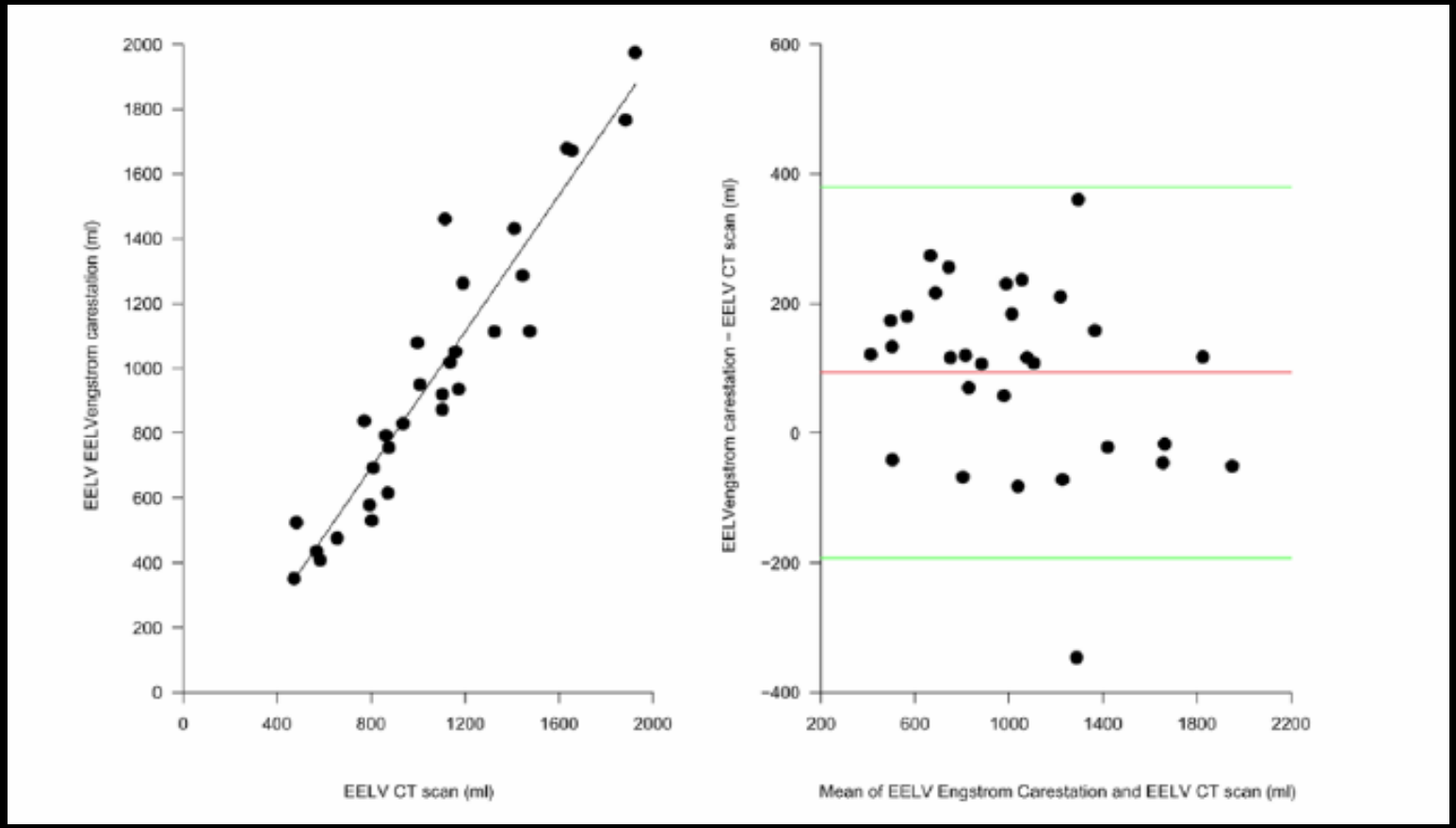
Nitrogen washout/washin, helium dilution and computed tomography in the assessment of end expiratory lung volume

Davide Chiumello[1], Massimo Cressoni[2], Monica Chierichetti[2], Federica Tallarini[2], Marco Botticelli[2], Virna Berto[2], Cristina Mietto[2] and Luciano Gattinoni[1,2]

Critical Care 2008, **12**:R150

CRITICAL CARE

r = 0,95



Critical Care 2008, **12**:R150

CRITICAL CARE

Accuracy and precision of end-expiratory lung-volume measurements by automated nitrogen washout/washin technique in patients with acute respiratory distress syndrome

Jean Dellamonica[1,2,9*], Nicolas Lerolle[3,4], Cyril Sargentini[4], Gaetan Beduneau[5], Fabiano Di Marco[6], Alain Mercat[4], Jean-Christophe M Richard[5], Jean-Luc Diehl[3], Jordi Mancebo[7], Jean-Jacques Rouby[8], Qin Lu[8], Gilles Bernardin[2] and Laurent Brochard[1,9,10]

Variability 4%
Largest difference 85±64ml

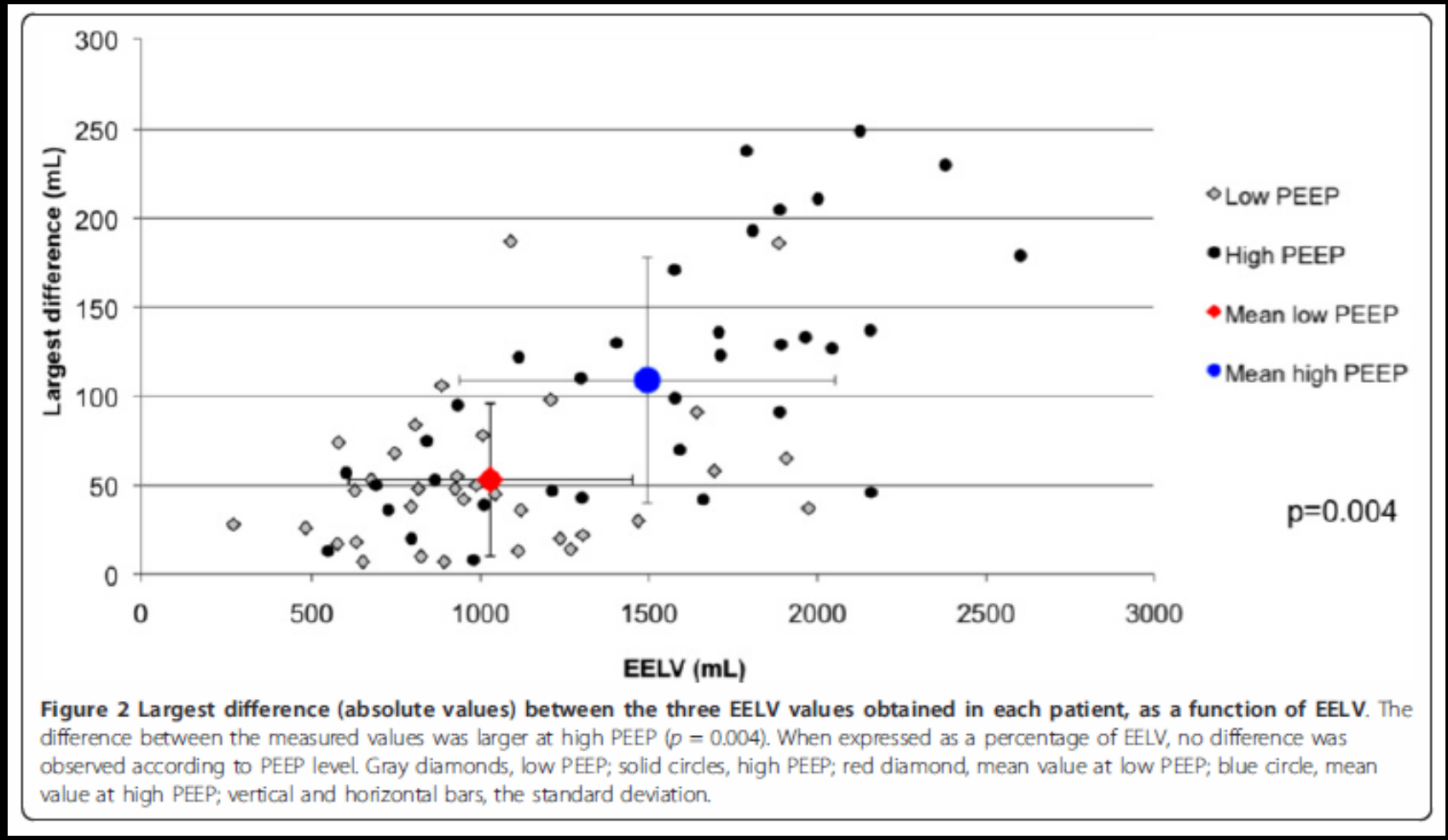
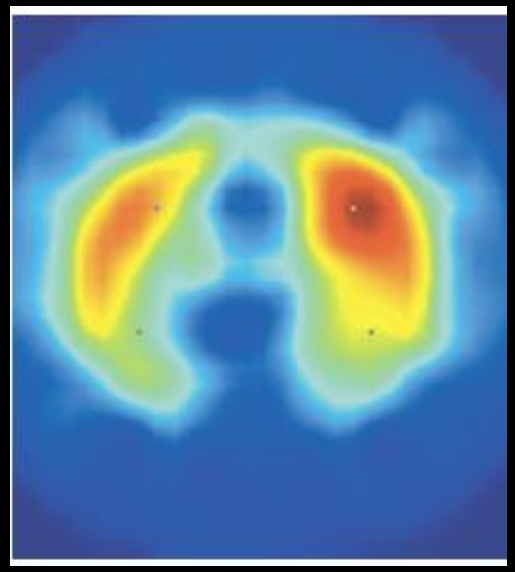


Figure 2 Largest difference (absolute values) between the three EELV values obtained in each patient, as a function of EELV. The difference between the measured values was larger at high PEEP ($p = 0.004$). When expressed as a percentage of EELV, no difference was observed according to PEEP level. Gray diamonds, low PEEP; solid circles, high PEEP; red diamond, mean value at low PEEP; blue circle, mean value at high PEEP; vertical and horizontal bars, the standard deviation.

Dellamonica *et al. Critical Care* 2011, **15**:R294

Electrical Impedance Tomography

GOE MF II System



Developed by Barber and Brown in the early 1980s

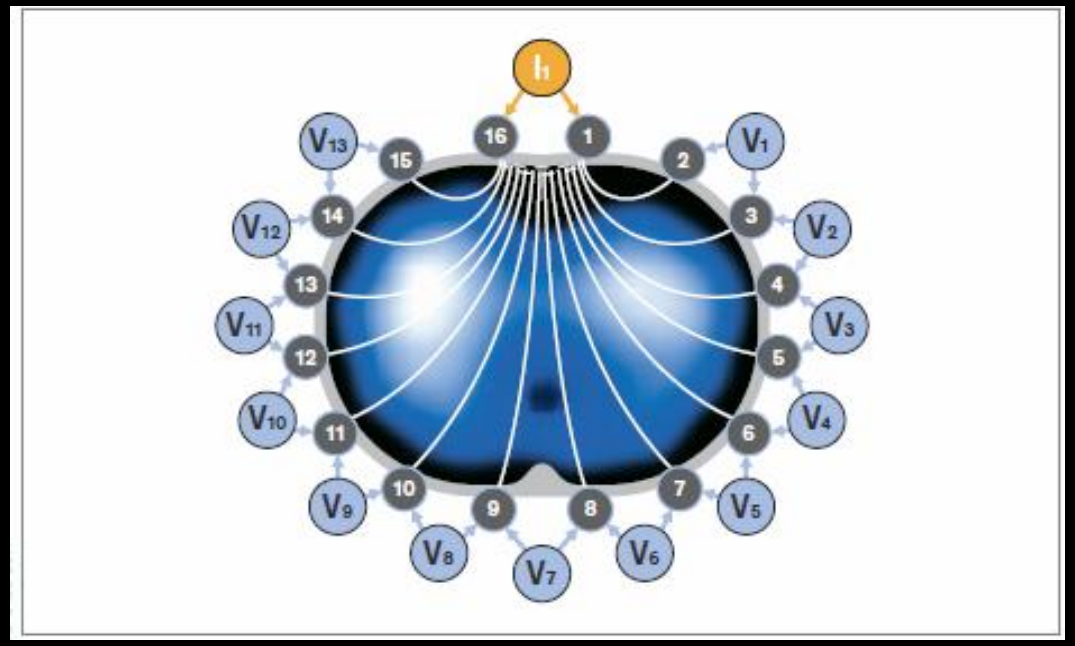
EIT systems

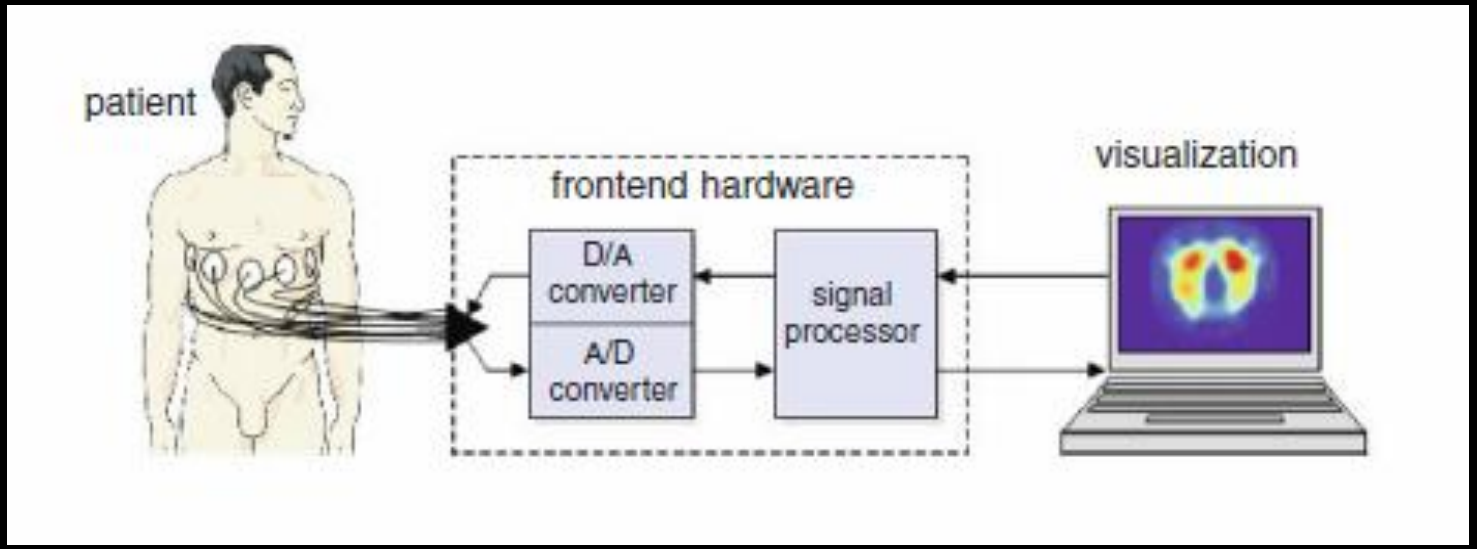
Pulmovista 500 (Draeger)

Swisstom BB2

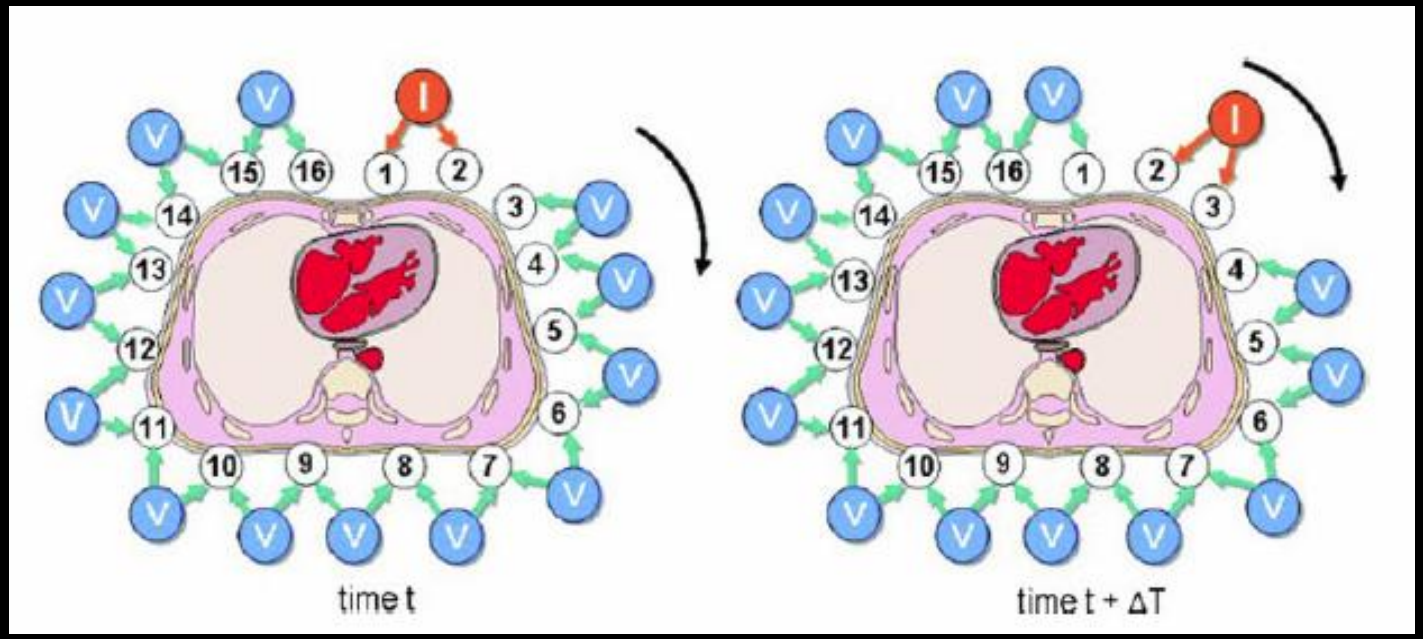
The principles of EIT

$$\text{Impedance (Z)} = \frac{\text{Voltage (V)}}{\text{Current (I)}}$$




patient
frontend hardware
D/A converter
A/D converter
signal processor
visualization

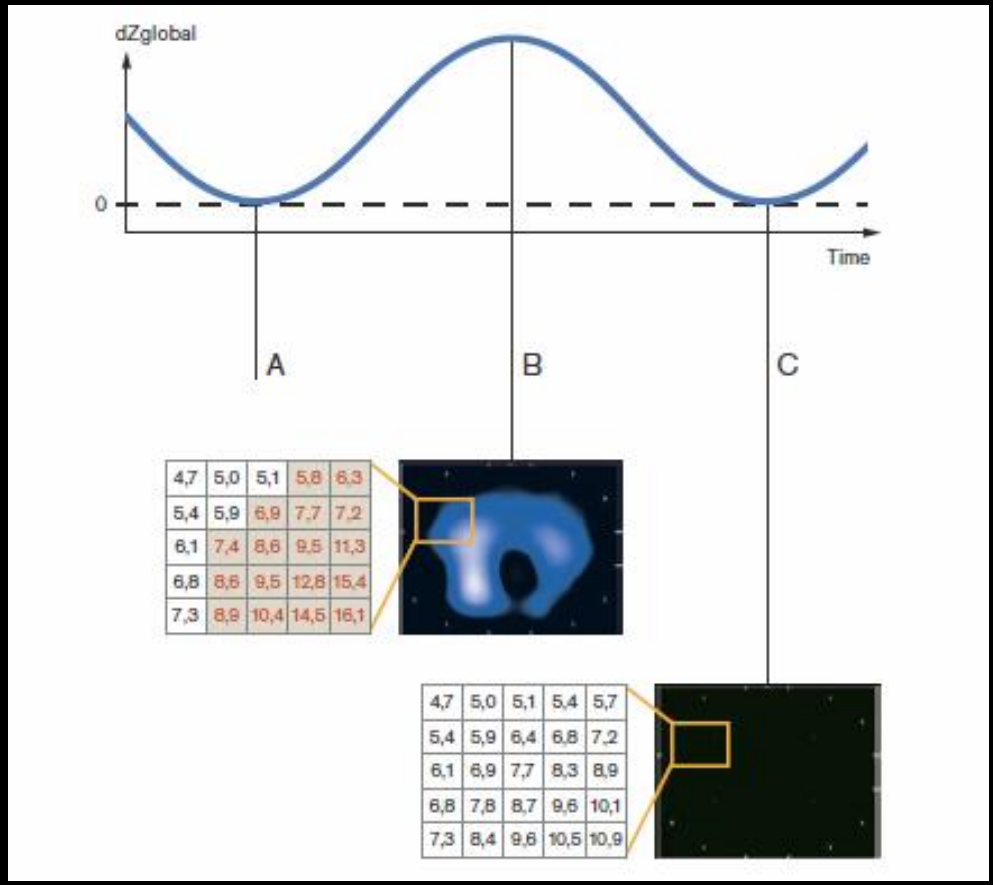
Continuous rotation of the location of current injection



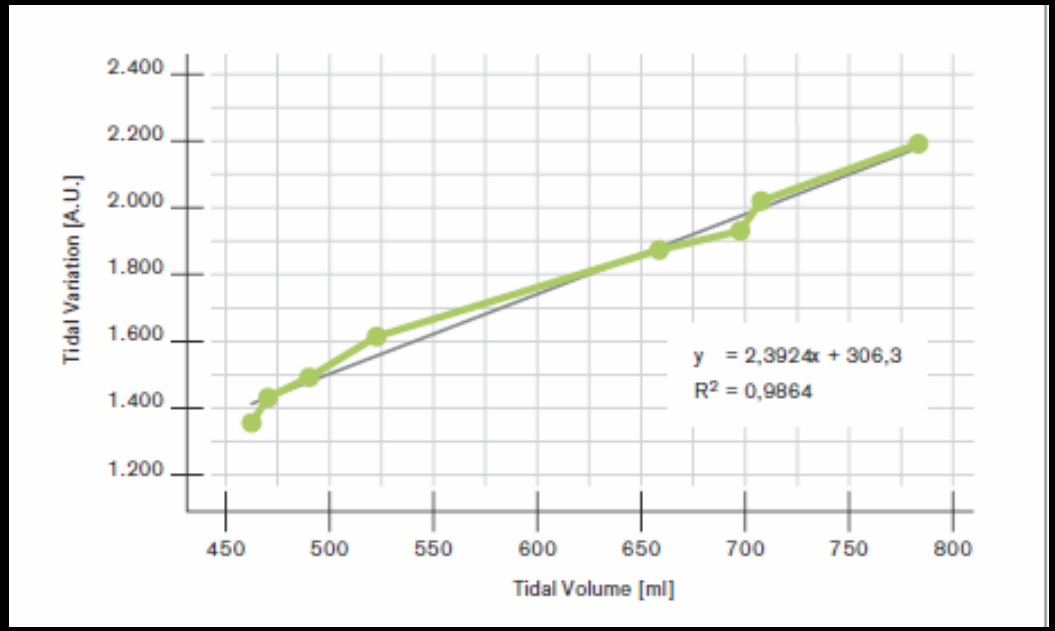
- Electrical current (5mA, 50KHz)
- 4th - 6th μεσοπλεύριο διάστημα
- 16 x 13 = 208 voltage measurements → one frame
- Frame rate = 20/sec

Intensive Care Med (2012) 38:1917–1929
DOI 10.1007/s00134-012-2684-z

Η μεταβολή των καταγραφόμενων δυναμικών «δημιουργεί» την εικόνα

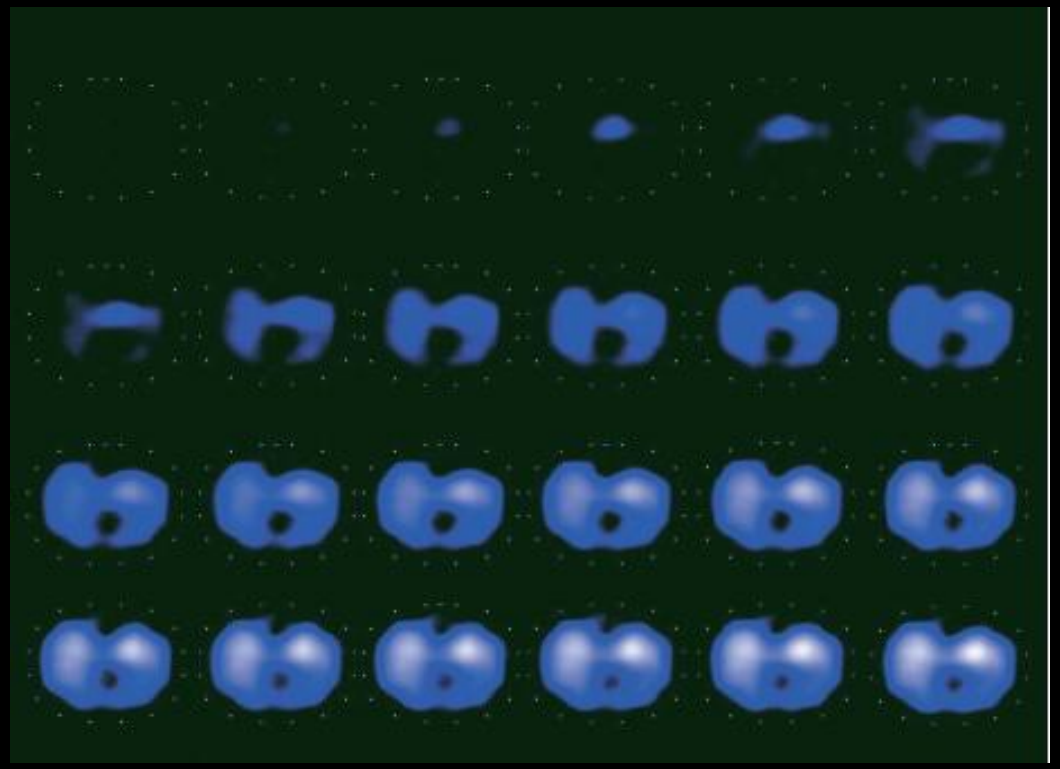


Correlation between Tidal (impedance) Variation and Tidal Volume



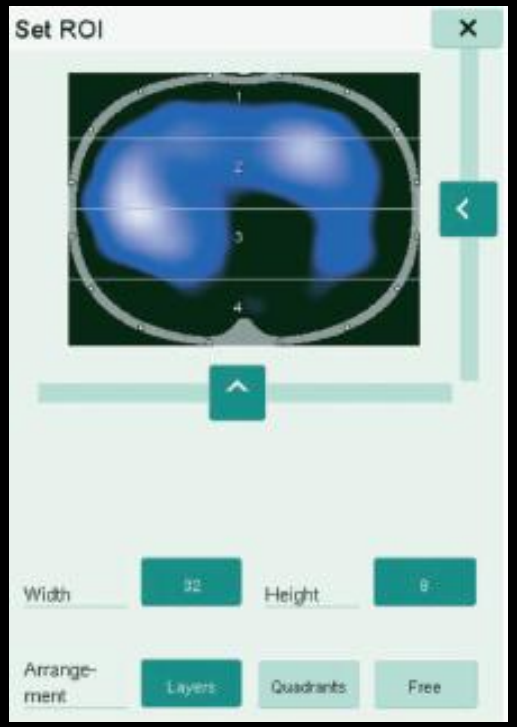
Inspiration from RV to TLC increases impedance by 300%

Series of dynamic images representing air filling during inspiration



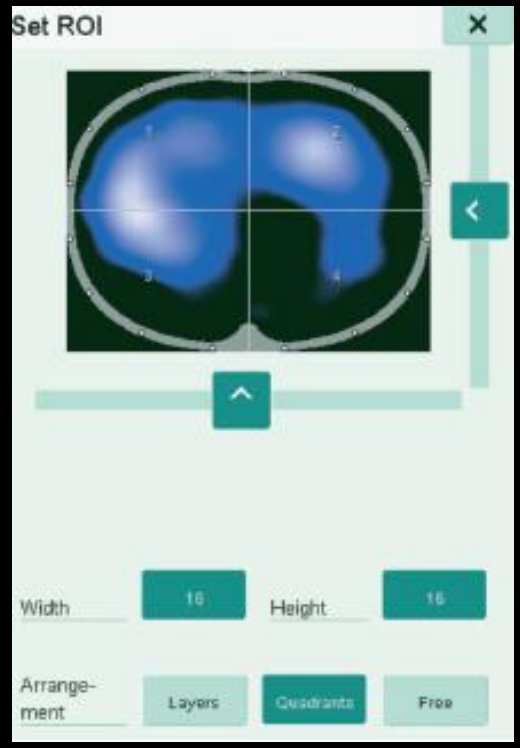
Regions of Interest (ROI)

Horizontally



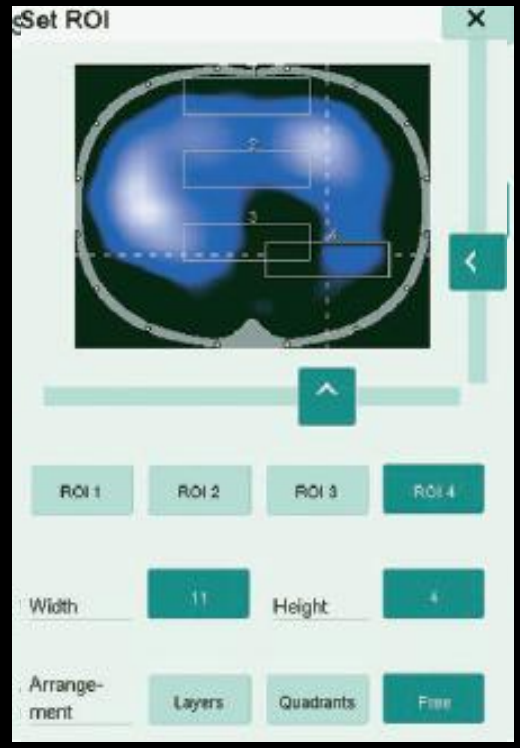
Regions of Interest (ROI)

Quadrants

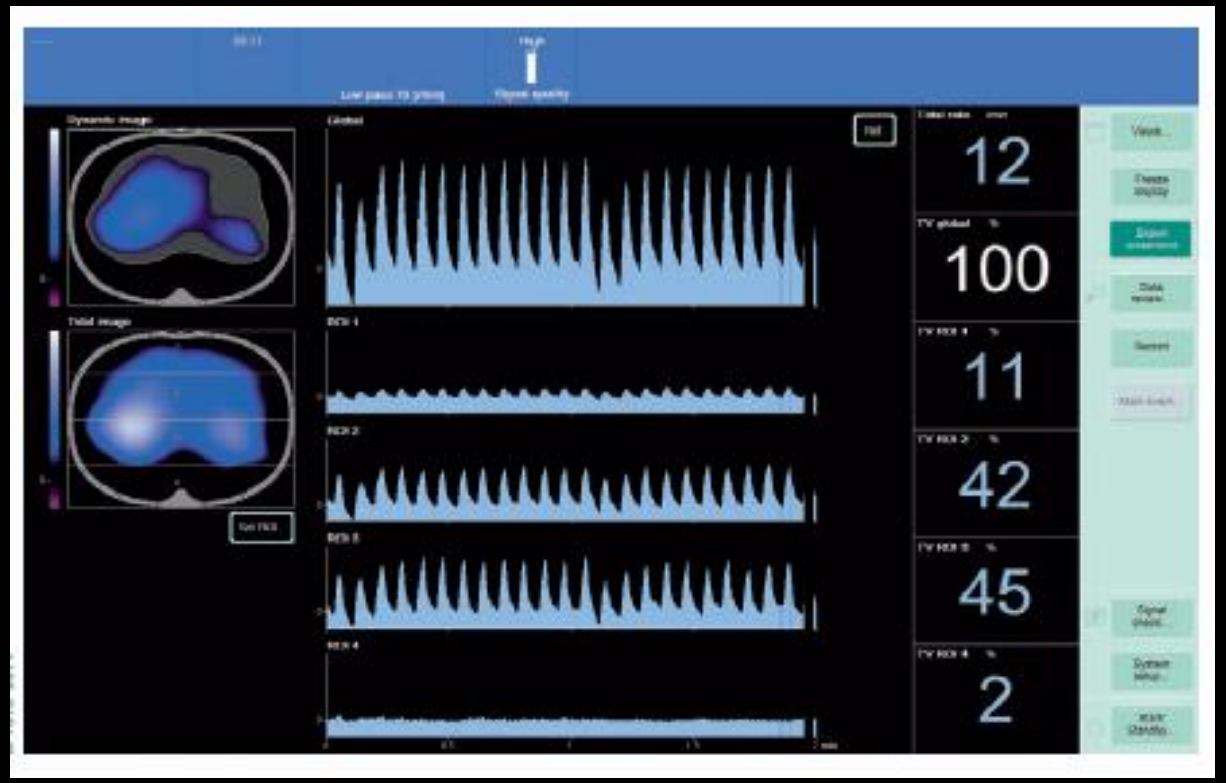


Regions of Interest (ROI)

Free mode



Screenshot of the main View

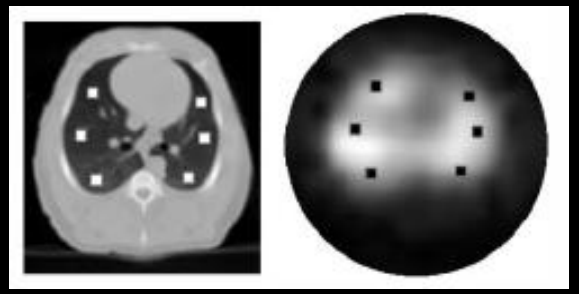


American Physiological Society Journal of Applied Physiology

Detection of local lung air content by electrical impedance tomography compared with electron beam CT

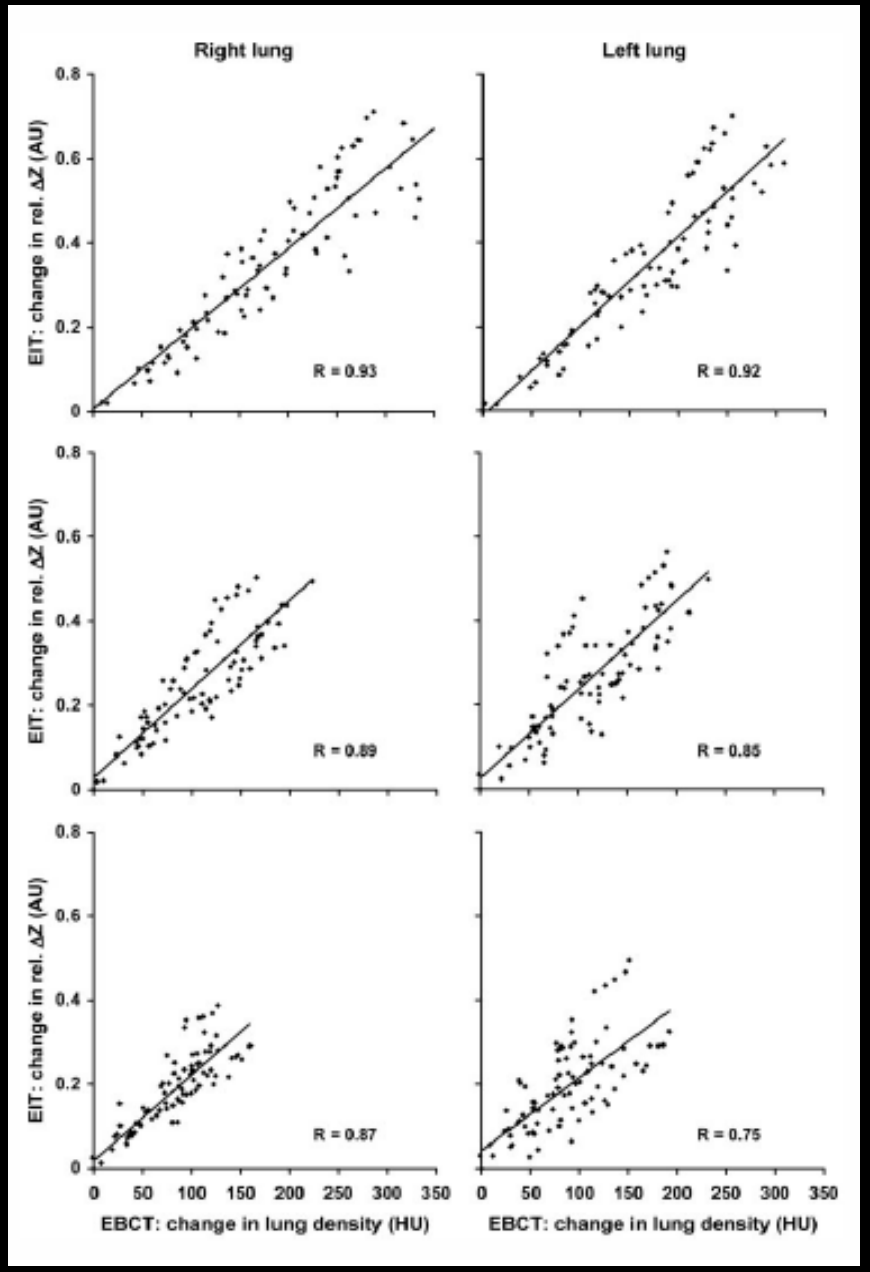
INÉZ FRERICHS,[1] JOSÉ HINZ,[1] PETER HERRMANN,[2] GERALD WEISSER,[3] GÜNTER HAHN,[1] TARAS DUDYKEVYCH,[1] MICHAEL QUINTEL,[2] AND GERHARD HELLIGE[1]

[1]*Department of Anesthesiological Research, Center of Anesthesiology, Emergency and Intensive Care Medicine, University of Göttingen, D-37075 Göttingen; and Institutes of* [2]*Anesthesiology and Operative Intensive Care and* [3]*Clinical Radiology, University Hospital Mannheim, D-68167 Mannheim, Germany*



J Appl Physiol 93: 660–666, 2002.

American Physiological Society
Journal of Applied Physiology



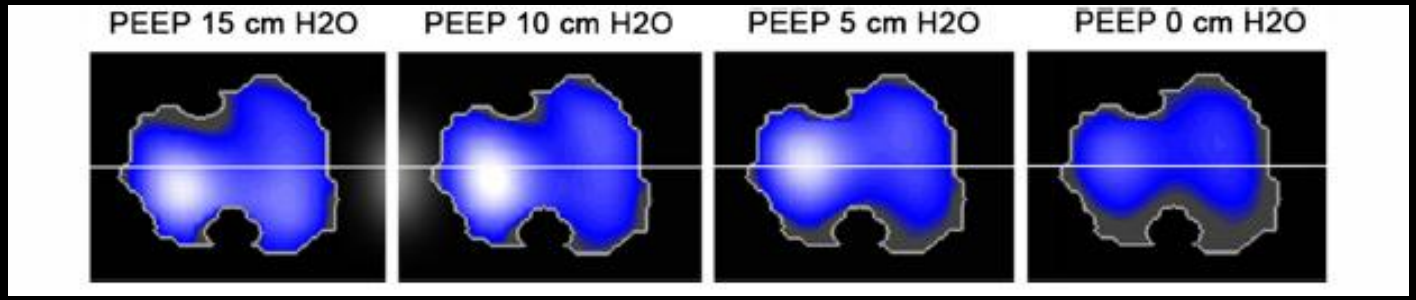
dorsal

middle

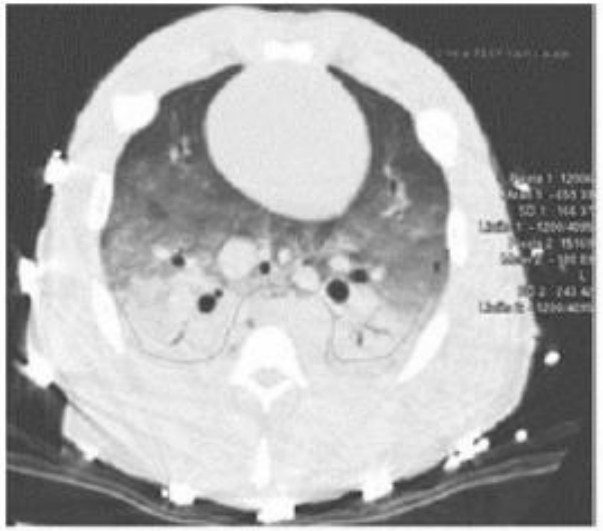
ventral

J Appl Physiol 93: 660–666, 2002.

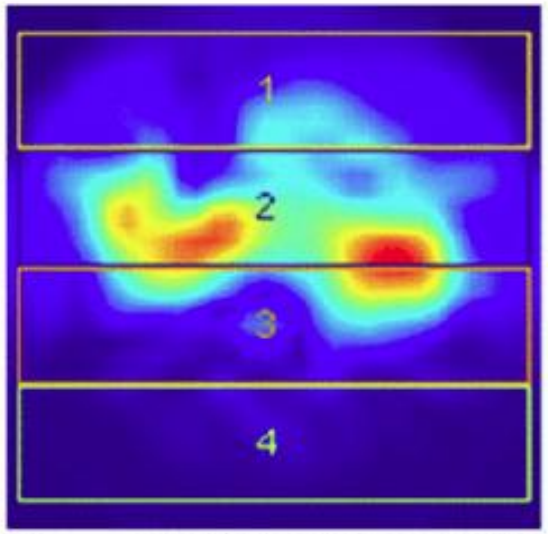
PEEP titration in ARDS



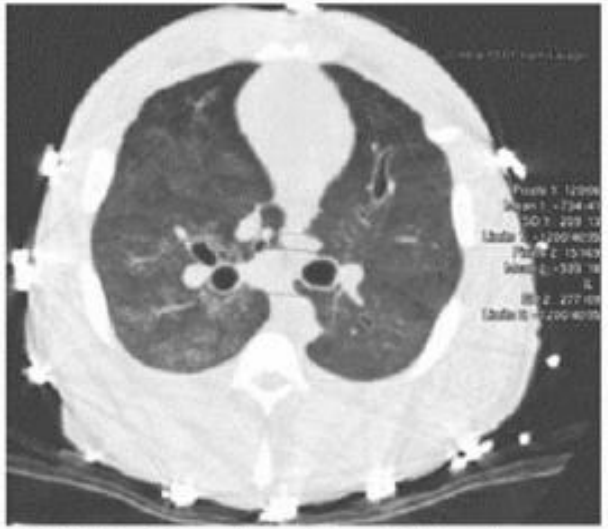
Blankman *et al. Critical Care* 2014, **18**:R95
http://ccforum.com/content/18/3/R95



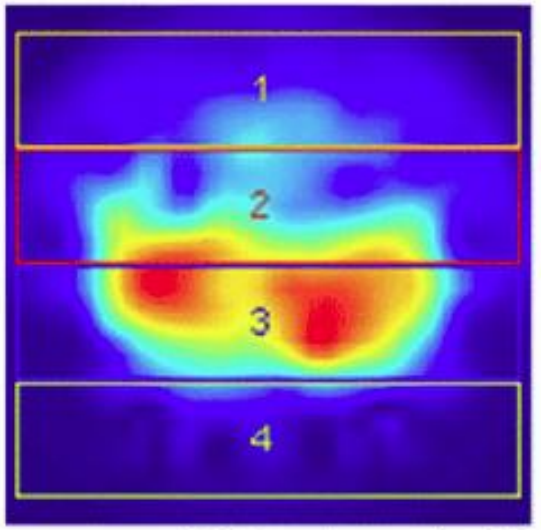
PEEP = 0 mbar, V_T = 150 ml
HU ventral -659.39, dorsal -180.89



Δz_{global} = 1860, color scale 5.1



PEEP = 20 mbar, V_T = 140 ml
HU ventral -734.41, dorsal -593.18



Δz_{global} = 1006, color scale 2.0

Estimation of EELV

Official Journal of the European Society of Intensive Care Medicine and the European Society of Pediatric & Neonatal Intensive Care

European Society of Intensive Care Medicine

INTENSIVE CARE MEDICINE

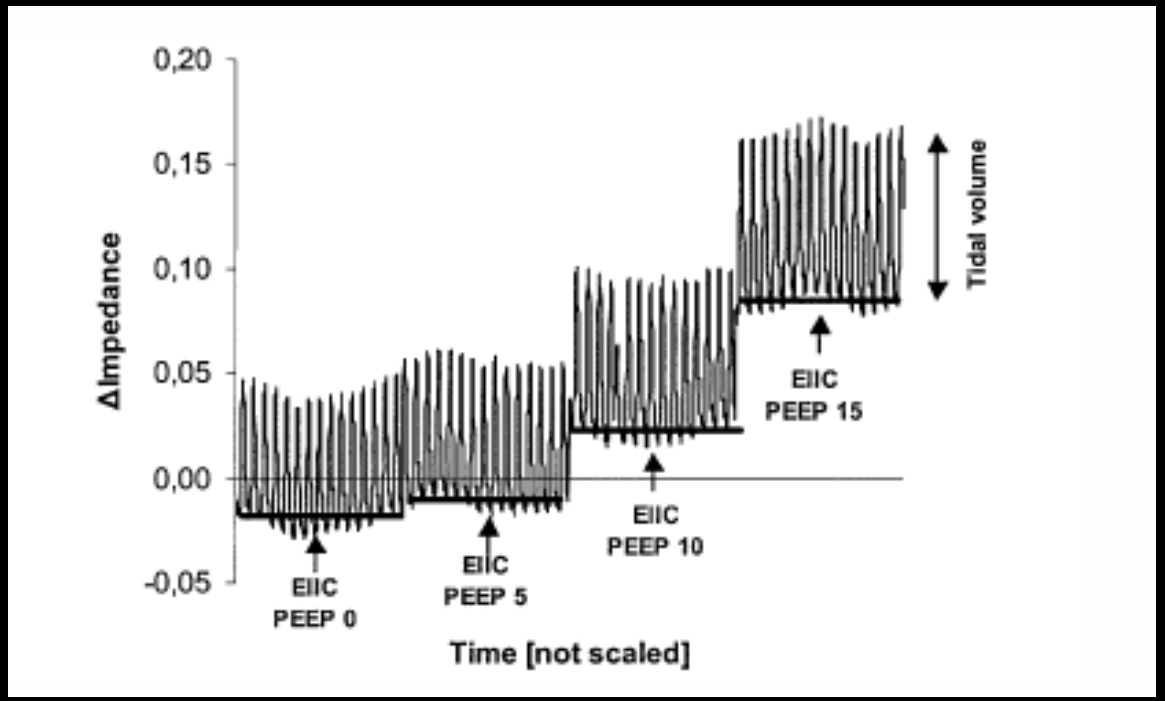
Intensive Care Med (2003) 29:37–43
DOI 10.1007/s00134-002-1555-4

ORIGINAL

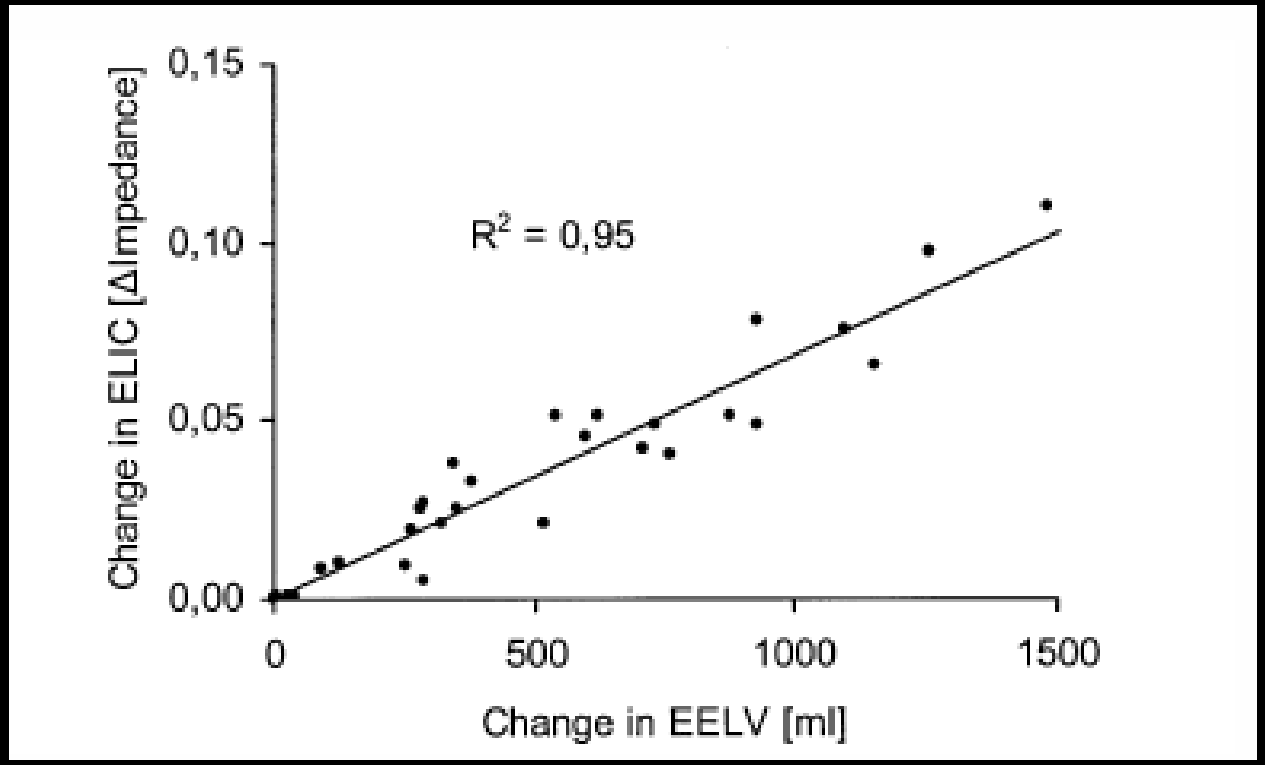
J. Hinz
G. Hahn
P. Neumann
M. Sydow
P. Mohrenweiser
G. Hellige
H. Burchardi

End-expiratory lung impedance change enables bedside monitoring of end-expiratory lung volume change

Official Journal of the European Society of Intensive Care Medicine and the European Society of Pediatric & Neonatal Intensive Care
INTENSIVE CARE MEDICINE



Official Journal of the European Society of Intensive Care Medicine and the European Society of Pediatric & Neonatal Intensive Care
INTENSIVE CARE MEDICINE



Mechanical ventilation guidance in ARDS

INTENSIVE CARE MEDICINE

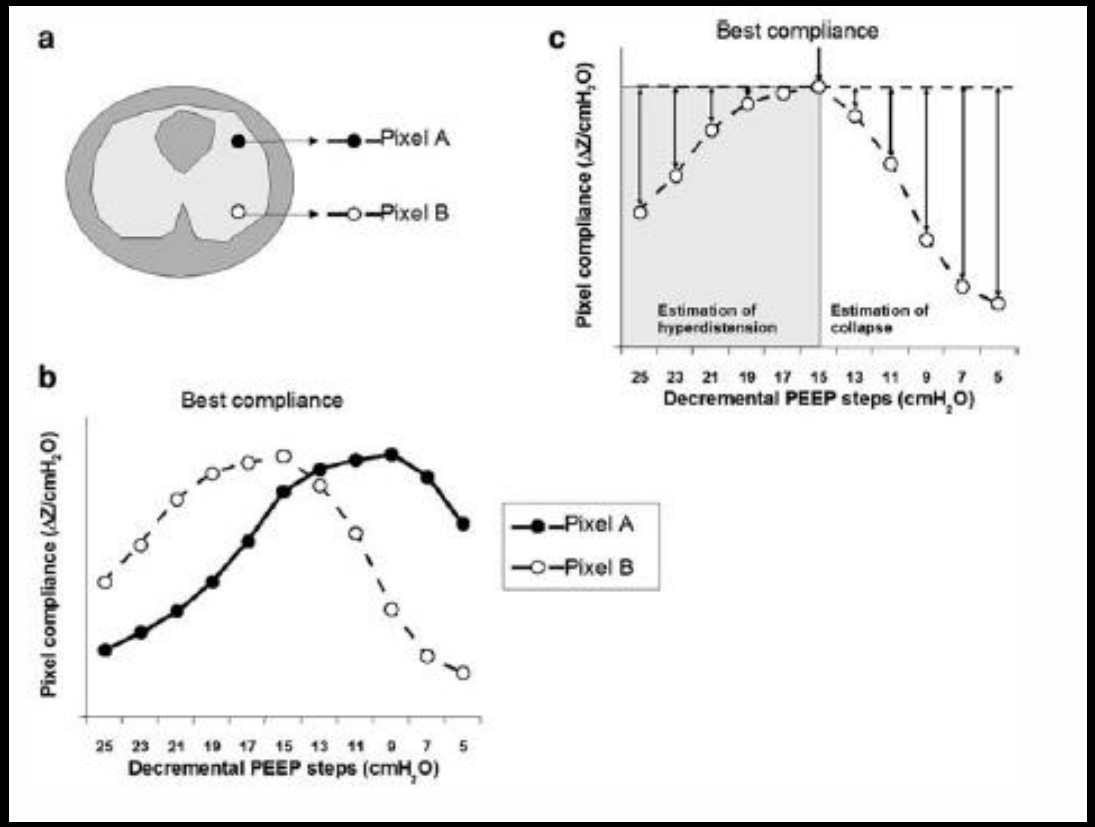
Bedside estimation of recruitable alveolar collapse and hyperdistension by electrical impedance tomography

Eduardo L. V. Costa
João Batista Borges
Alexandre Melo
Fernando Suarez-Sipmann
Carlos Toufen Jr
Stephan H. Bohm
Marcelo B. P. Amato

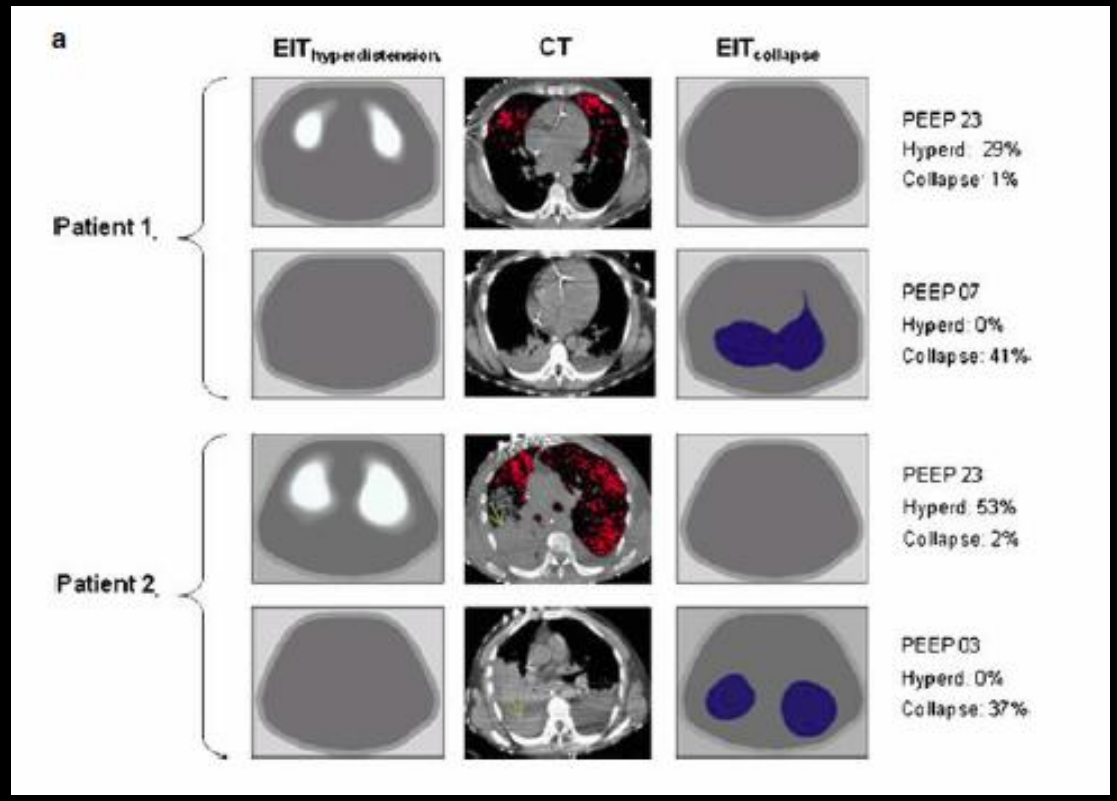
Intensive Care Med (2009) 35:1132–1137

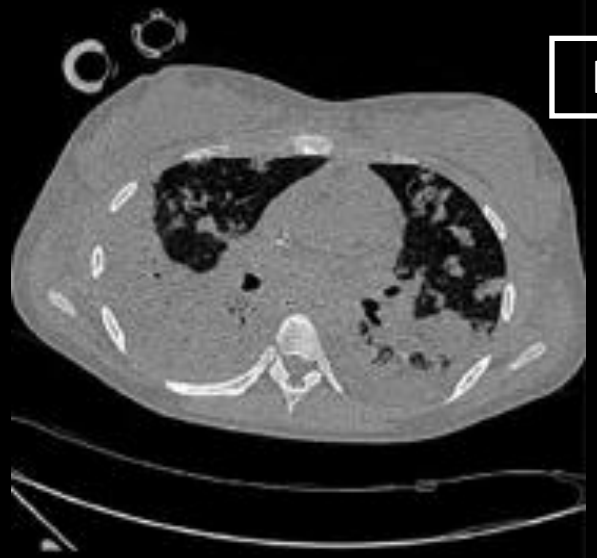
INTENSIVE CARE MEDICINE

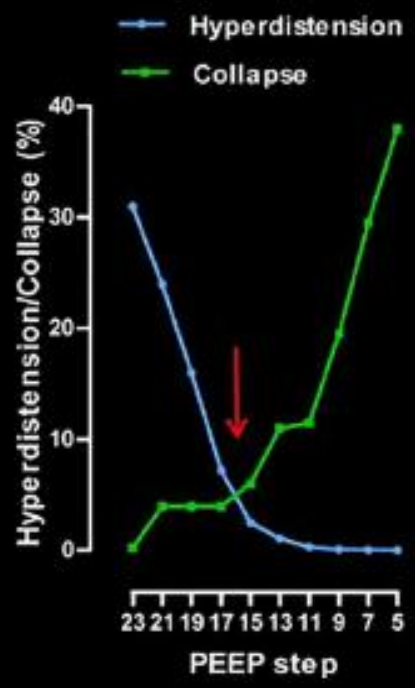
$$\text{Compliance}_{\text{pixel}} = \frac{\Delta Z}{P_{\text{plateau}} - \text{PEEP}}$$



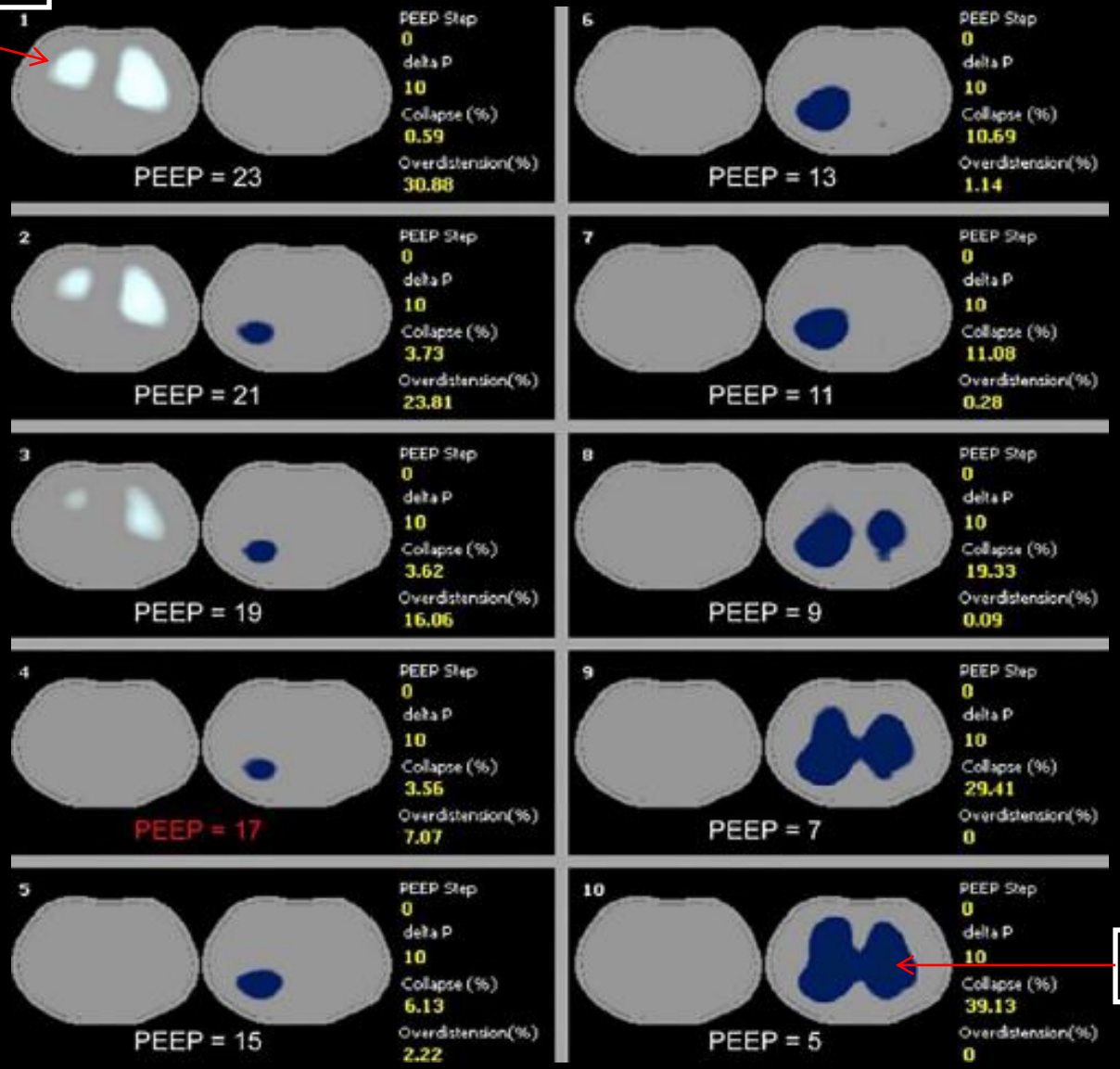
Intensive Care Med (2009) 35:1132–1137


a
EIT hyperdistension
CT
EIT collapse
Patient 1
PEEP 23
Hyperd: 29%
Collapse: 1%
PEEP 07
Hyperd: 0%
Collapse: 41%
Patient 2
PEEP 23
Hyperd: 53%
Collapse: 2%
PEEP 03
Hyperd: 0%
Collapse: 37%



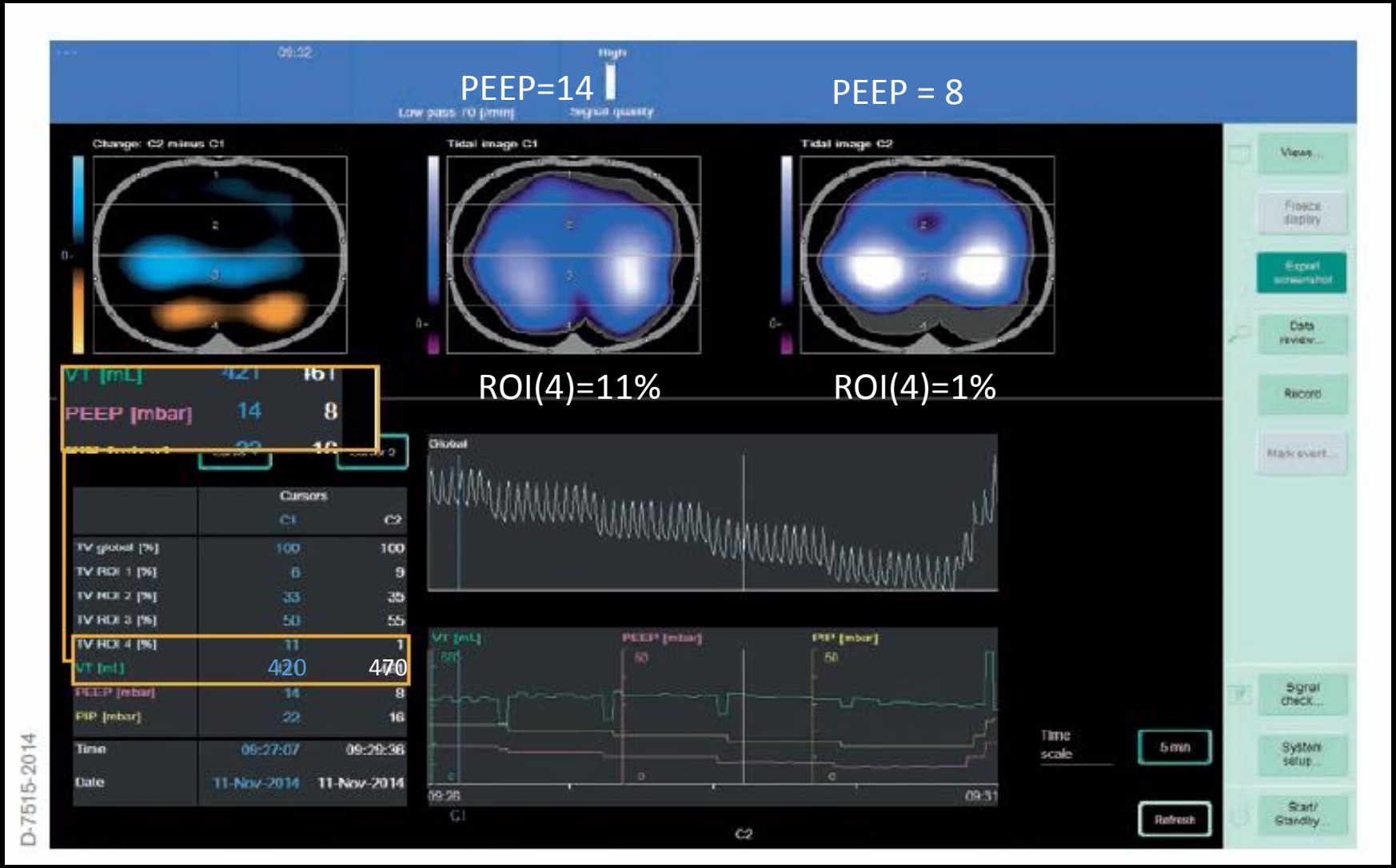


hyperdistension



Collapsed

Distribution of ventilation during a decremental PEEP trial



Critical Care Medicine

Mechanical Ventilation Guided by Electrical Impedance Tomography in Experimental Acute Lung Injury*

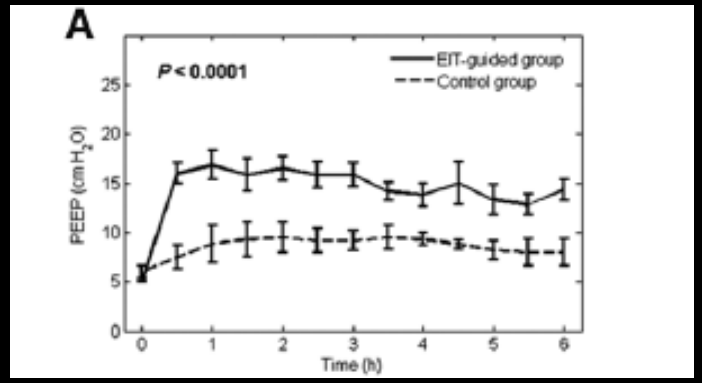
Gerhard K. Wolf, MD[1]; Camille Gómez-Laberge, PhD[1]; Jordan S. Rettig, MD[1]; Sara O. Vargas, MD[2]; Craig D. Smallwood, RRT[3]; Sanjay P. Prabhu, MBBS[4]; Sally H. Vitali, MD[1]; David Zurakowski, PhD[1]; John H. Arnold, MD[1]

- 12 Yorkshire swine
- Saline lavage induced lung injury
- Control group was ventilated with ARDSnet guidelines
- EIT guided → maximize recruitment of dependent regions
  → minimize overdistension of nondependent regions

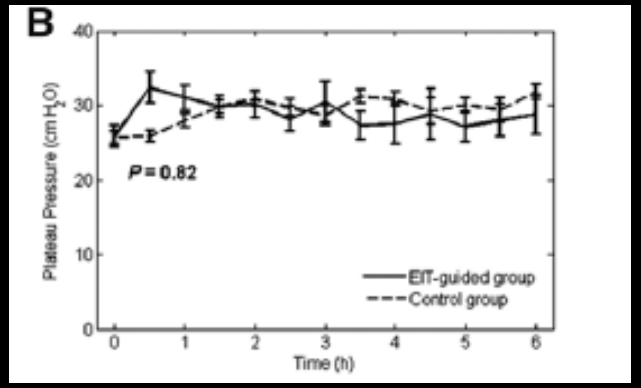
May 2013 • Volume 41 • Number 5

Critical Care Medicine

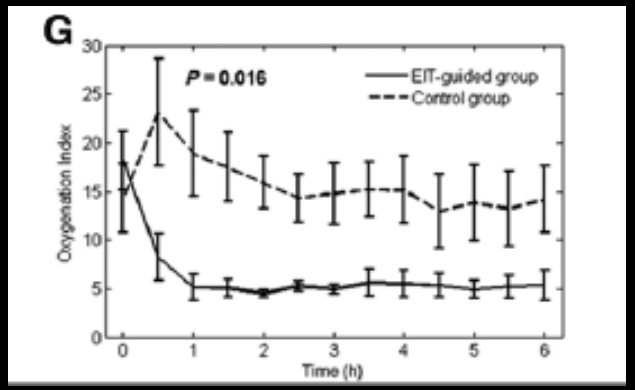
PEEP



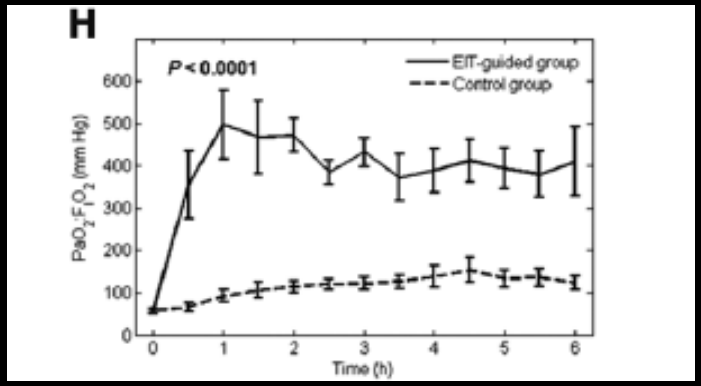
Plateau Pressure



Oxygenation index



PaO_2/FiO_2

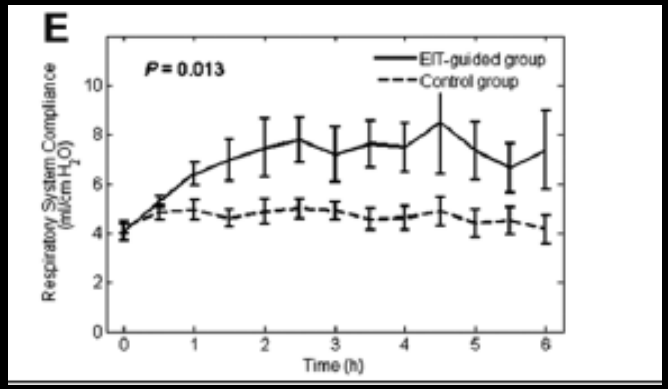


May 2013 • Volume 41 • Number 5

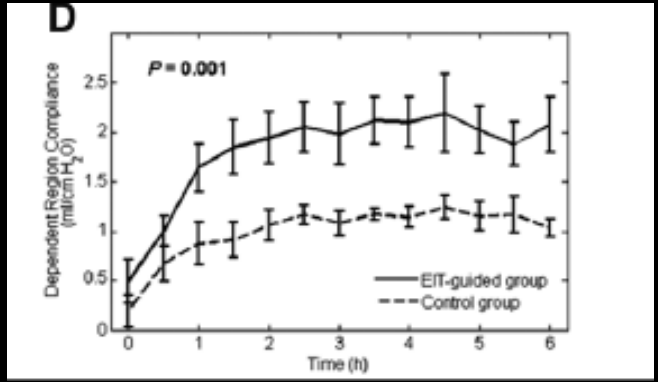
Critical Care Medicine

Compliance

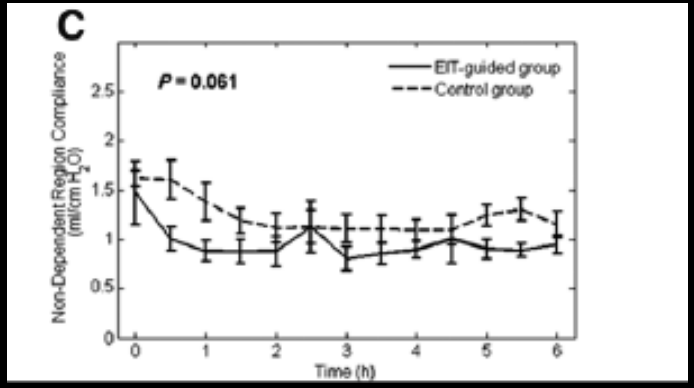
Respiratory system



Dependent region



Non-Dependent region



May 2013 • Volume 41 • Number 5

Critical Care Medicine

Lung Pathology

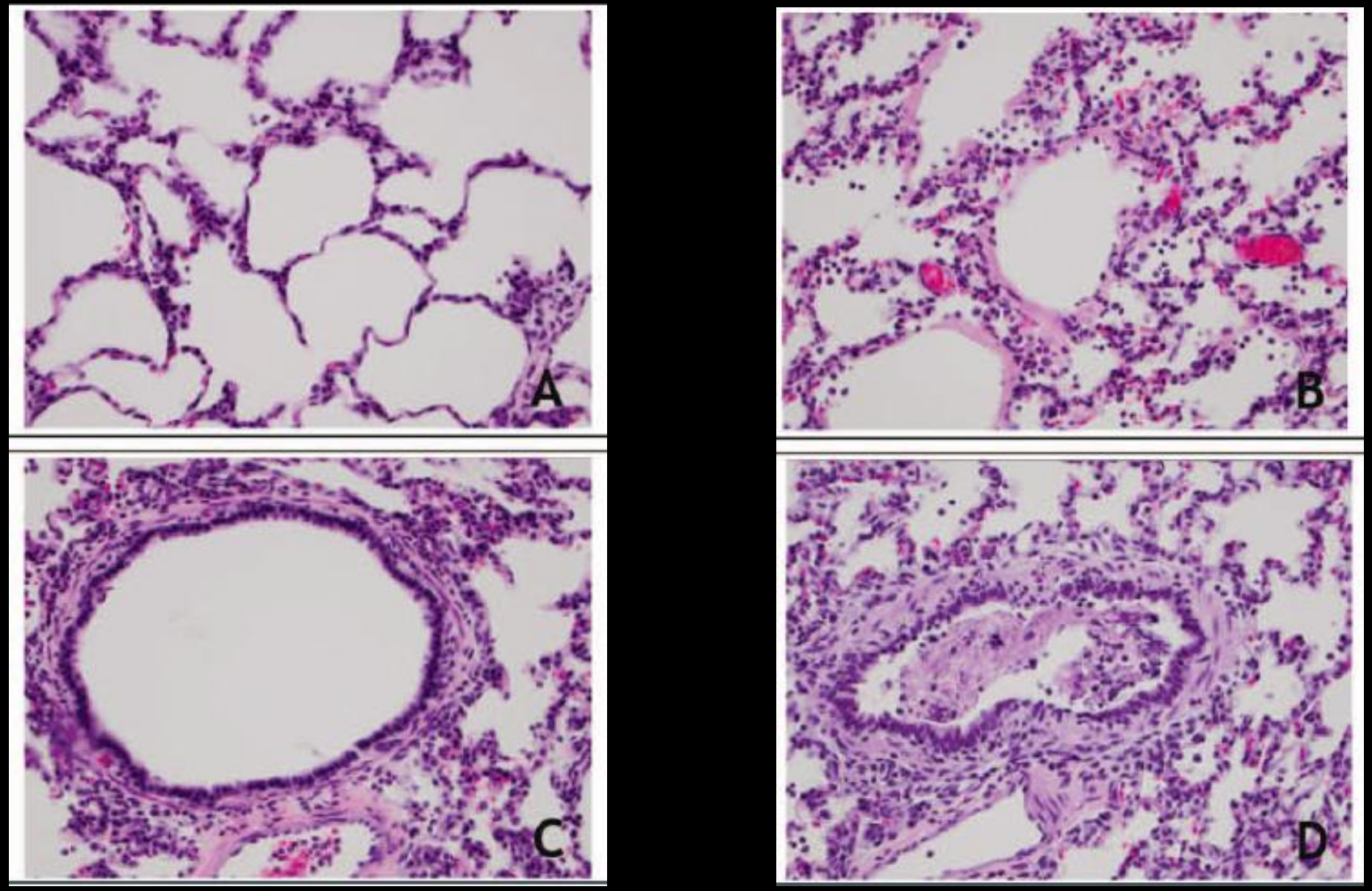
Variable	Whole Lung (24 Samples Per Group)	
	EIT	Control
Granulocytes	2 (1–3)	2 (1–3)
Alveolar blood	1 (0–2)	1 (1–3)
Interstitial hemorrhage	1 (0–2)	1 (0–3)
Alveolar septal expansion	2 (1–3)	2 (1–3)
Hyaline membrane	10 (42%)[a]	16 (67%)
Airway fibrin	18 (75%)[a]	24 (100%)

May 2013 • Volume 41 • Number 5

Critical Care Medicine

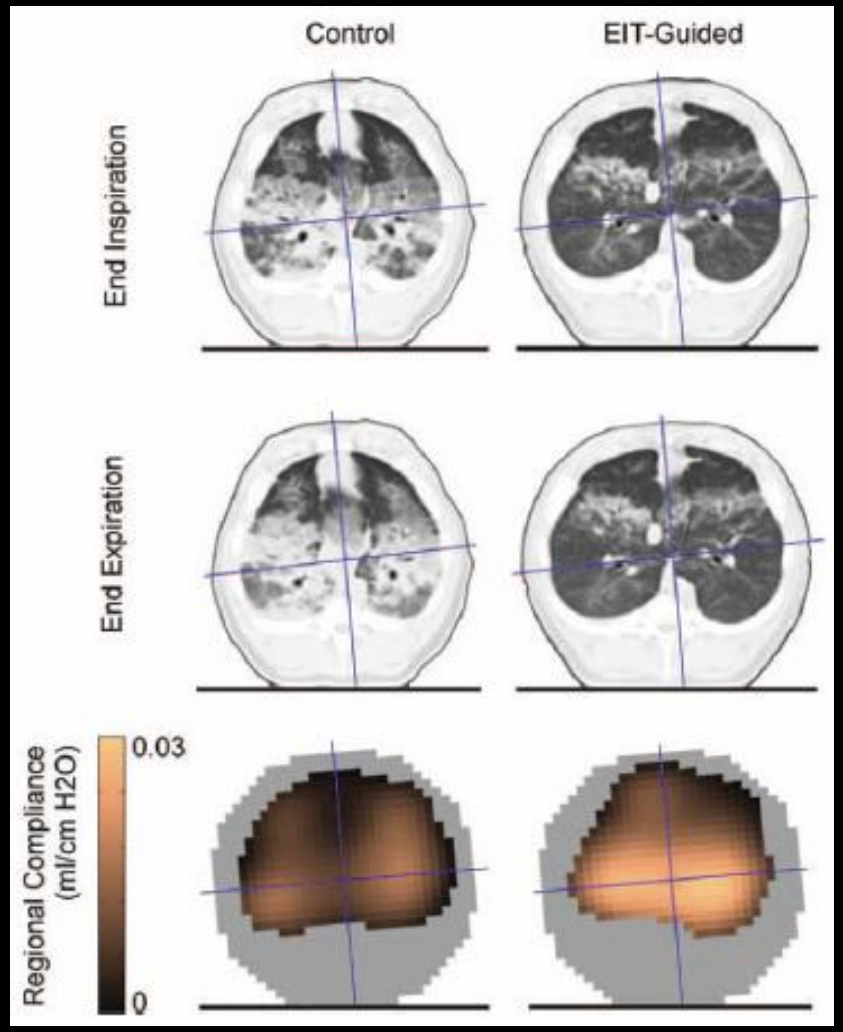
EIT

ARDSnetwork



May 2013 • Volume 41 • Number 5

Critical Care Medicine



May 2013 • Volume 41 • Number 5

Ability to identify various adverse events during mechanical ventilation

- Pneumothorax

Bhatia R, Schmölzer GM, Davis PG, *et al*. Electrical impedance tomography can rapidly detect small pneumothoraces in surfactant-depleted piglets. *Intensive Care Med* 2012;38:308–15.

- Selective intubation and one sided ventilation

Pulletz S, Elke G, Zick G, *et al*. Performance of electrical impedance tomography in detecting regional tidal volumes during one-lung ventilation. *Acta Anaesthesiol Scand* 2008;52:1131–9.

- Derecruitment after endotracheal suction

Tingay DG, Copnell B, Grant CA, *et al*. The effect of endotracheal suction on regional tidal ventilation and end-expiratory lung volume. *Intensive Care Med* 2010;36:888–96.

- atelectasis

Alves SH, Amato MB, Terra RM, *et al*. Lung reaeration and reventilation after aspiration of pleural effusions. A study using electrical impedance tomography. *Ann Am Thorac Soc* 2014;11:186–91.

Critical Care Medicine

Real-time detection of pneumothorax using electrical impedance tomography*

Eduardo L. V. Costa, MD; Caroline N. Chaves; Susimeire Gomes; Marcelo A. Beraldo, RRT; Márcia S. Volpe, RRT; Mauro R. Tucci, MD, PhD; Ivany A. L. Schettino, MD, PhD; Stephan H. Bohm, MD, PhD; Carlos R. R. Carvalho, MD, PhD; Harki Tanaka, Eng, MD; Raul G. Lima, Eng, PhD; Marcelo B. P. Amato, MD, PhD

Crit Care Med 2008 Vol. 36, No. 4

Critical Care Medicine

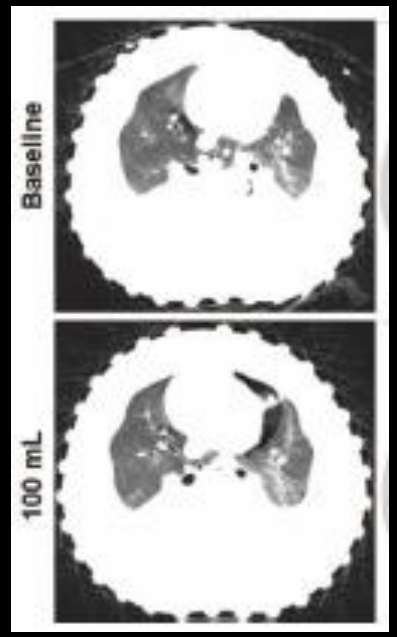
C/T scan

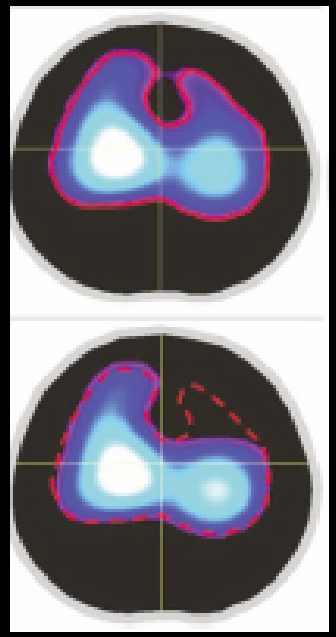
Ventilation map

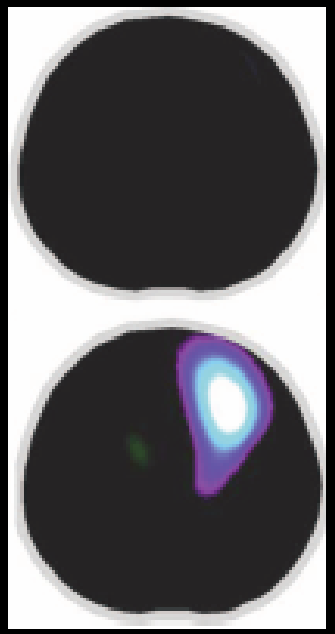
Aeration change map

Baseline

100ml air





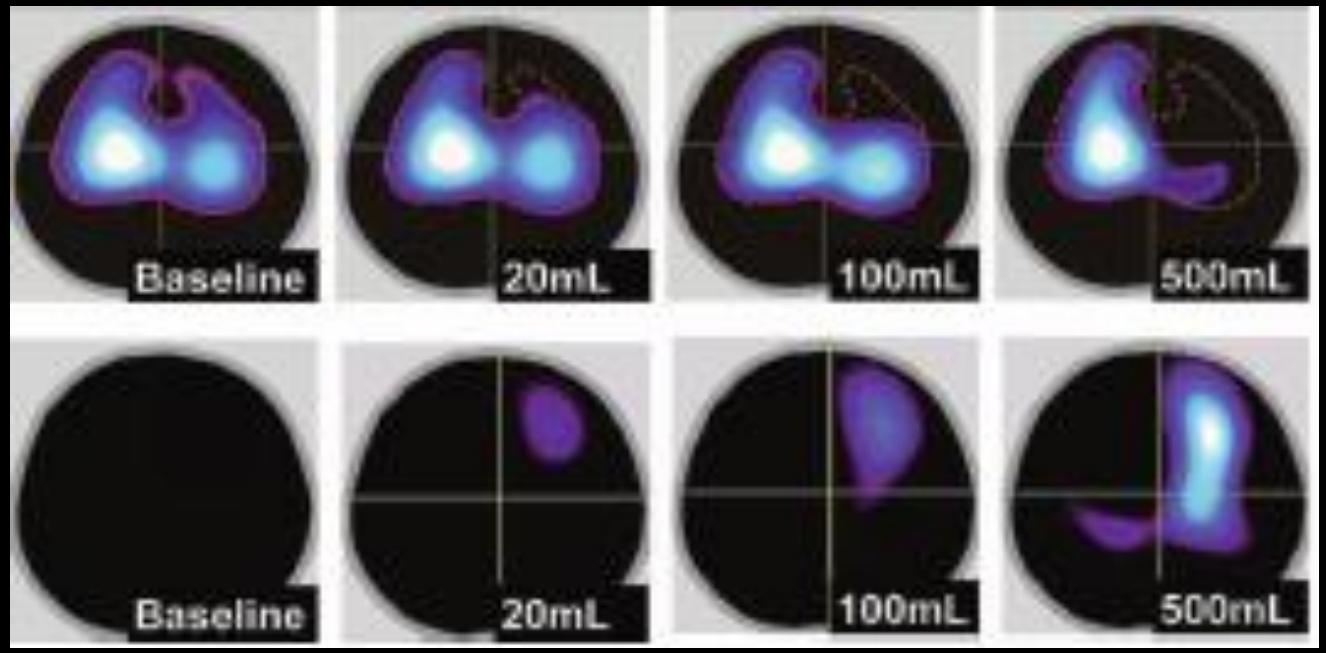


Crit Care Med 2008 Vol. 36, No. 4

Critical Care Medicine

Ventilation map

Aeration change map



- Sensitivity 100%
- Specificity 95%
- Easily distinguished from overdistension (PEEP or recruitment)
- Delay of 3 respiratory cycles

Crit Care Med 2008 Vol. 36, No. 4

AMERICAN JOURNAL OF
Respiratory and Critical Care Medicine

Spontaneous Effort Causes Occult Pendelluft during Mechanical Ventilation

Takeshi Yoshida[1,2], Vinicius Torsani[1], Susimeire Gomes[1], Roberta R. De Santis[1], Marcelo A. Beraldo[1], Eduardo L. V. Costa[1], Mauro R. Tucci[1], Walter A. Zin[3], Brian P. Kavanagh[4,5], and Marcelo B. P. Amato[1]

Am J Respir Crit Care Med Vol 188, Iss. 12, pp 1420–1427, Dec 15, 2013

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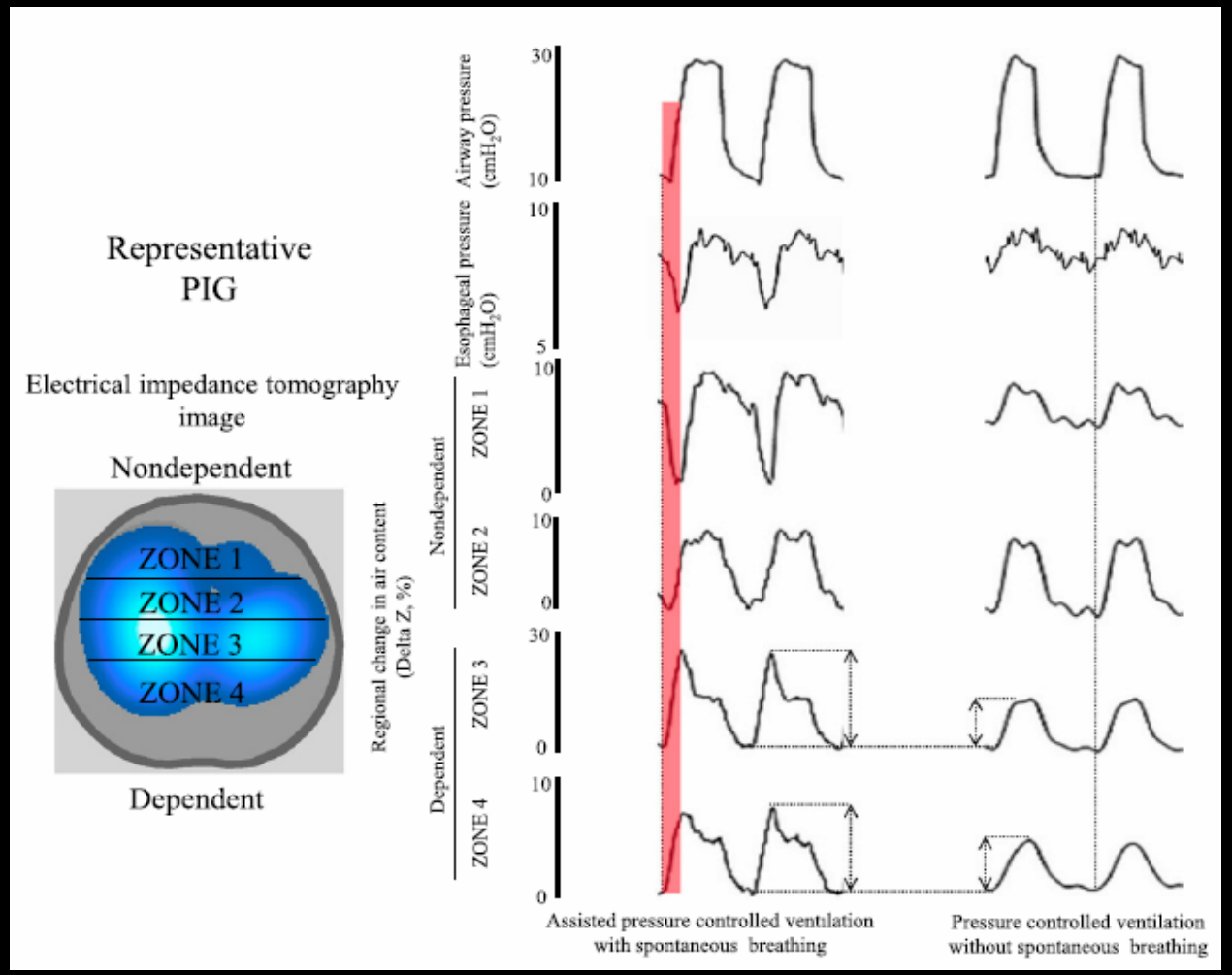

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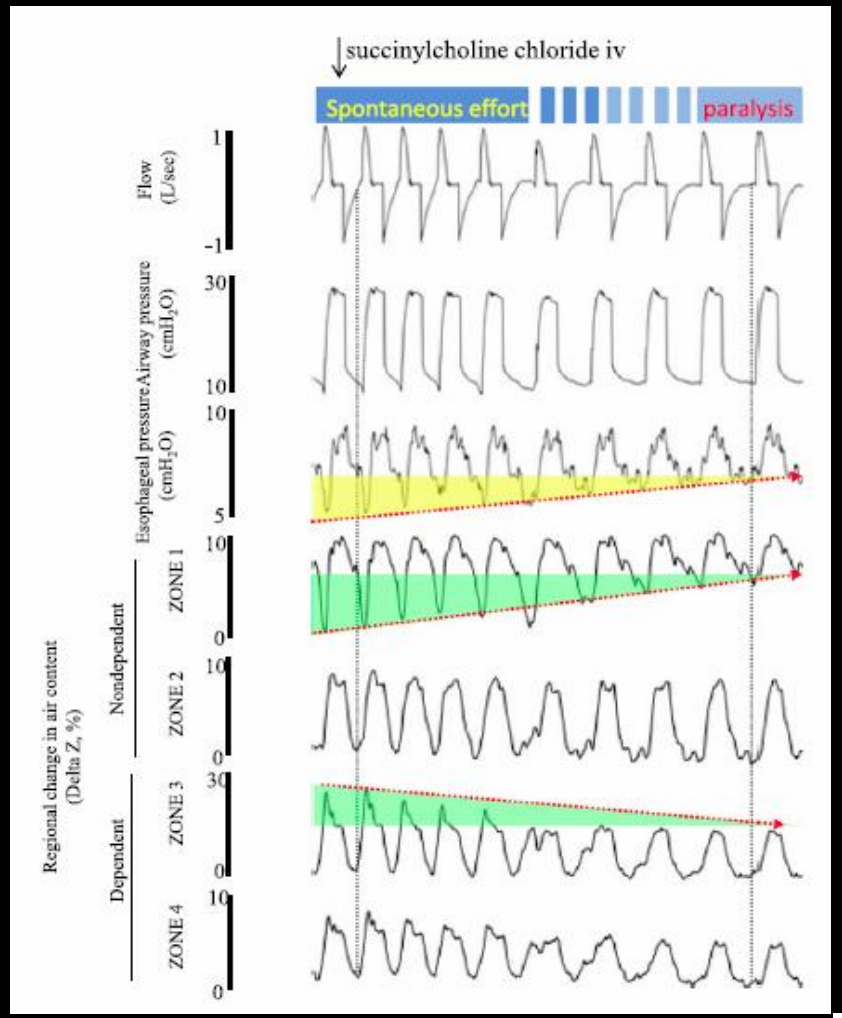
Respiratory and Critical Care Medicine

Το φαινόμενο pendelluft είναι ανάλογο της εισπνευστικής προσπάθειας



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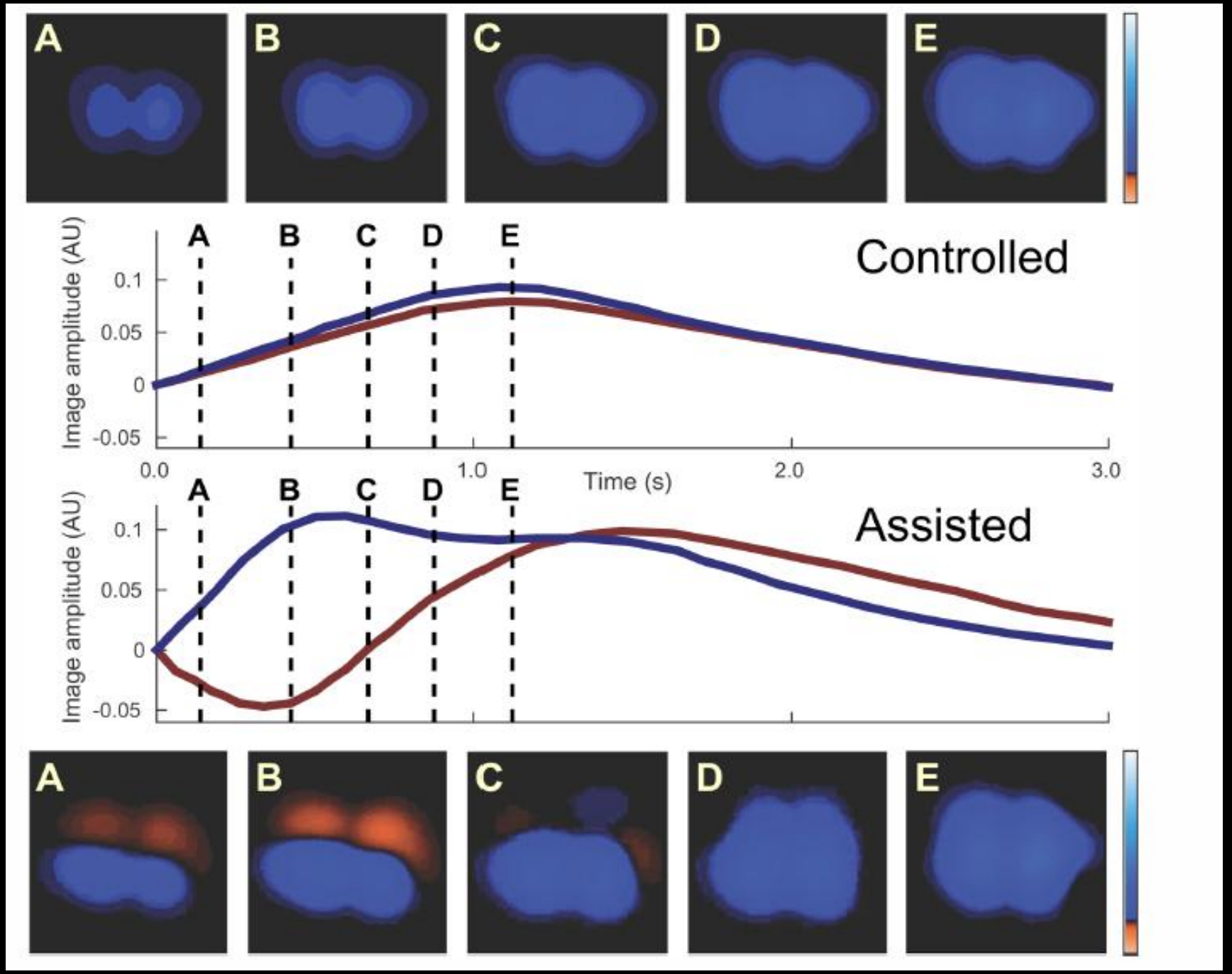
A
B
C
D
E
Controlled
Image amplitude (AU)
0.1
0.05
0
-0.05
0.0
1.0
2.0
3.0
Time (s)
Assisted

Συμπεράσματα

- Η παρά την κλίνη μέτρηση του EELV δίνει τη δυνατότητα μέτρησης του strain

- Η EIT αποτελεί τεχνολογία που επιτρέπει την παρακολούθηση του αερισμού σε πραγματικό χρόνο, παρέχοντας πληροφορίες για την εξατομικευμένη μηχανική υποστήριξη σε ασθενείς με ARDS και για την έγκαιρη διάγνωση επιπλοκών.

…our perspective is that EIT will become a standard monitoring technique for personalized protective mechanical ventilation and optimized ventilator adjustments, increasing patient safety and providing continuous surveillance.

Frerichs I, *et al. Thorax* 2016;**0**:1–11

Intensive Care Med (2012) 38:1917–1929
DOI 10.1007/s00134-012-2684-z

REVIEW

Steffen Leonhardt
Burkhard Lachmann

Electrical impedance tomography: the holy grail of ventilation and perfusion monitoring?

Intensive Care Med (2008) 34:400–401
DOI 10.1007/s00134-007-0871-0

EDITORIAL

Andreas Schibler
Enrico Calzia

Electrical impedance tomography: a future item on the "Christmas Wish List" of the intensivist?

Ευχαριστώ