

Ventilatory Imaging

John H. Arnold, M.D.
Children's Hospital
Harvard Medical School
Boston, MA



Children's Hospital Boston



HARVARD MEDICAL SCHOOL

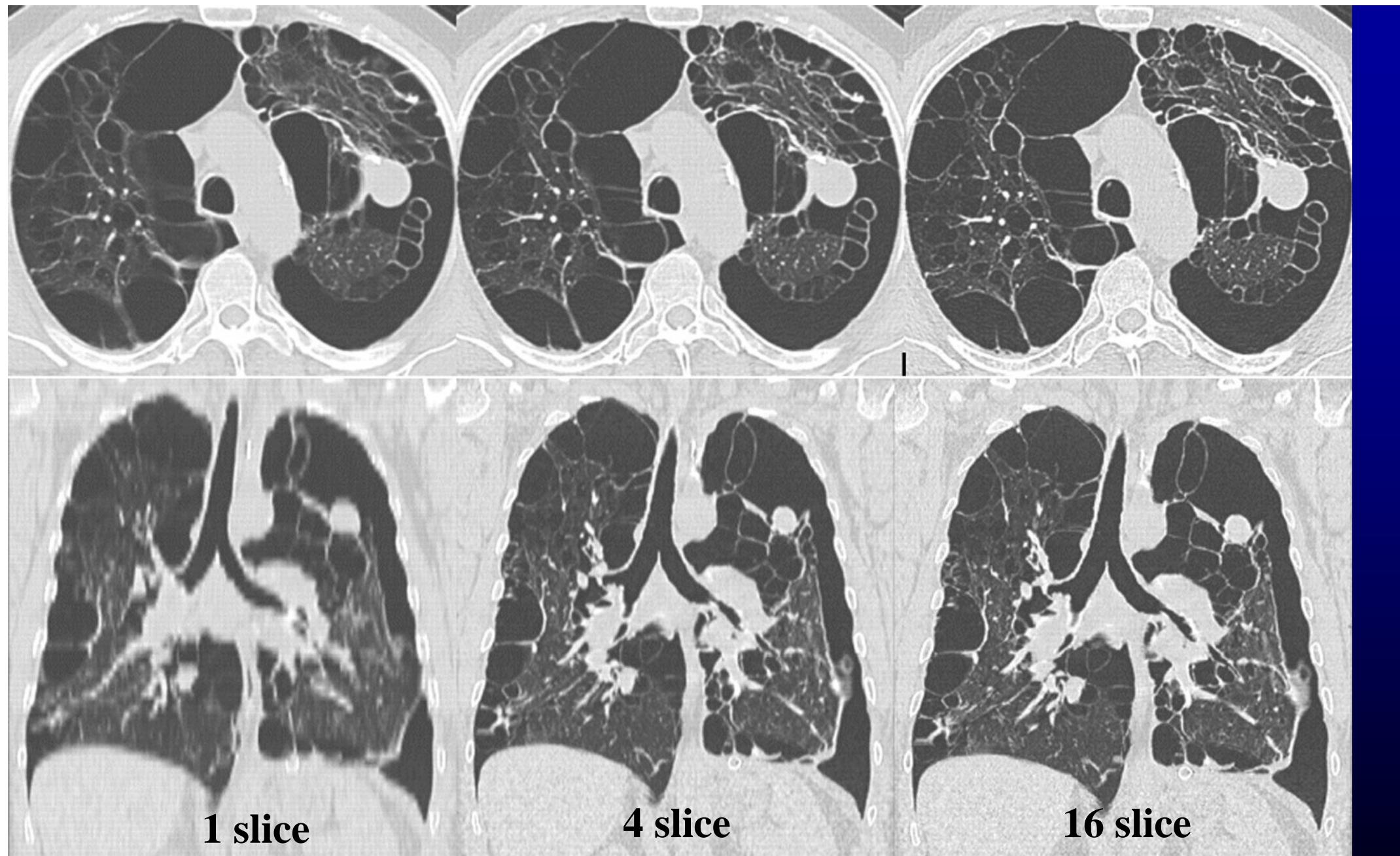


Pulmonary Imaging

- Anatomic imaging
- Functional imaging
- Molecular imaging

Anatomic Imaging

- Multislice CT
- Micro-computed CT
- MRI
- Reconstruction techniques
- Ultrasound imaging



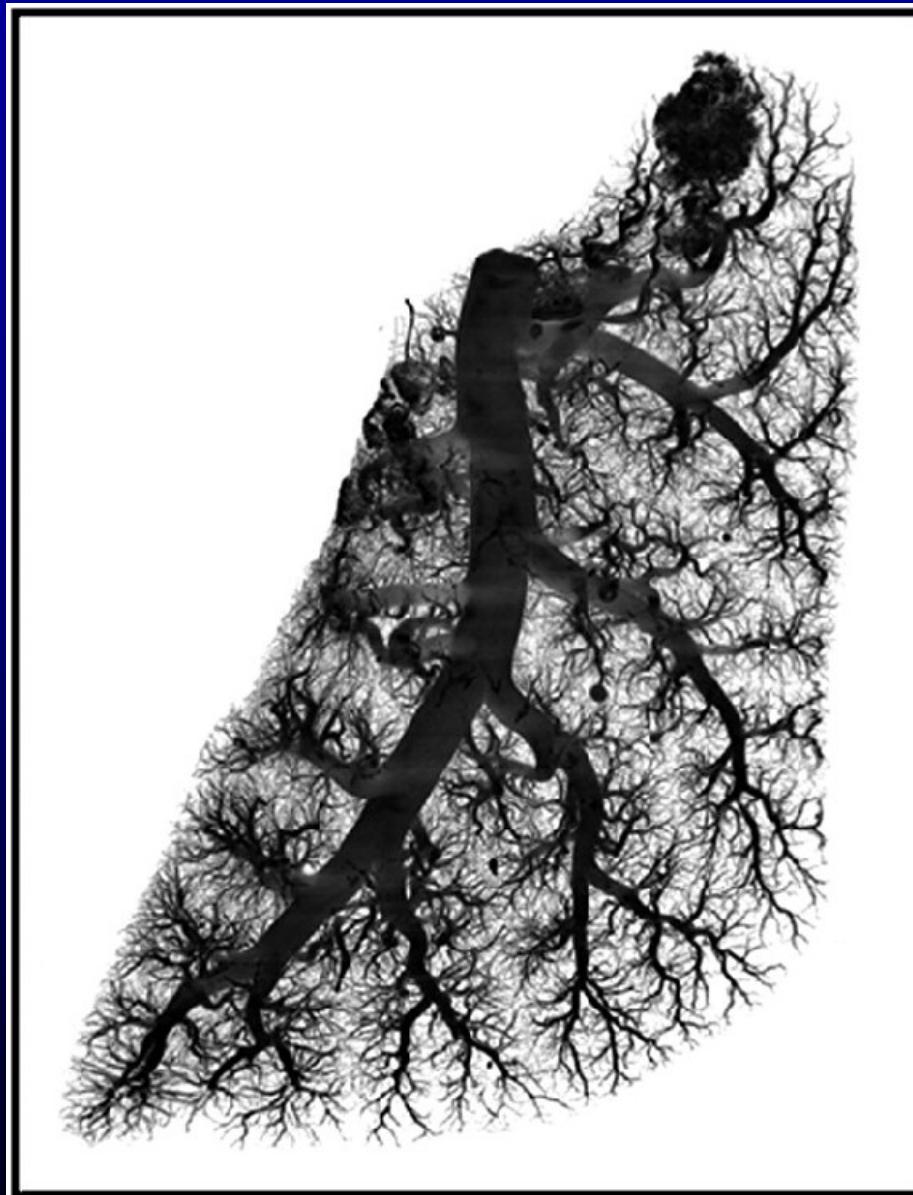
64 slice CT

Carotid stenosis

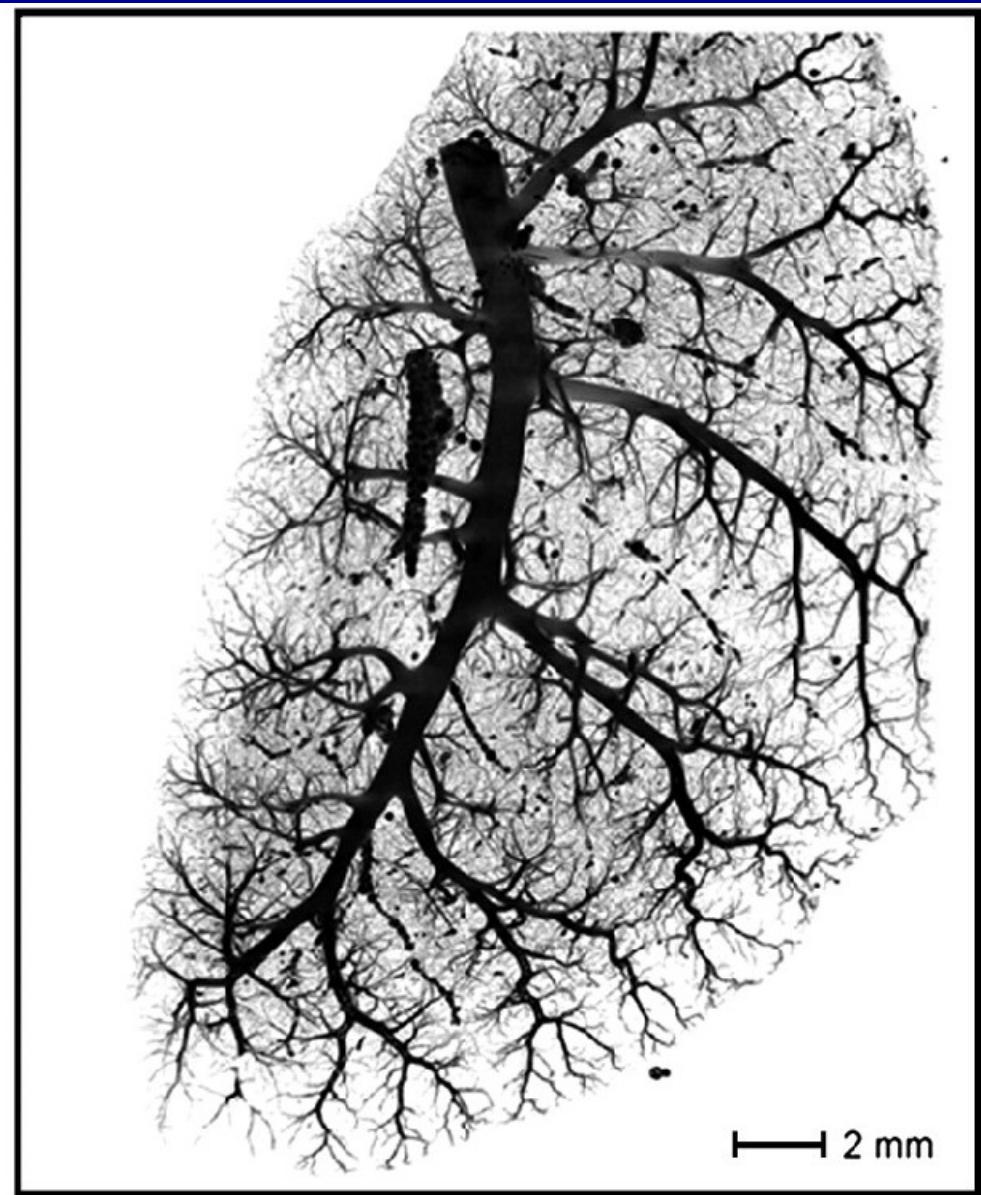
16 slice

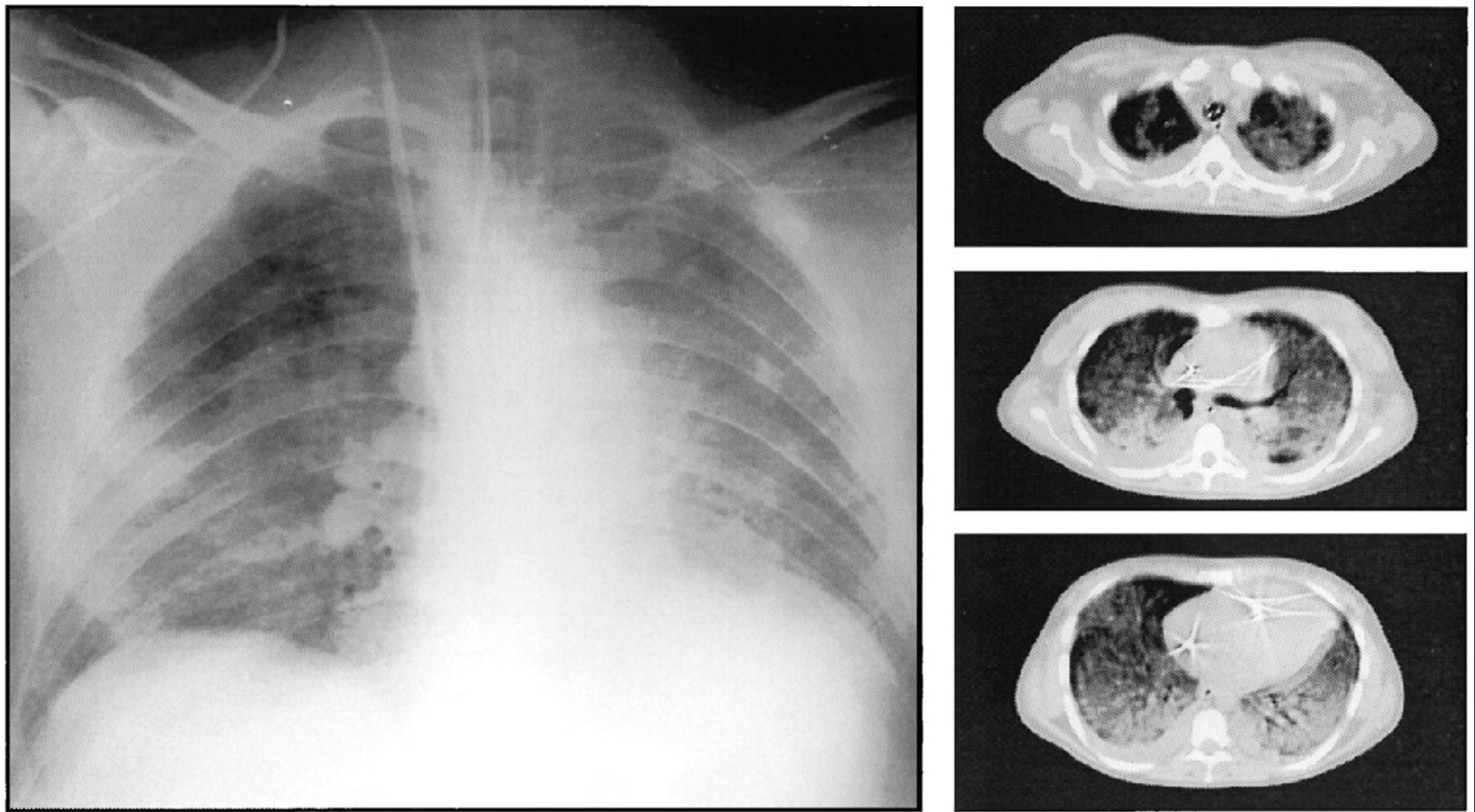
Proc ATS 2:2005: 470-76

Micro-CT reconstruction

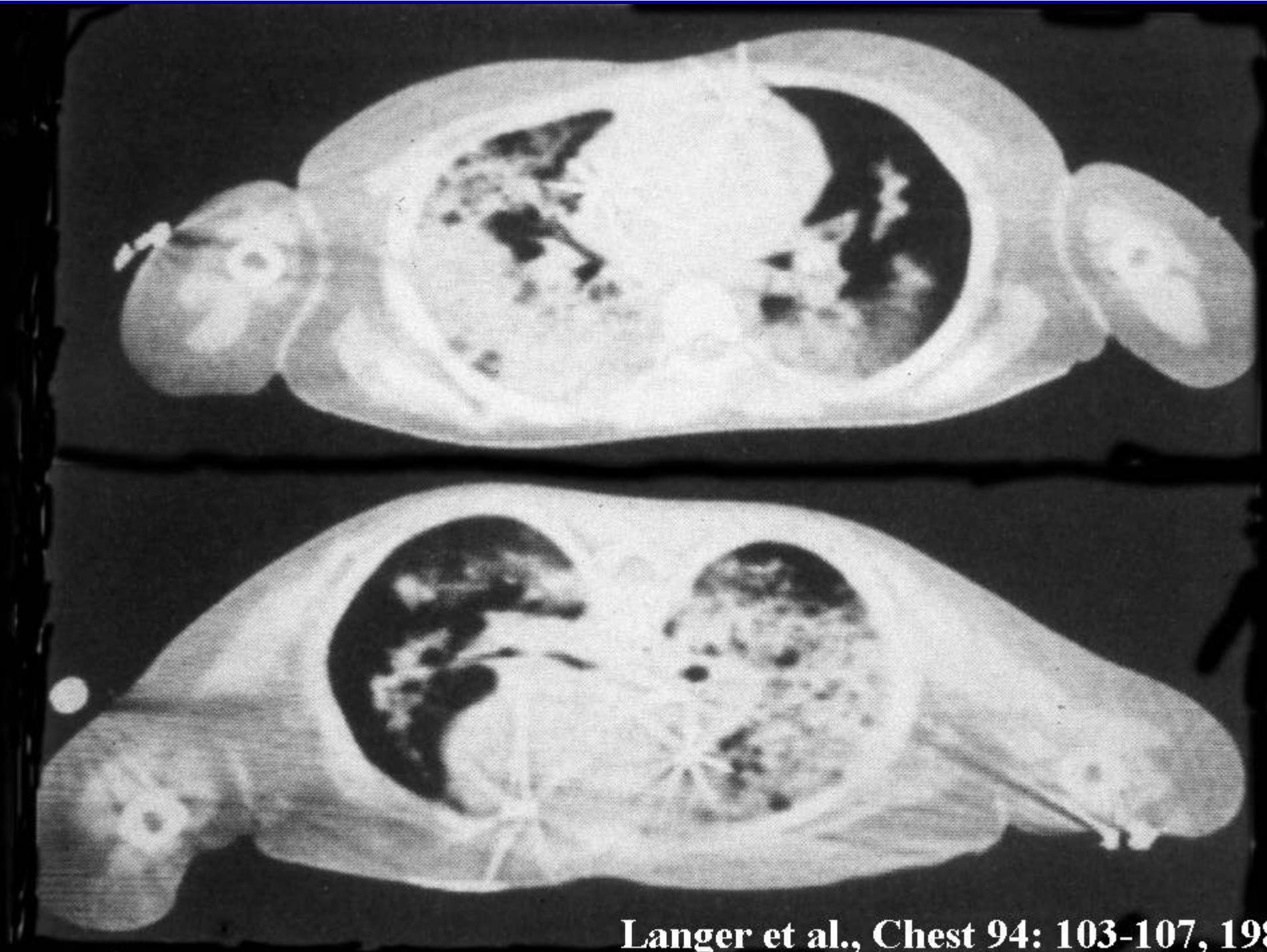


Monocrotaline injection



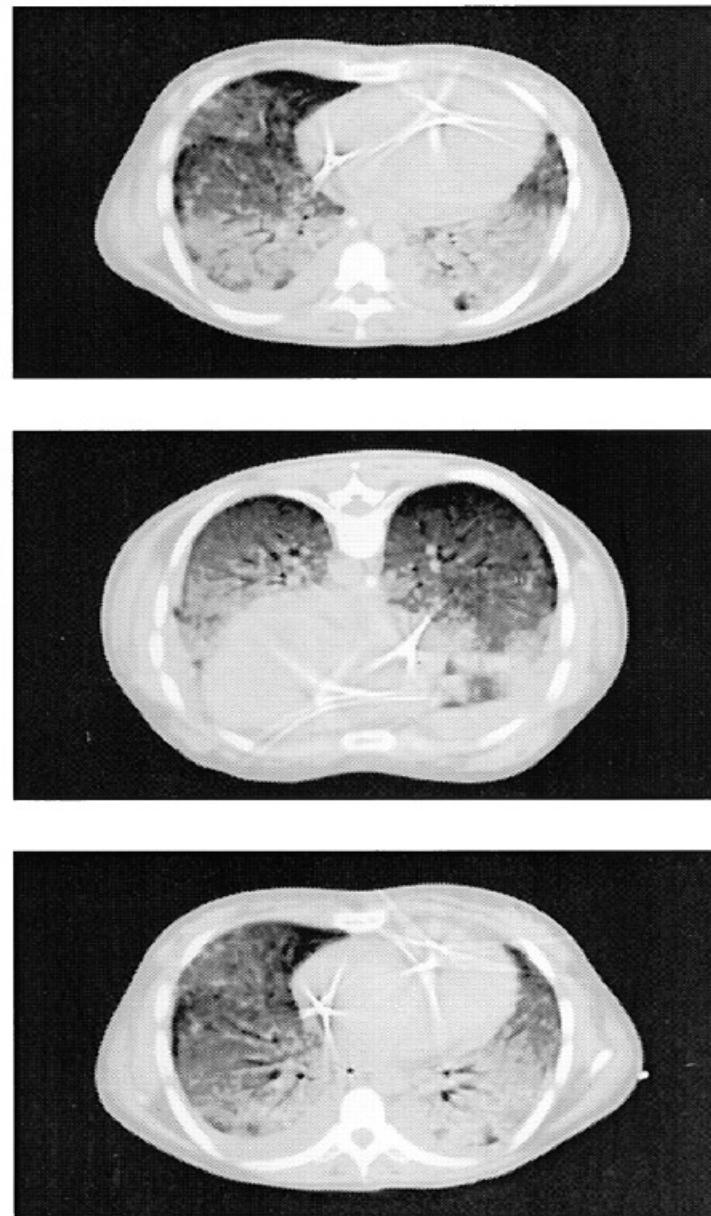


AJRCCM 164:1701-1711, 2001



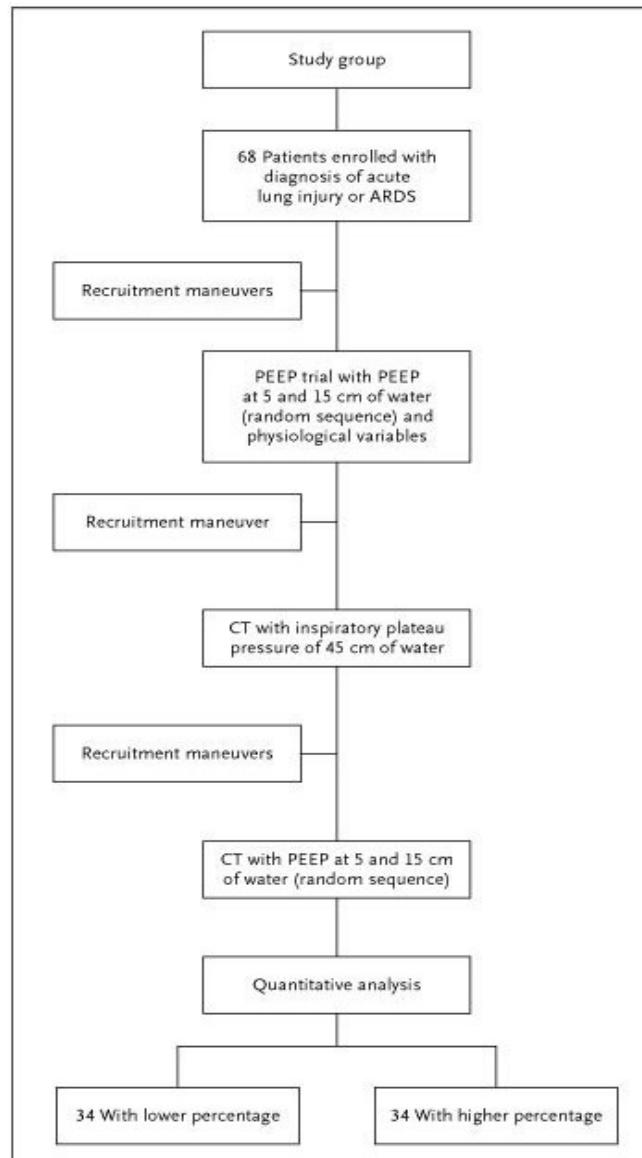
Langer et al., Chest 94: 103-107, 1988

Supine



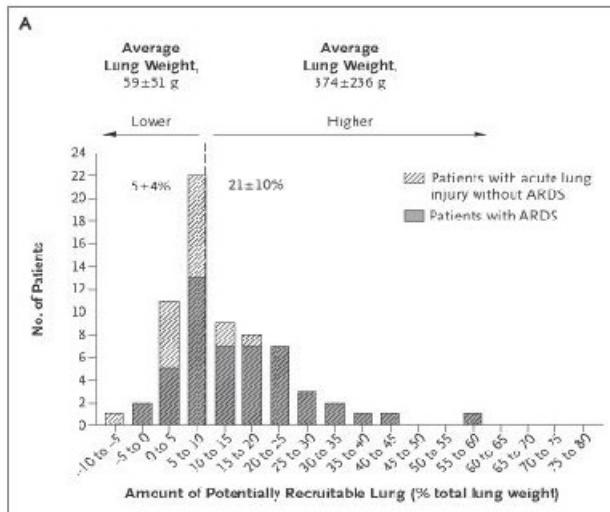
**End expiratory images at 10 cm
 H_2O PEEP within minutes of
postural change**

Study Protocol



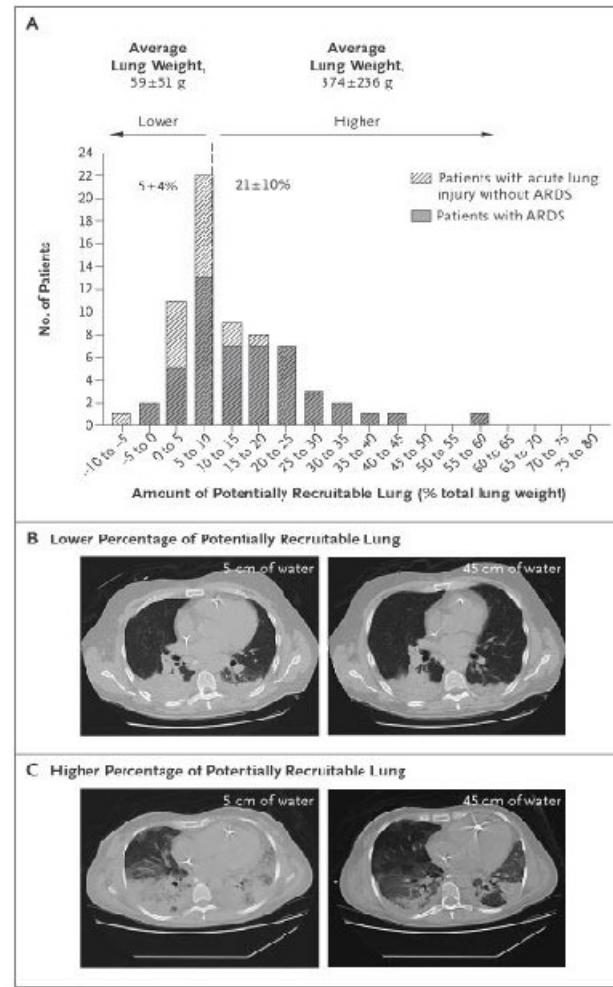
Gattinoni L et al. N Engl J Med 2006;354:1775-1786

Distribution of Patients According to the Percentage of Potentially Recruitable Lung



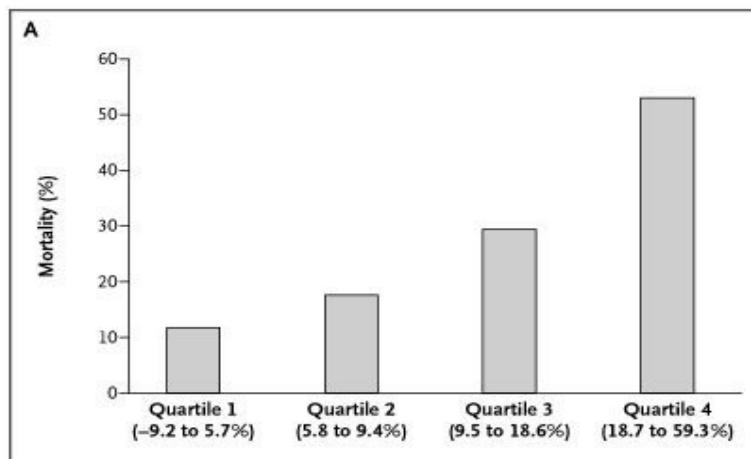
Gattinoni L et al. N Engl J Med 2006;354:1775-1786

Distribution of Patients According to the Percentage of Potentially Recruitable Lung and CT Images at 5 and 45 cm



Gattinoni L et al. N Engl J Med 2006;354:1775-1786

Mortality in Relation to the Percentage of Potentially Recruitable Lung

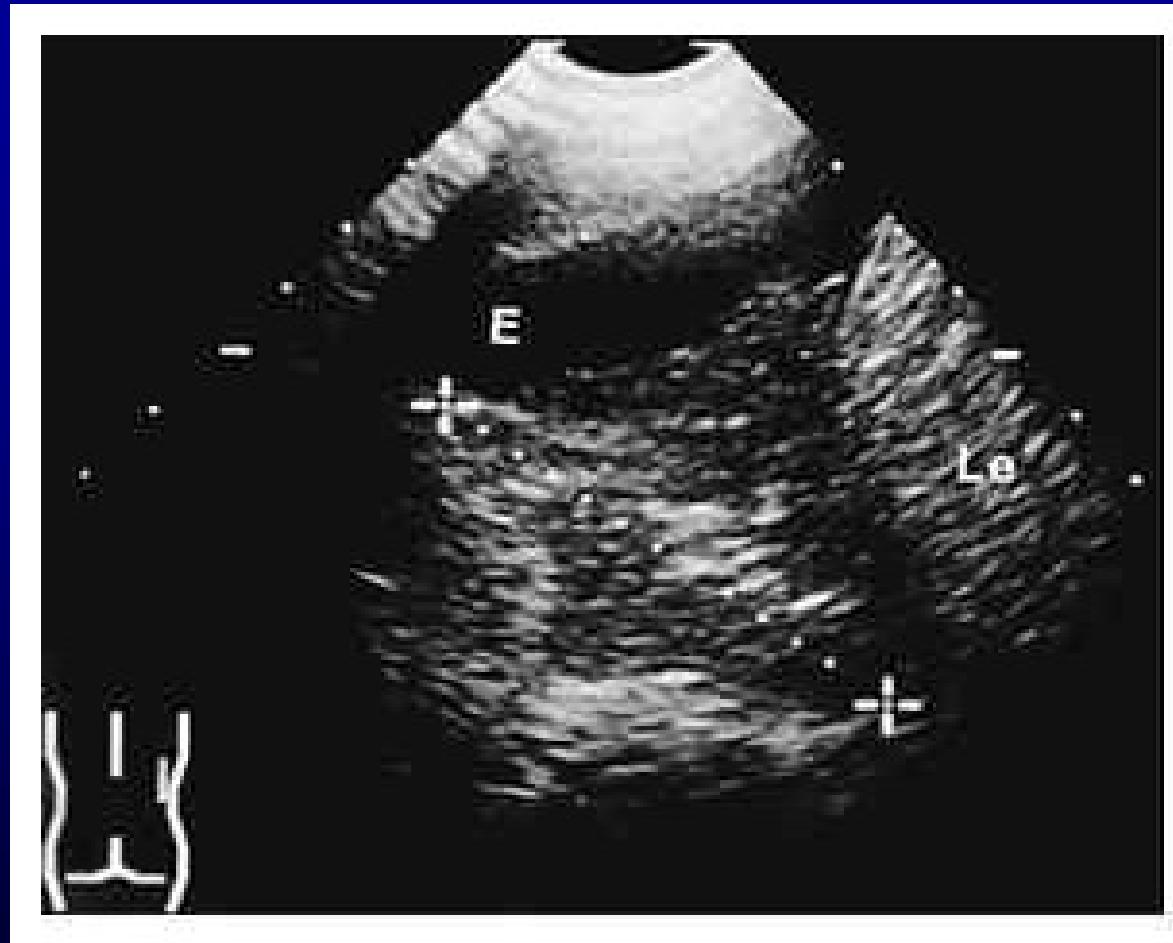


Gattinoni L et al. N Engl J Med 2006;354:1775-1786

Anatomic Imaging by CT

- CT densities may represent airway/alveolar fluid rather than collapse
- Where is the lung edema distributed?
 - airway/alveoli or interstitium
- Are we over-treating CT densities at the risk of injury to non-dependent lung?

Sonography after Pulmonary Embolism

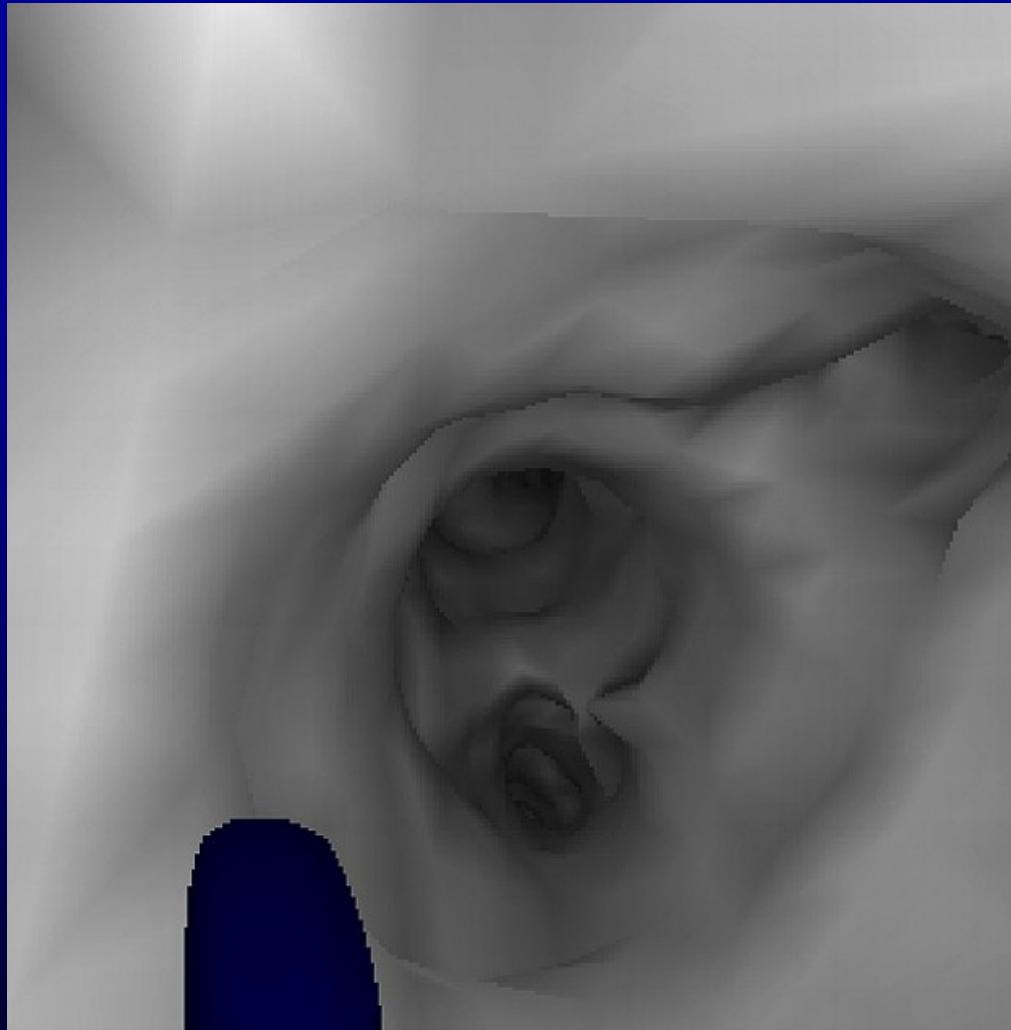


Respiration 2003;70:87-94

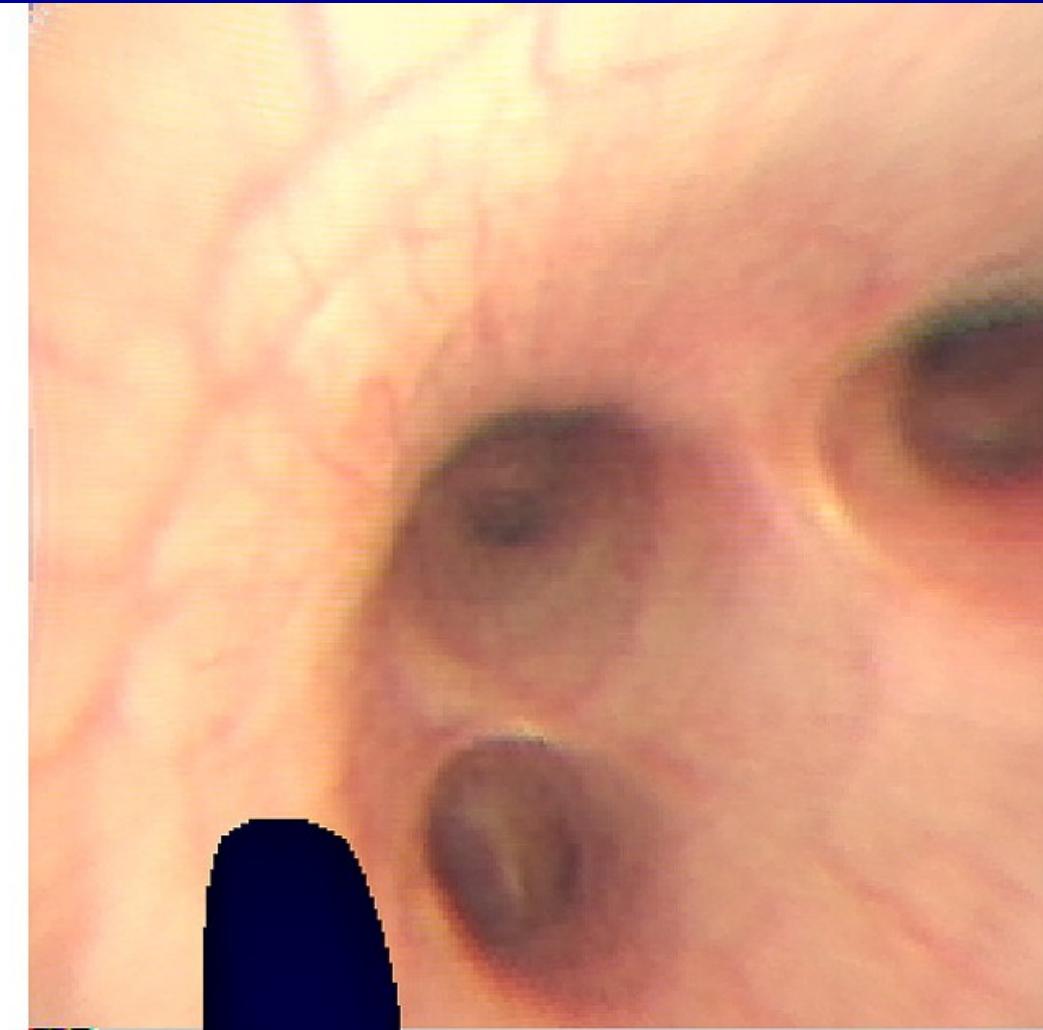
Functional Imaging

- Virtual bronchoscopy
- CT evaluation of ventilation and perfusion
- CT evaluation of lung mechanics
- Positron emission tomography
- Hyperpolarized 3-He MRI
- Electrical impedance tomography

Multidetector CT reconstruction



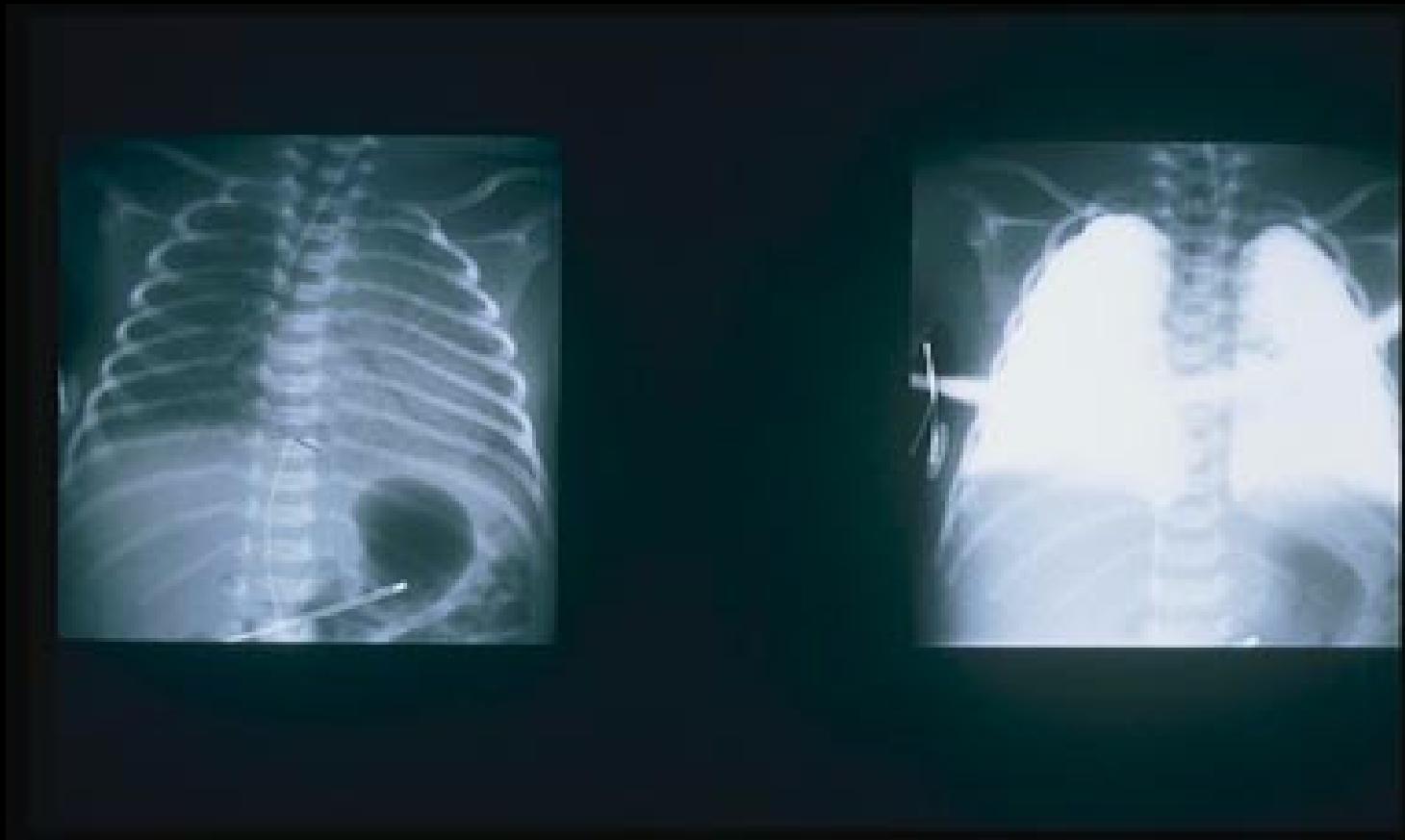
Bronchoscopy



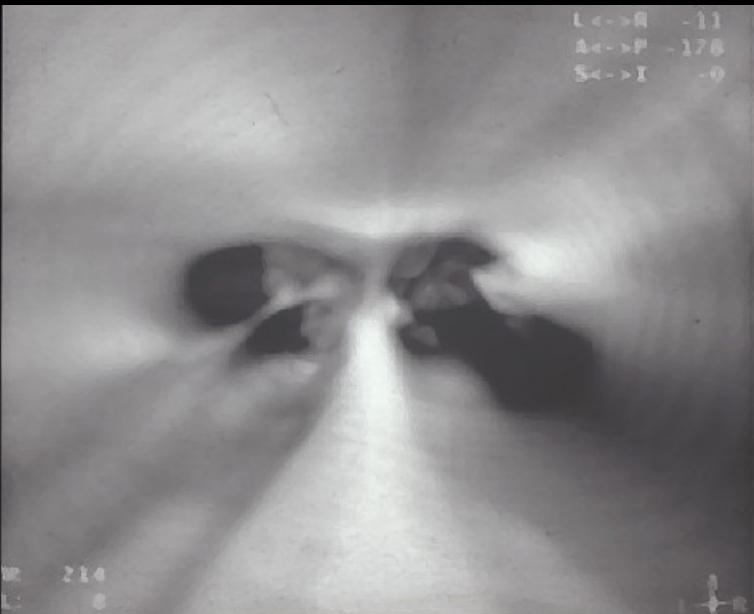
Proc ATS 2:2005; 488-91

PERFLUROCHEMICALS AS PULMONARY CONTRAST AGENTS

- **Plain film x-ray**
limited perspective to assess distribution
- **Computerized tomography (CT)**
3D imaging along X, Y, and Z axes
qualitative and quantitative analysis
- **High resolution CT**
thin section 3D imaging along X, Y, and Z axes
qualitative and quantitative analysis



Partial Liquid Ventilation in Premature Newborns



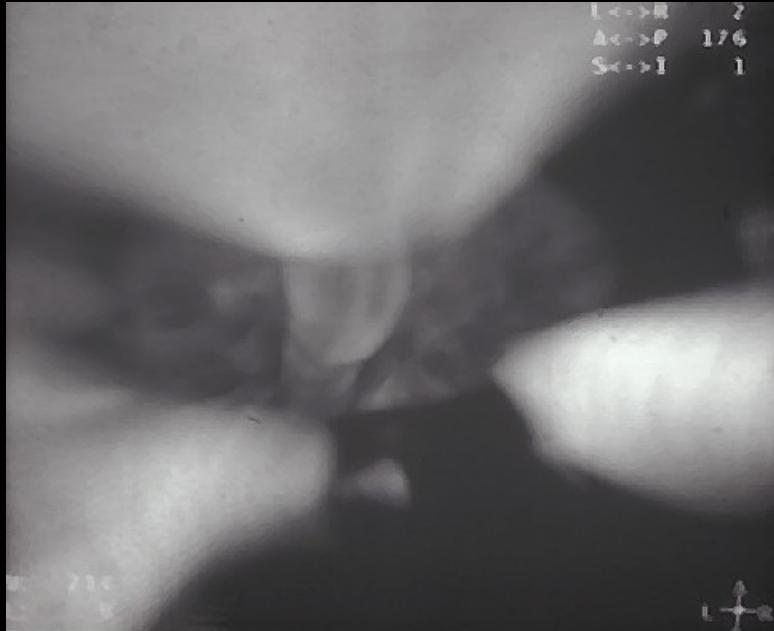
Carina 3D Image

No PFC



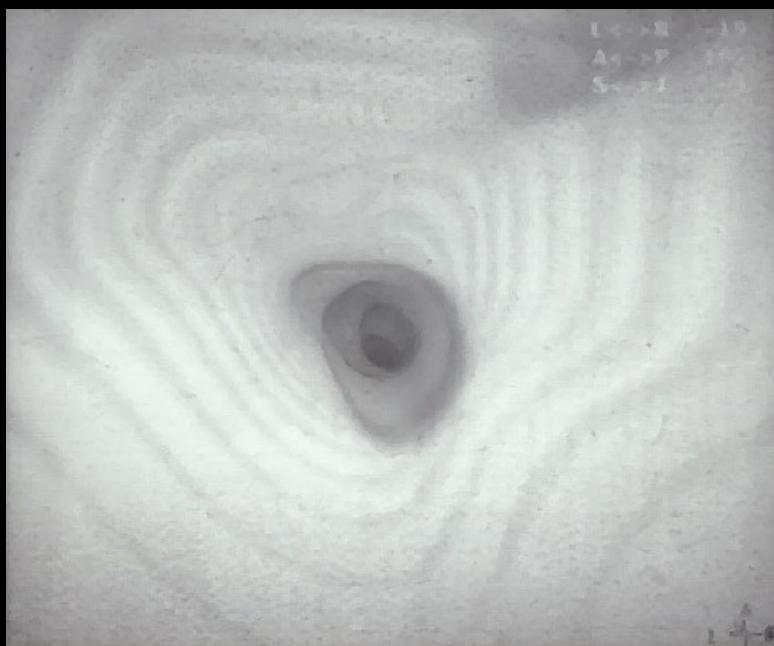
PFC

Acad Radiol 8:583-586, 1997



4th Generation 3D Image

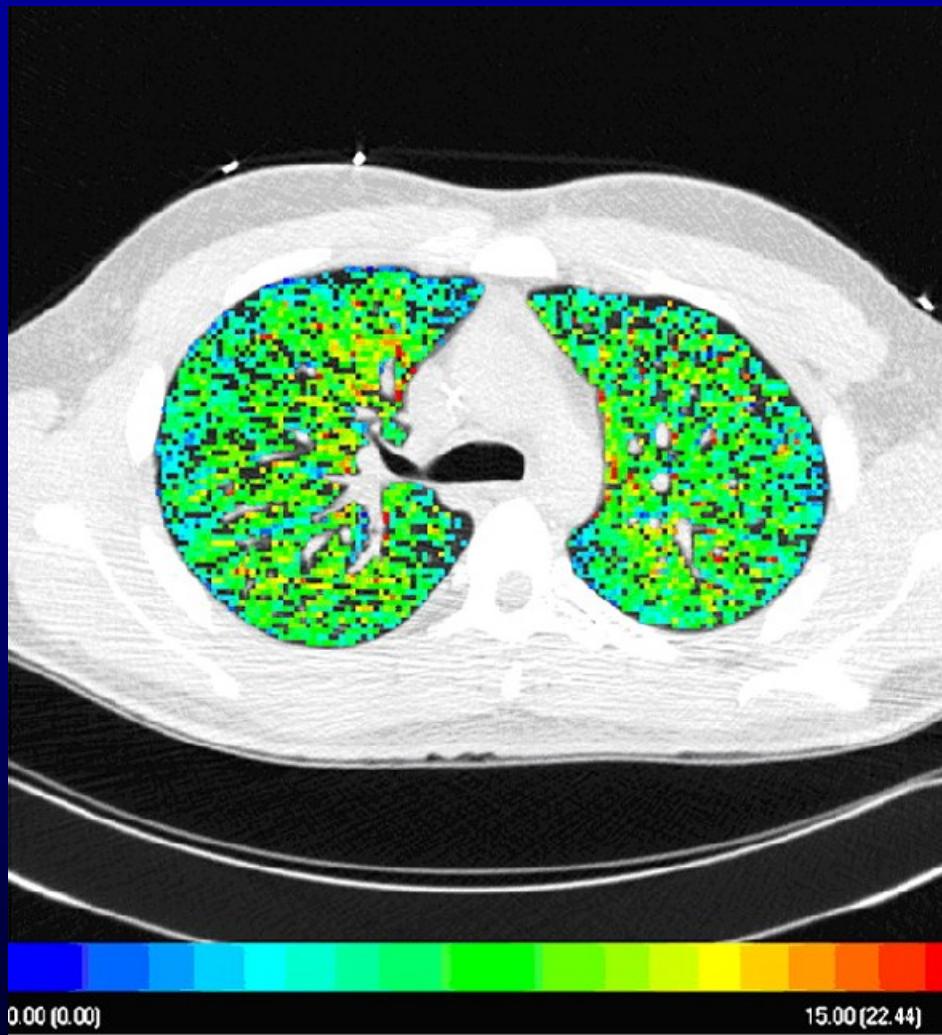
No PFC



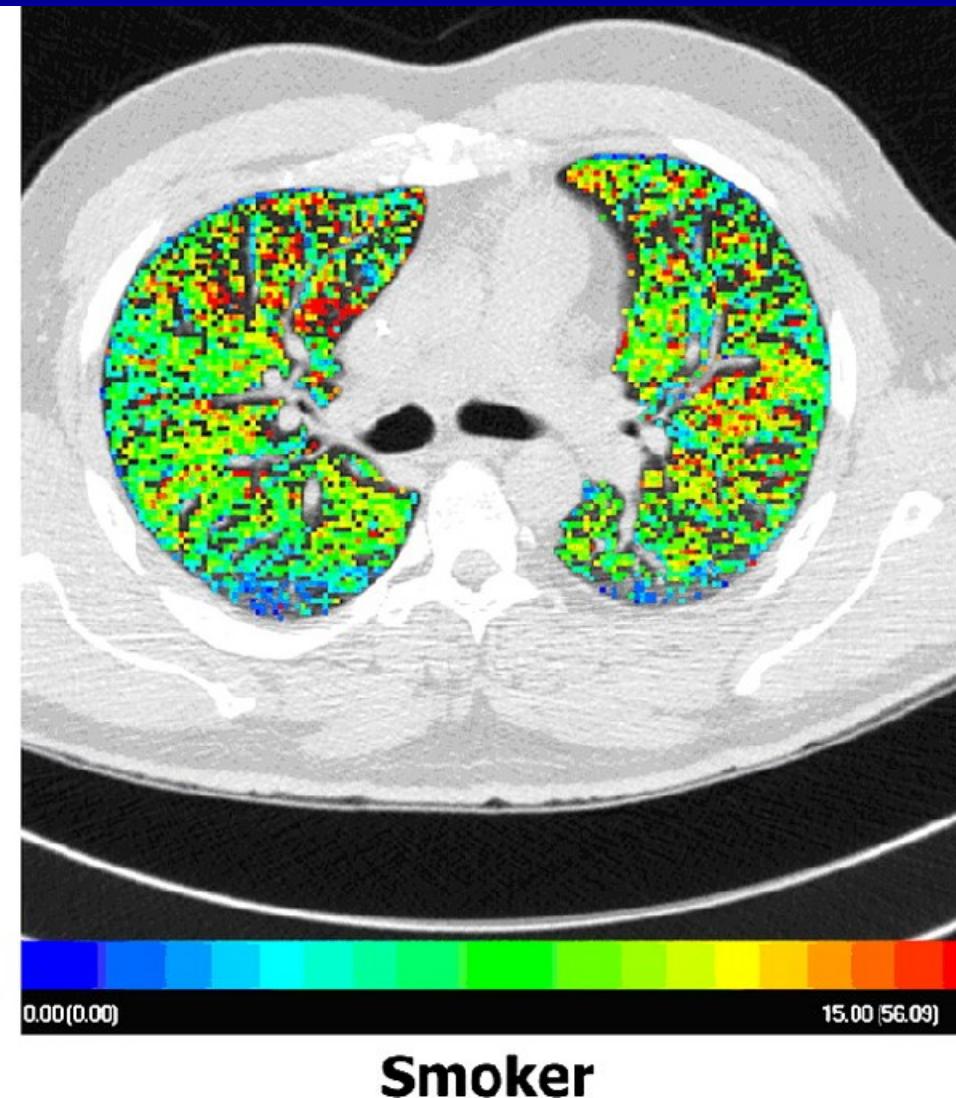
PFC

Acad Radiol 8:583-586, 1997

Regional Pulmonary Blood Flow



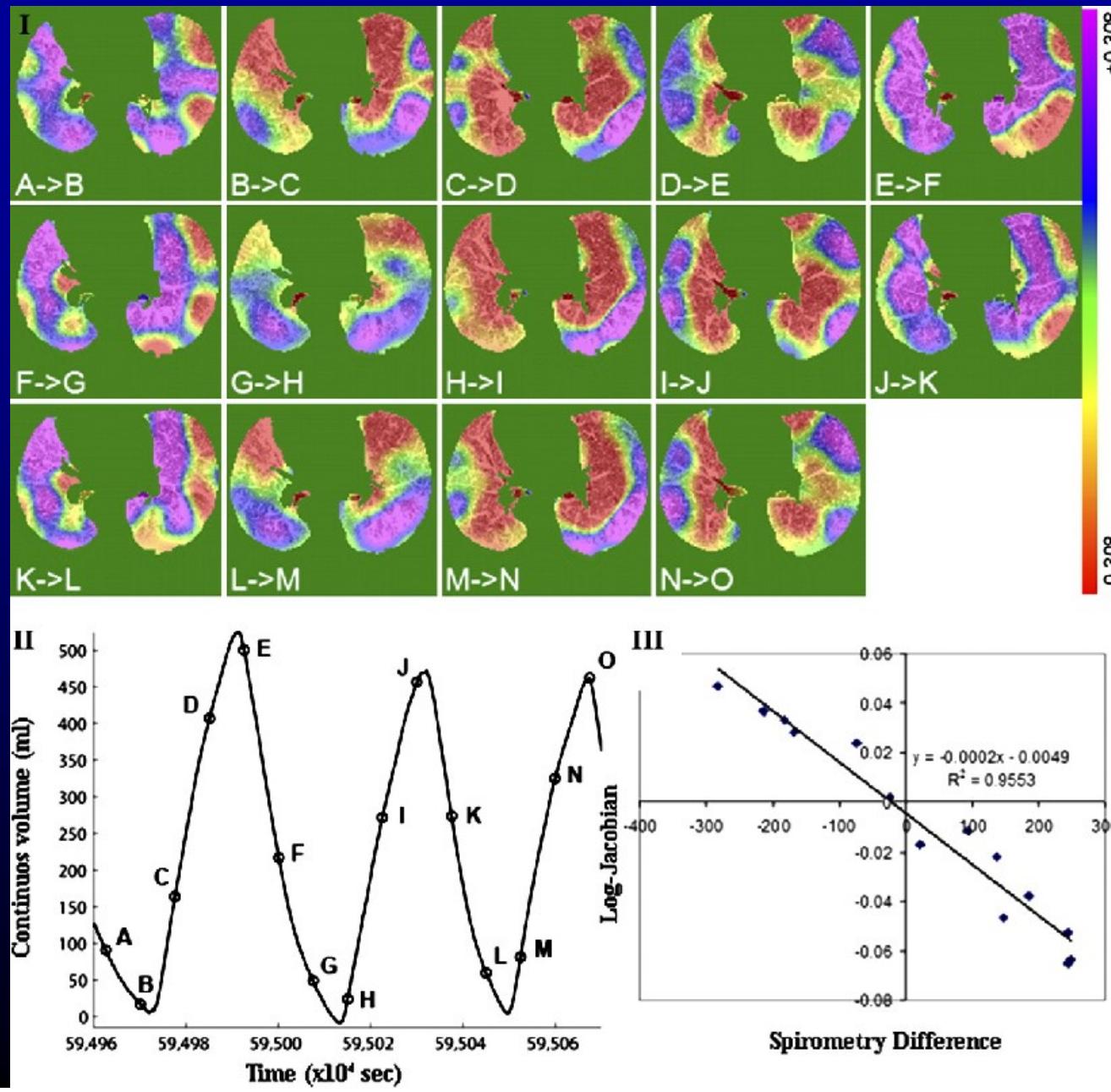
Non-Smoker



Smoker

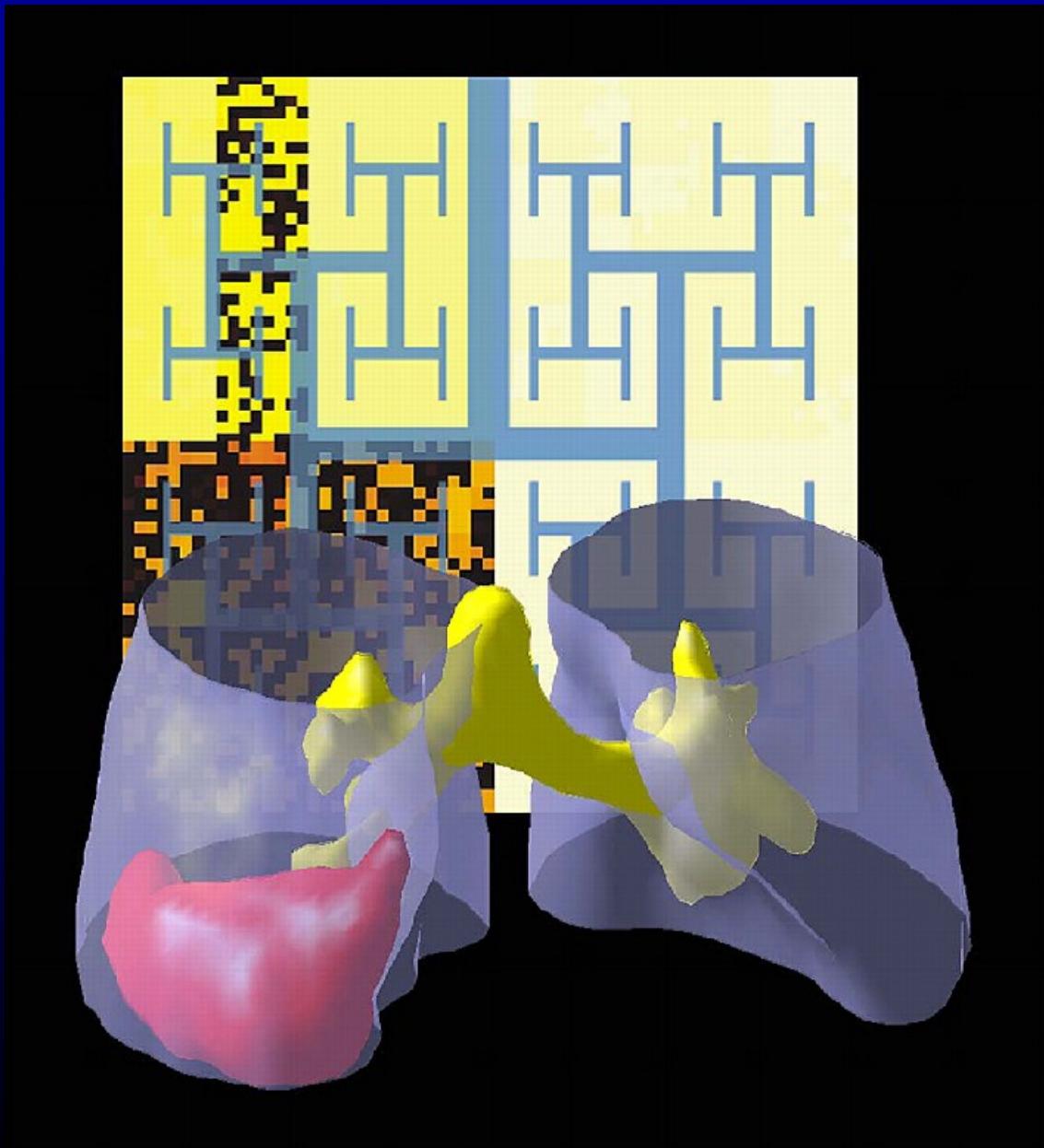
Proc ATS 2:2005; 492-98

Quantitative Regional Lung Expansion by CT



Proc ATS 2:2005; 517-21

PET Image During Methacholine-induced Bronchoconstriction



Proc ATS 2:2005; 522-27

Functional Imaging

- Electrical impedance tomography

Electrical Impedance Tomography (EIT)

Production of a cross-sectional image of
(changes in)
electrical impedance distribution in order to estimate
(changes in)
air distribution

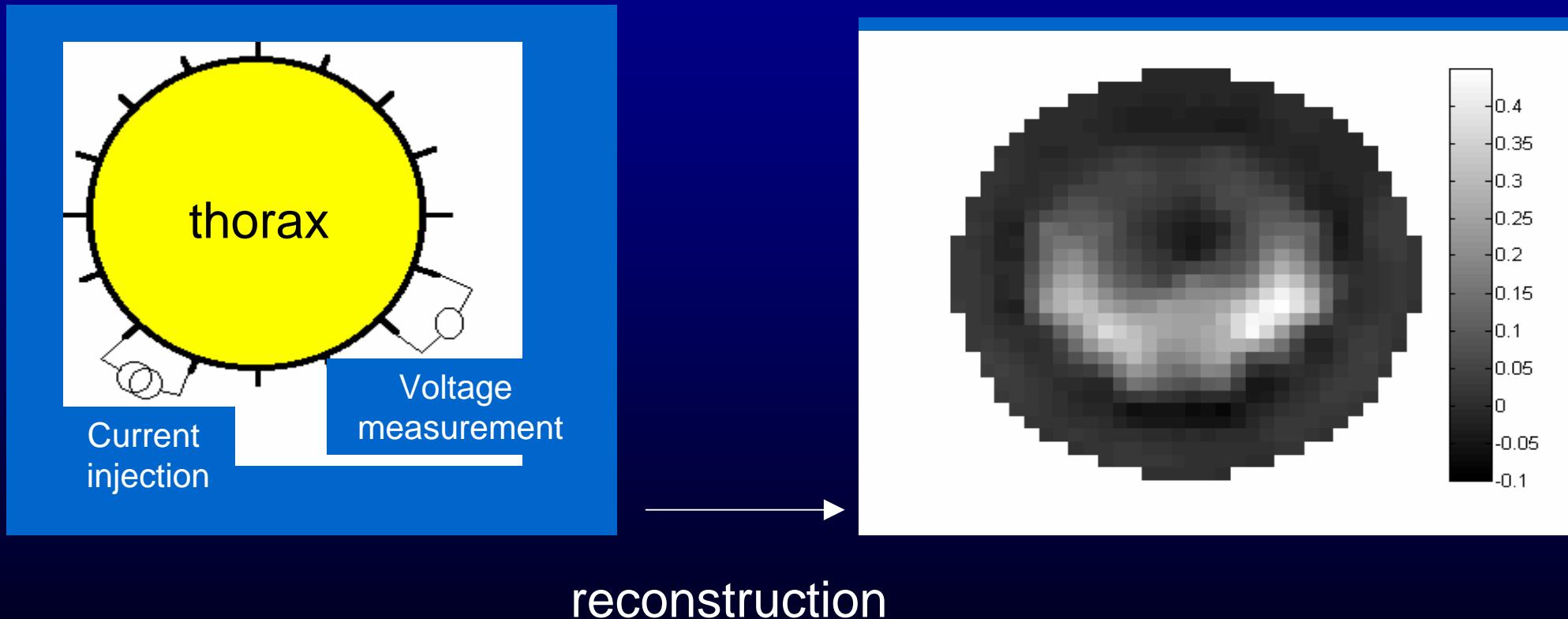
Electrical Impedance Tomography (EIT)

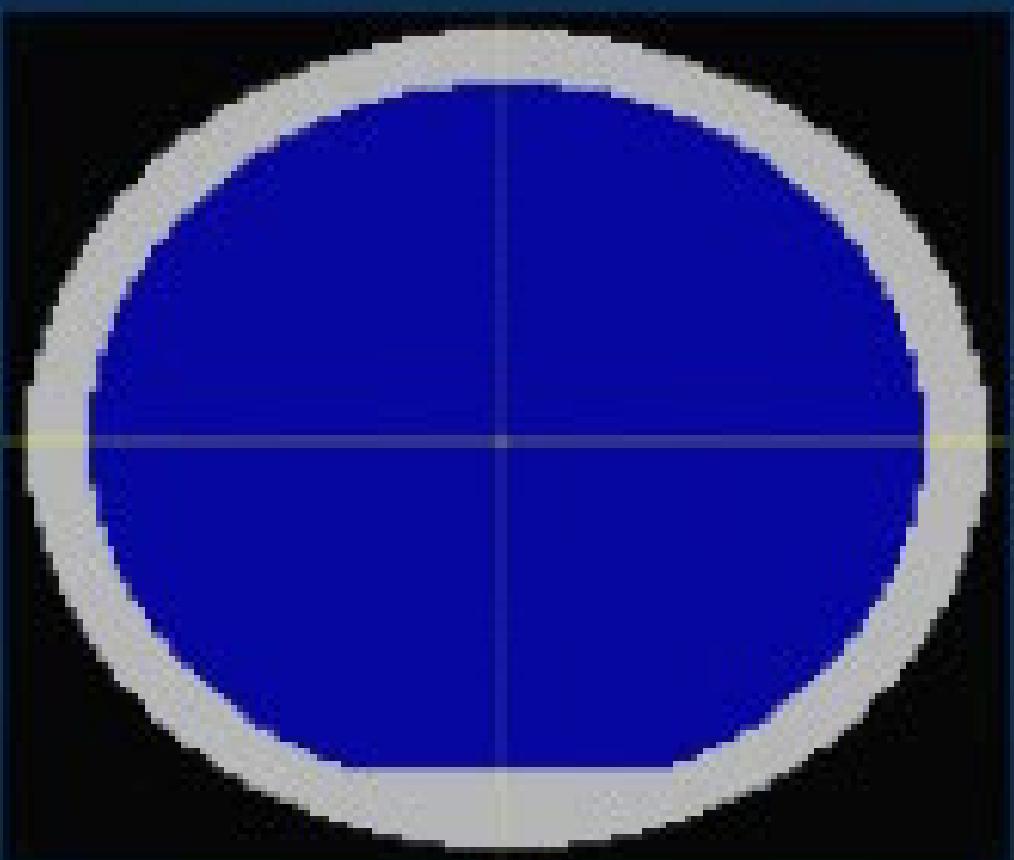
Resistivity (at 50 KHz) relative to blood:

whole blood	1
muscle	1.6
liver	5
lung, deflated	8
lung, inflated	16
bone	50

Electrical Impedance Tomography

Cross-sectional image of electrical impedance change





Victorino et al., AJRCCM 2004;169:791-800

special communication

Monitoring changes in lung air and liquid volumes with electrical impedance tomography

A. ADLER,^{1,2} R. AMYOT,³ R. GUARDO,¹ J. H. T. BATES,² AND Y. BERTHIAUME³

³*Centre de Recherche Hôtel-Dieu de Montréal and Department of Medicine, Université de Montréal,*

¹*Institut de Génie Biomédical, École Polytechnique, and ²Meakins-Christie Laboratories and
Department of Biomedical Engineering, McGill University, Montreal, Quebec, Canada H2W 1T8*

J Appl Physiol 83 (5), 1997

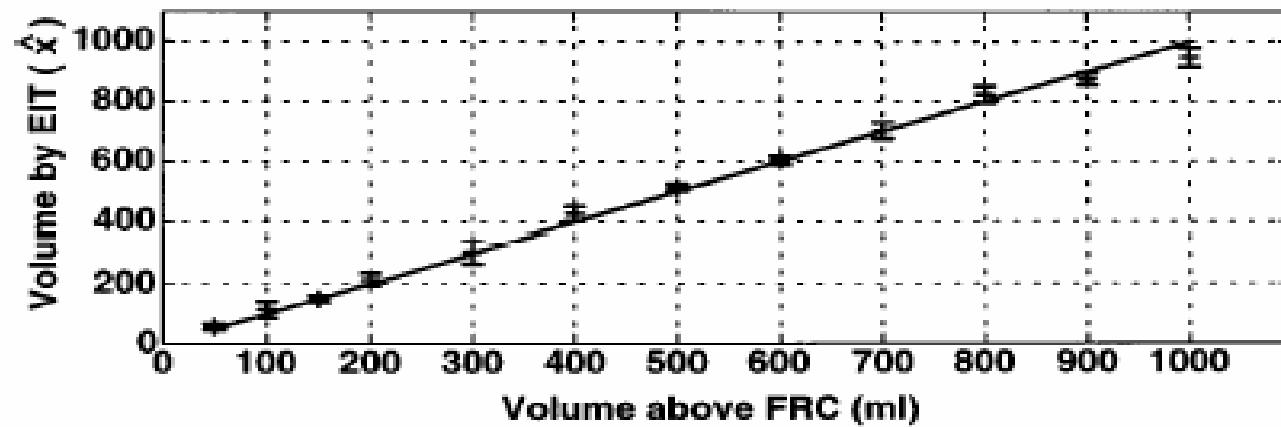
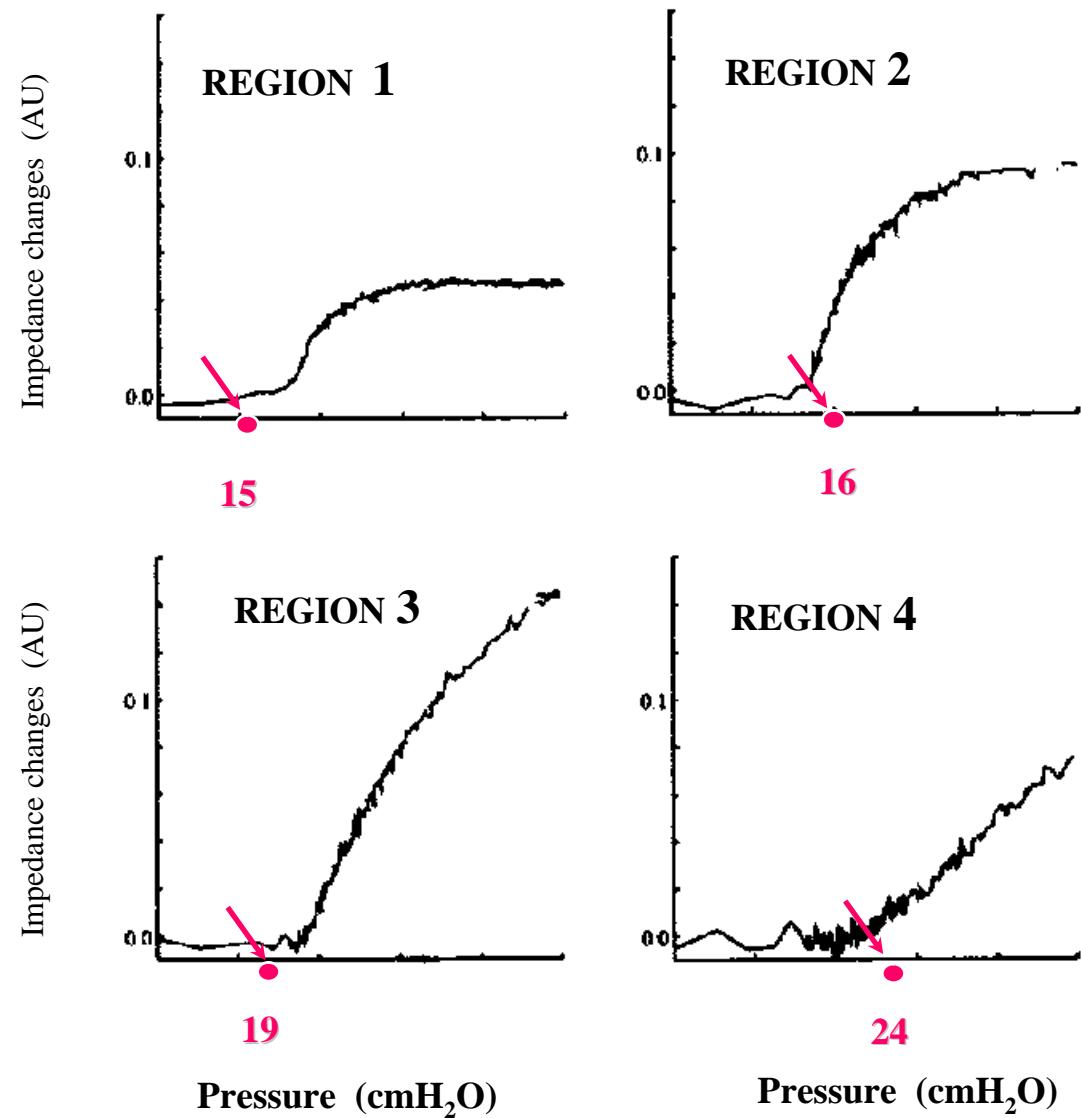
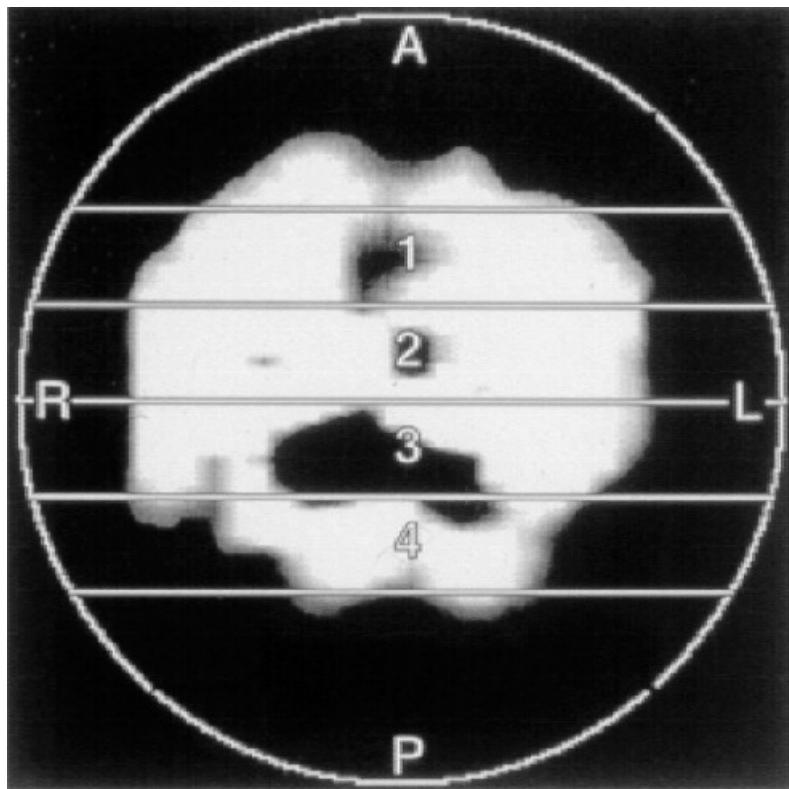


Fig. 4. Lung volume calculated by EIT (\bar{x}) as a function of syringe volume. Values are means \pm SD; $n = 9$ animals. FRC, functional residual capacity.

Regional pressure volume curves by electrical impedance tomography in a model of acute lung injury

Peter W. A. Kunst, MD; Stephan H. Bohm, MD Gilberto Vazquez de Anda, MD;
Marcelo B.P. Amato, MD; Burkhard Lachmann, MD, PhD; Piet E. Postmus, MD,
PhD; Peter M. J. M. de Vries, MD, PhD

Crit Care Med 2000; 28:178-183



Huibert R. Genderingen
Adrianus J. Vugt
Jos R. C. Jansen

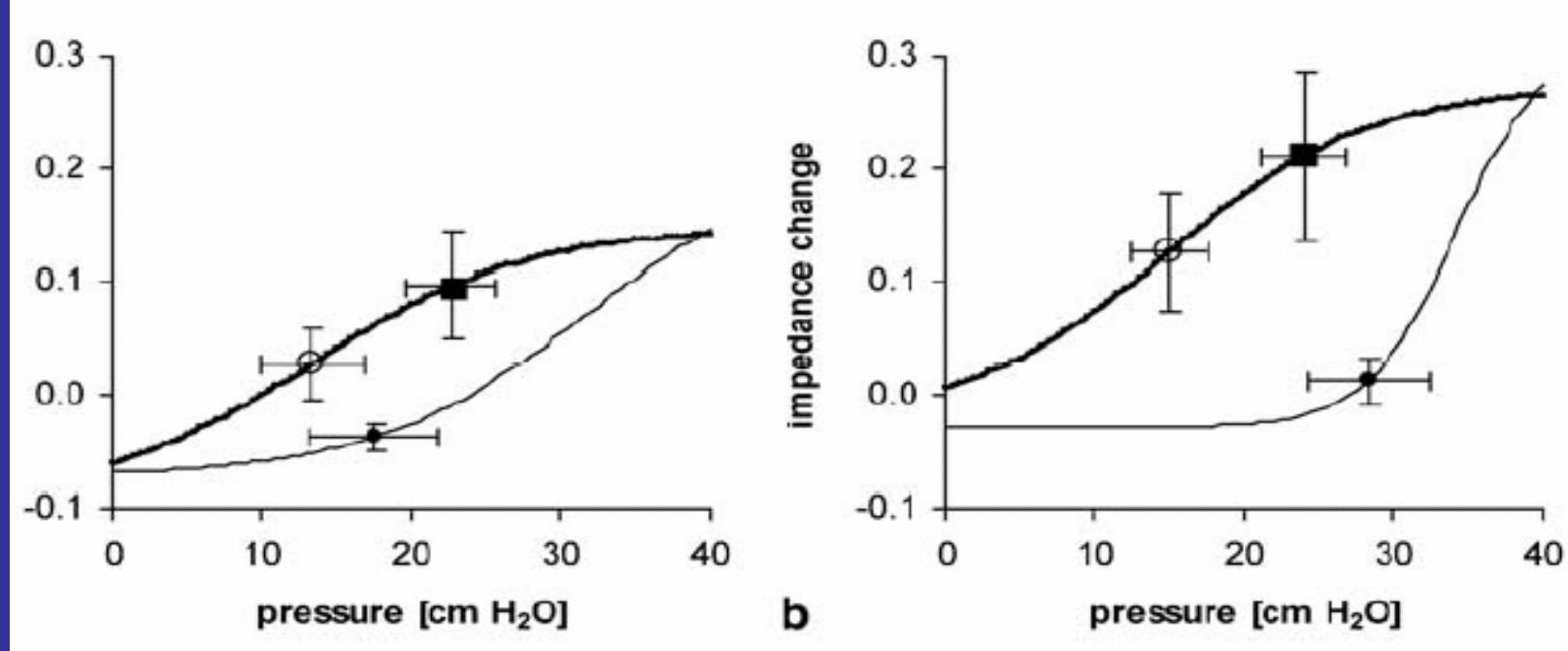
**Estimation of regional lung volume changes
by electrical impedance tomography
during a pressure-volume maneuver**

Regional pressure-volume curve

Ventral

- † lower corner point
- O maximal slope
- * linear upper edge

Dorsal



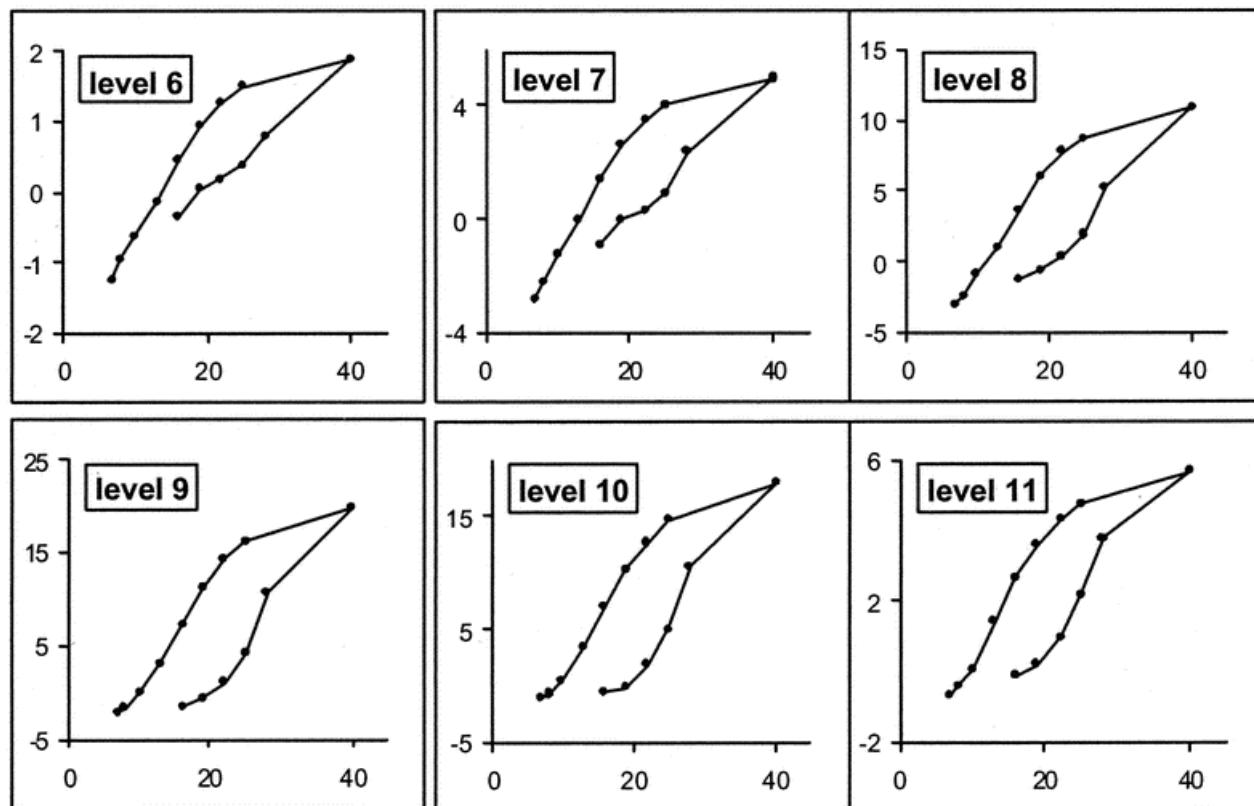
Regional lung volume during high-frequency oscillatory ventilation by electrical impedance tomography*

Huibert R. van Genderingen, PhD; Adrianus J. van Vugt, MD, PhD; Jos R. C. Jansen, PhD

Crit Care Med 2004; 32:787–794

Relationship between impedance change and mean airway pressure during HFOV

Crit Care Med 2004; 32:787–794



IMPEDANCE CHANGES

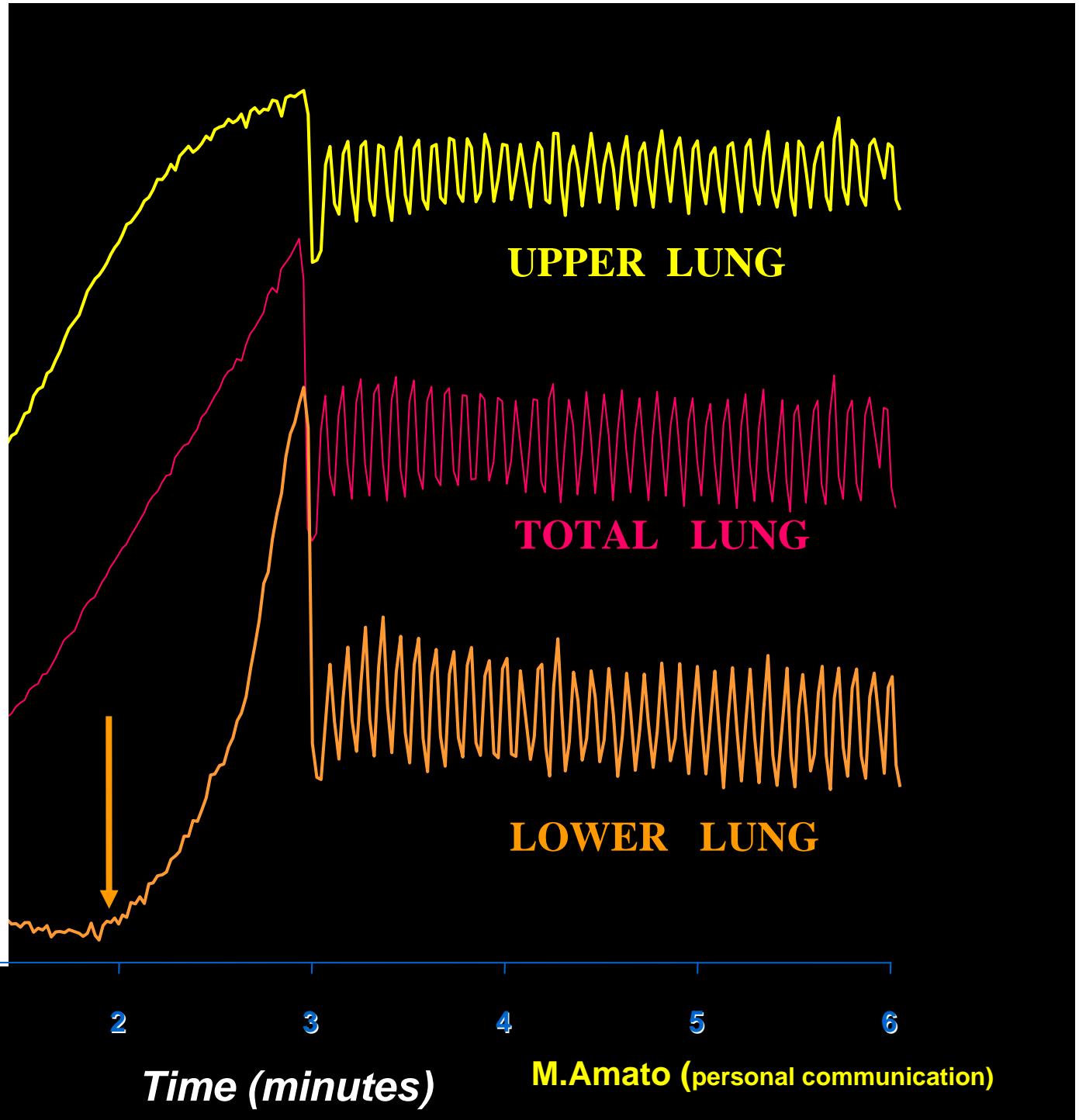
0.08
0.06
0.04
0.02
0.00
-0.02
-0.04
-0.06
-0.08
-0.10

DERECRUITMENT

0 1 2 3 4 5 6

Time (minutes)

M.Amato (personal communication)



U/L:

.2 .3 .5 .8 **1.1** 1.7 5.9 6.7 6.9

PEEP:

25 25 23 21 19 17 15 13 11

IMPEDANCE CHANGES

0.02

-0.02

-0.06

-0.10

0

5

10

15

20

25

Time (min)

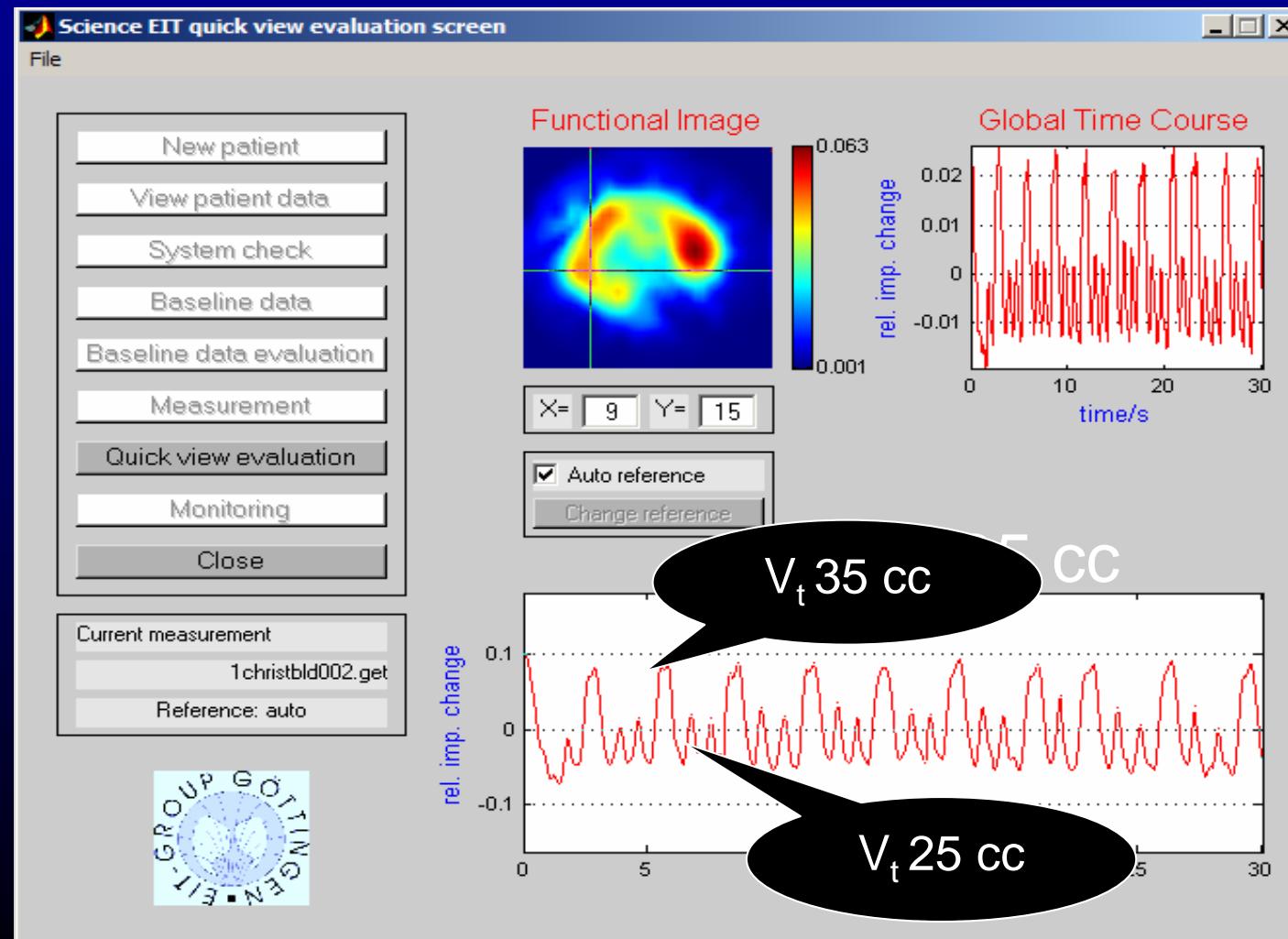
UPPER

LOWER

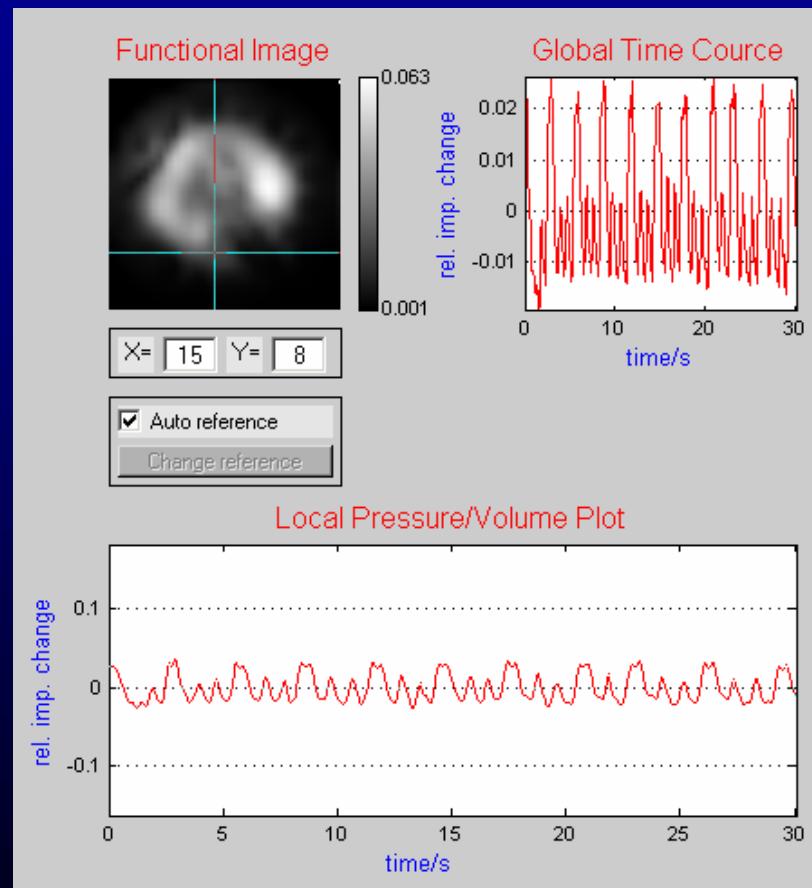
M.Amato (personal communication)

3 m/o, Bronchiolitis

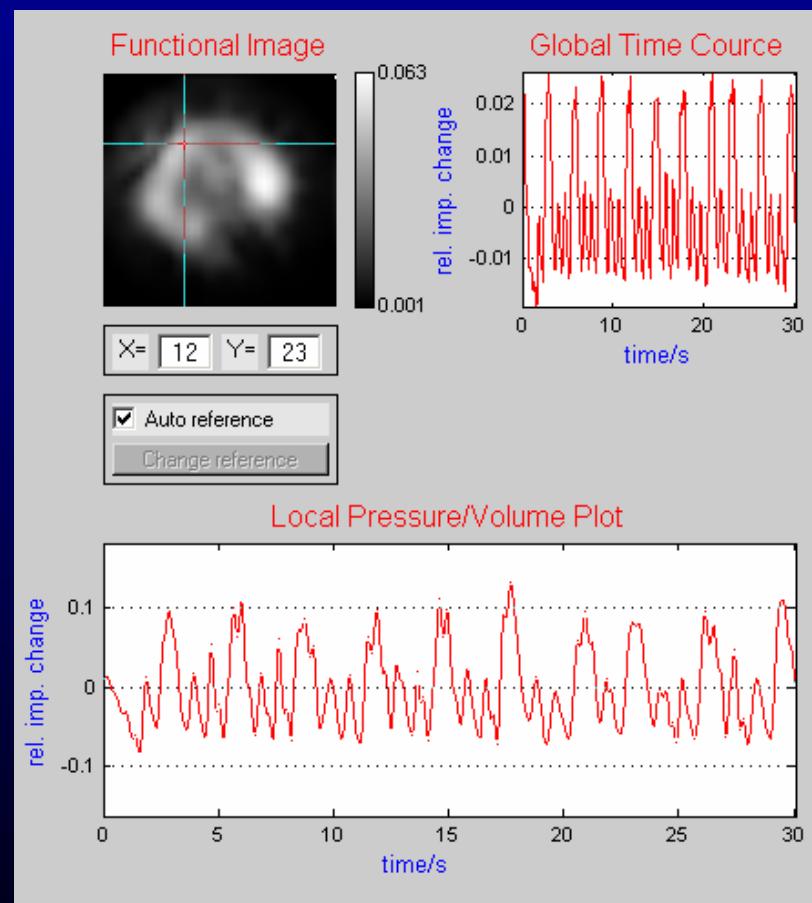
Servo 300, PC/PS PIP 27, PS 10,PEEP 5



Regional ventilation in dependent areas



Regional ventilation in nondependent areas





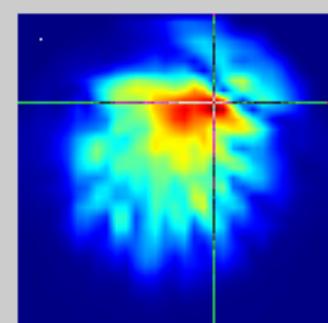
MCFEIT quick view evaluation screen

File

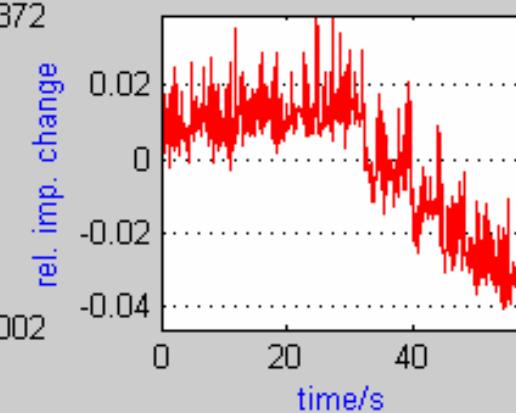
- New patient
 - View patient data
 - System check
 - Baseline data
 - Baseline data evaluation
 - Measurement (1 min)
 - Quick view evaluation
 - Monitoring
 - Close
- Current measurement
1tylersecond026.get
Reference: auto



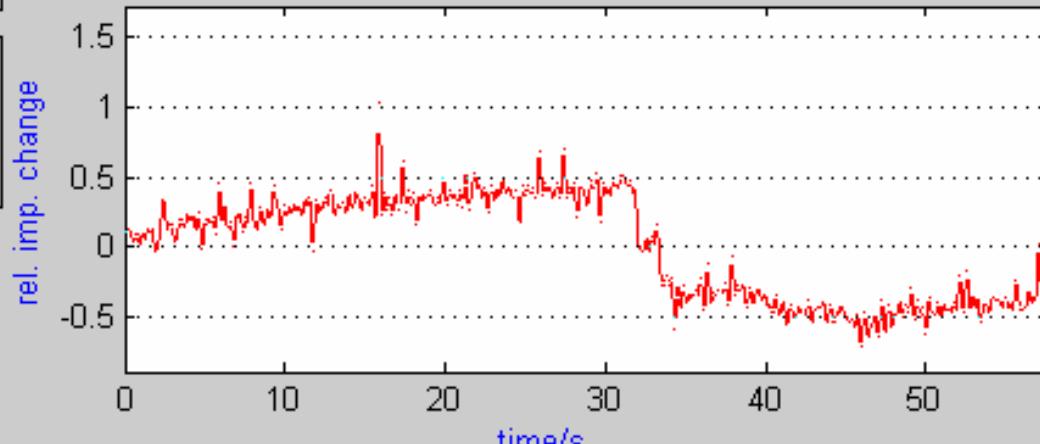
Functional Image



Global Time Course



Local Time Course



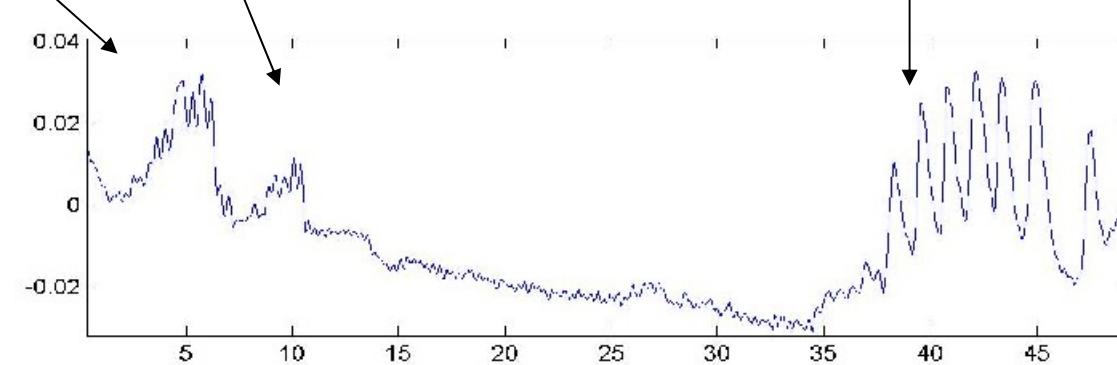
Patient on Sensormedics – disconnection -suctioning

Handventilation

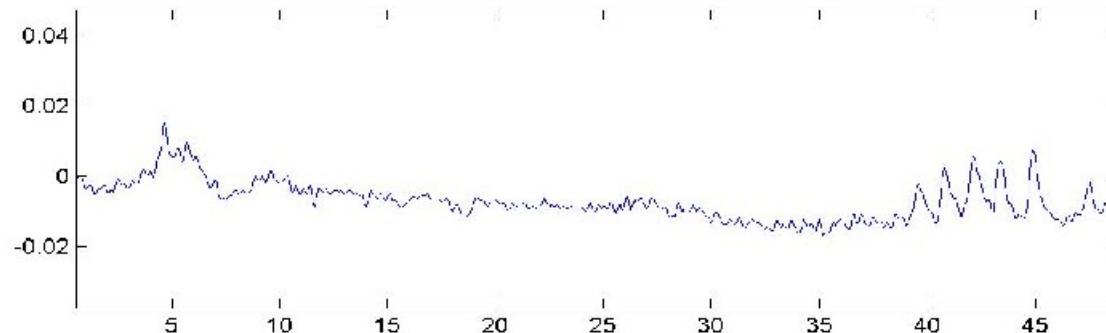
Inline-suctioning

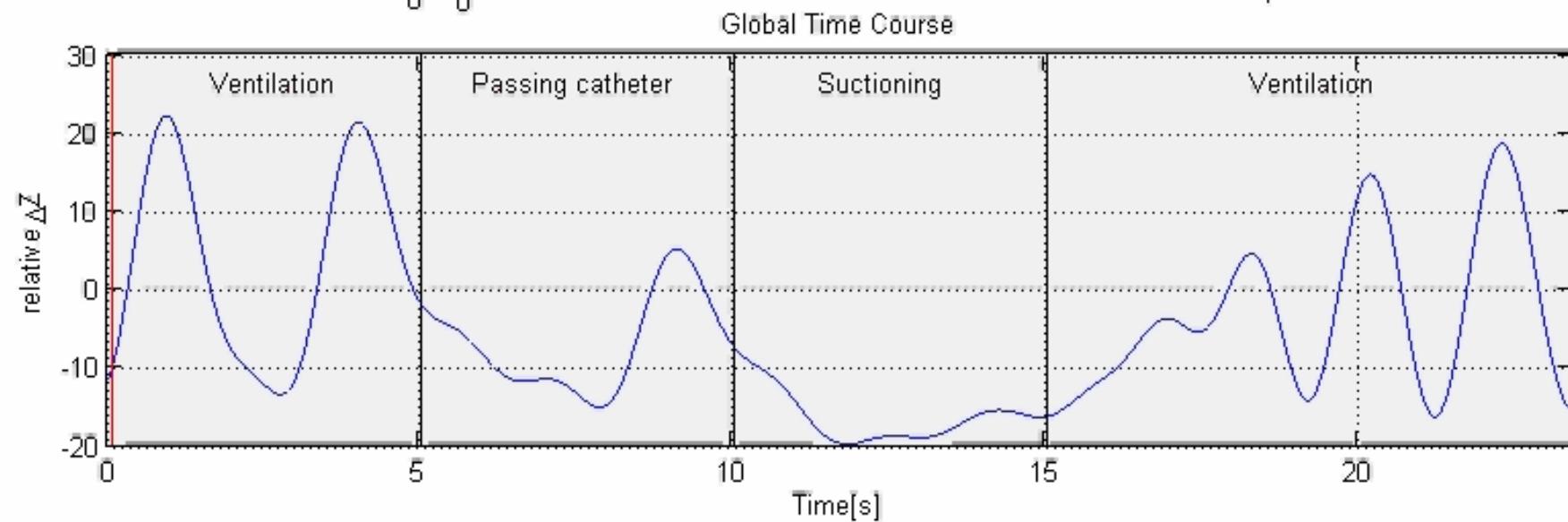
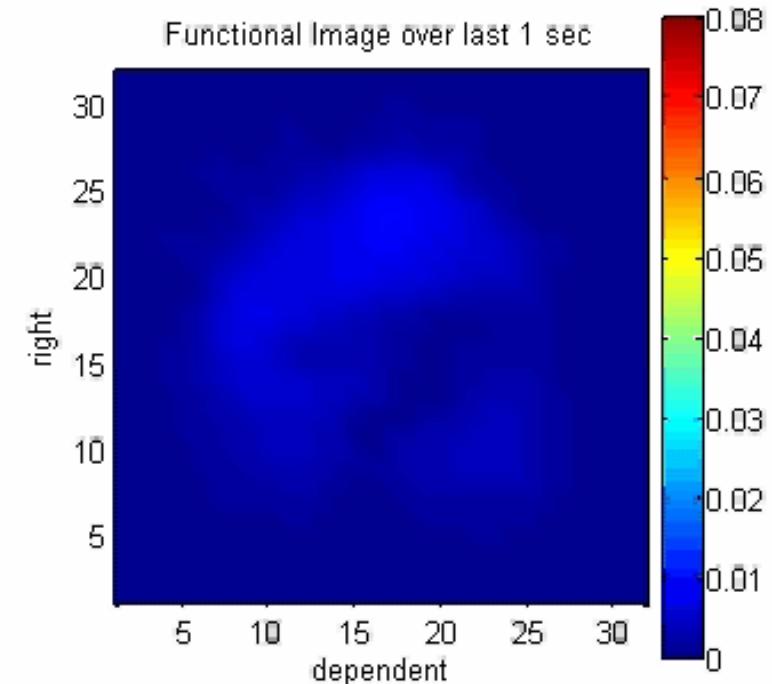
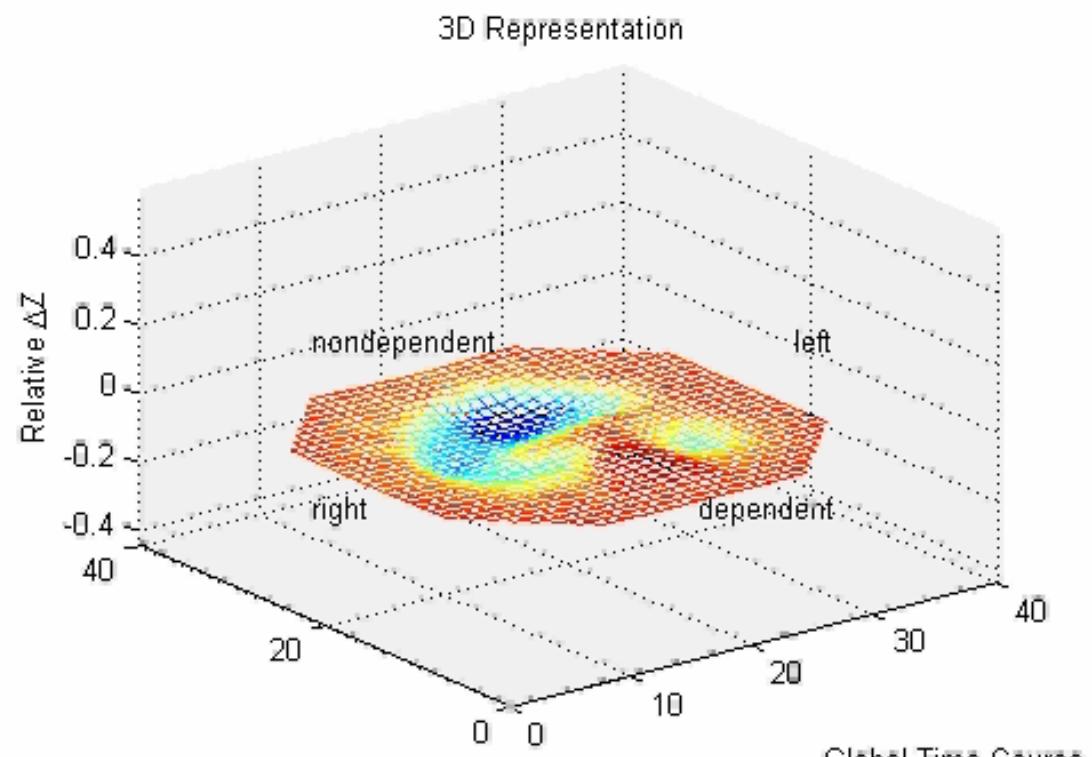
Handventilation

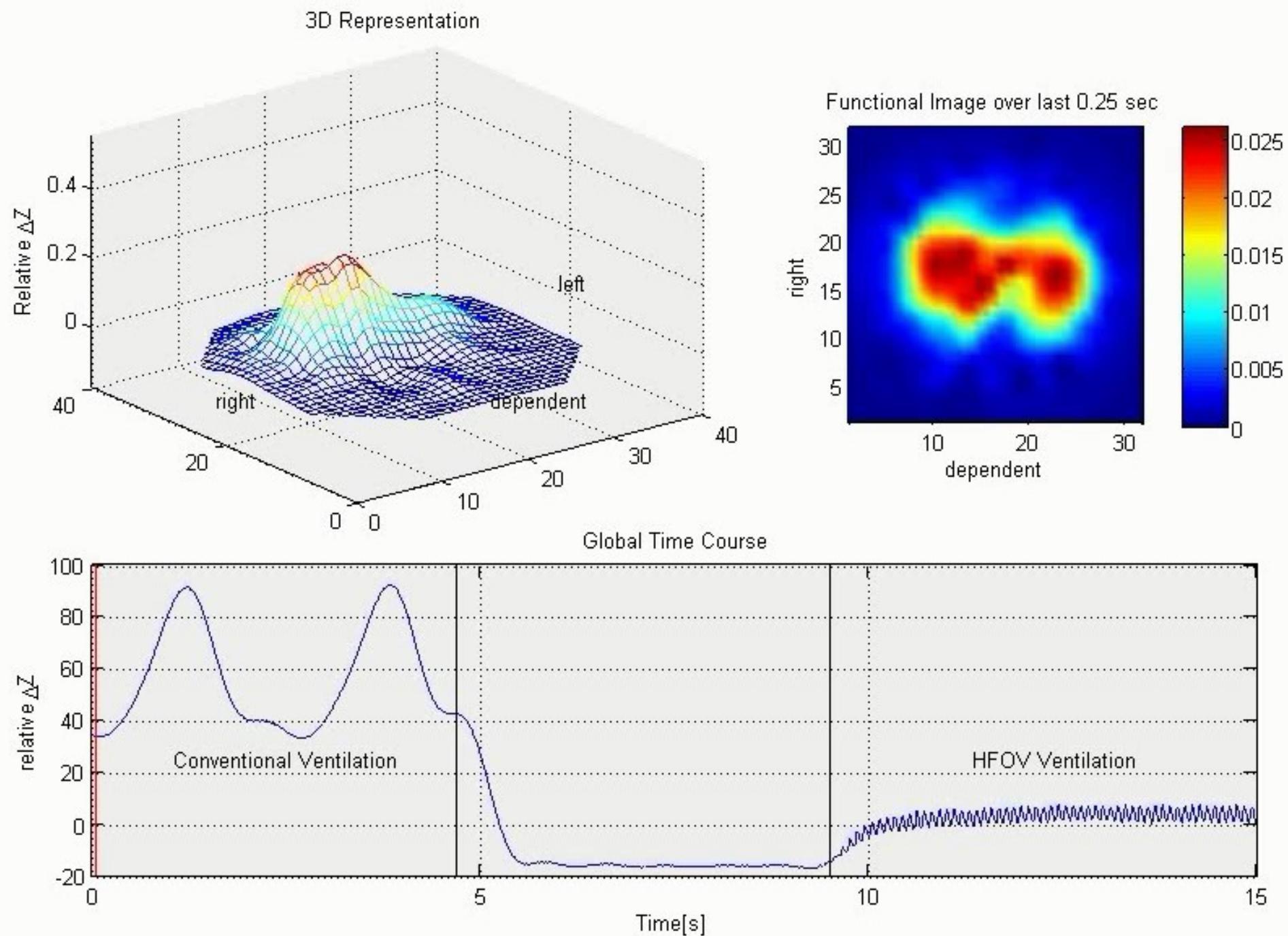
ventral



dorsal







Ideal Clinical Monitor

- Describes regional changes in anatomy/physiology
- Non-invasive
- Portability to the bedside
- Short processing time
- Dynamic data updating

Molecular Imaging

- Micro-PET and micro-SPECT
- Bioluminescence imaging
- Inflammation imaging
- Molecular imaging of pulmonary gene expression using PET

**“Americans will always do the right thing
once they have tried everything else....”**

Winston Churchill