RespiratoryAssociates.com

Chest Electrical Impedance Tomography

Part 1: Principles and validation

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Universidade Federal de Pernambuco

Medicina USP

Conflict of Interest Disclosure

Caio C. A. Morais

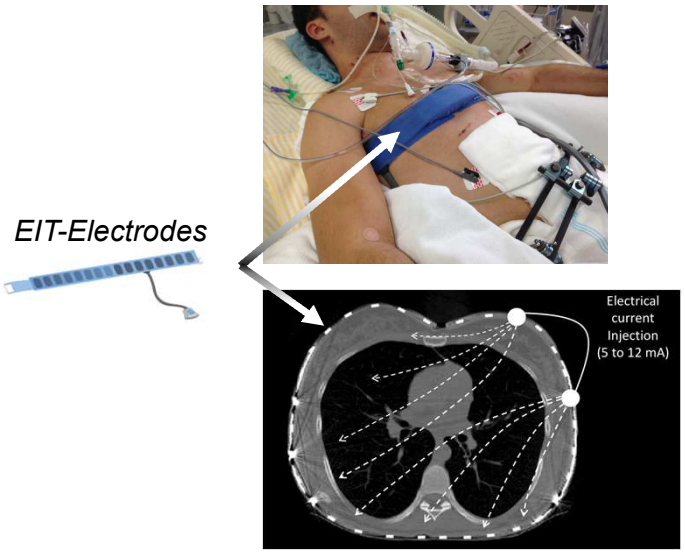
COMPANY:	RELATIONSHIP:	CONTENT AREA:
Timpel Medical	Research grants	EIT

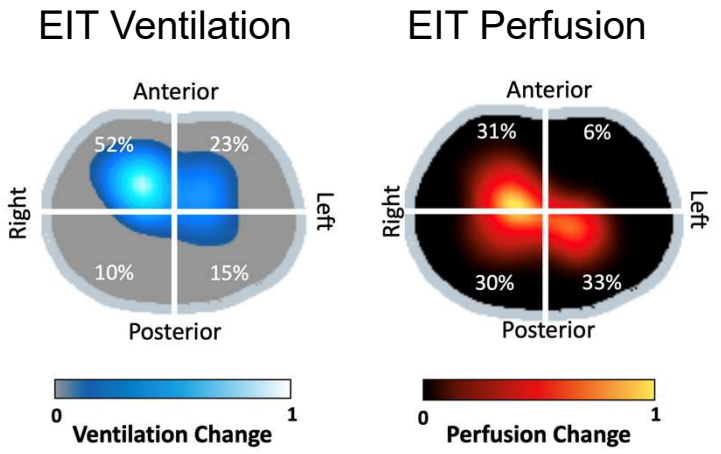
Agenda:

1. Principles of Electrical Impedance Tomography - EIT.
2. Validation of lung ventilation and perfusion distribution imaging.
3. Clinical applications to assist in respiratory care.

Electrical Impedance Tomography: Basic Principles

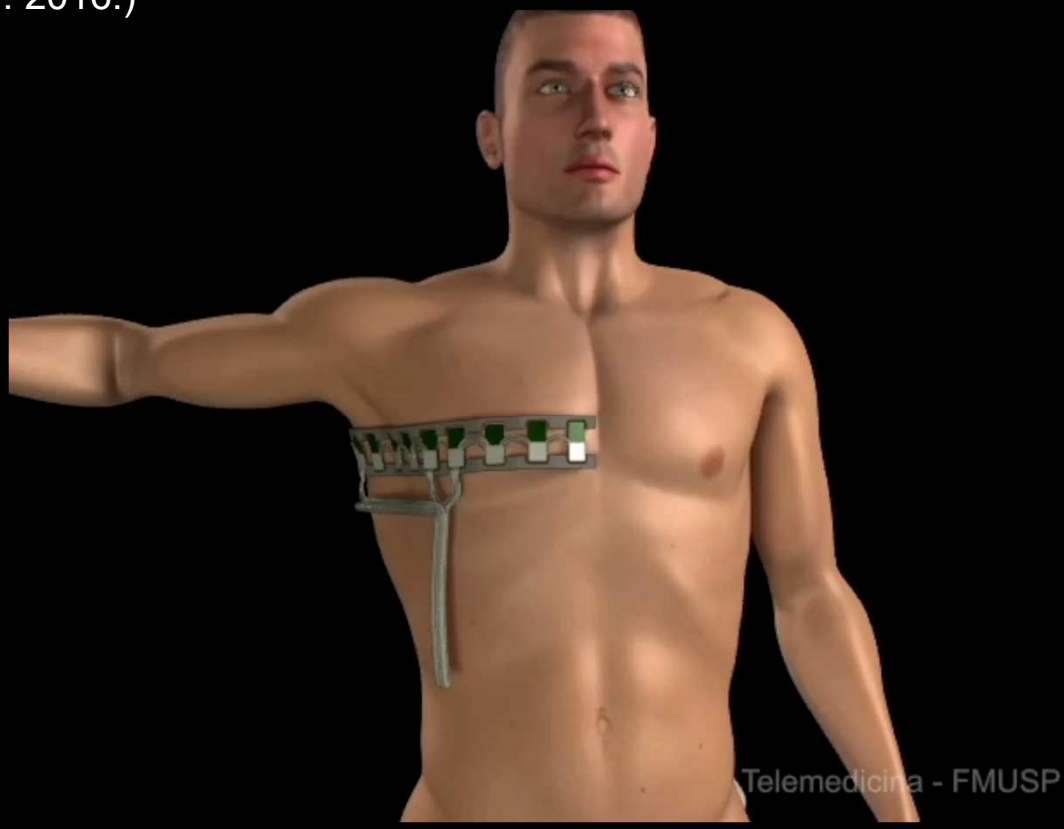
- Noninvasive, radiation-free clinical imaging tool.
- Image reconstruction is based on the estimation of the resistivity changes across the lungs.



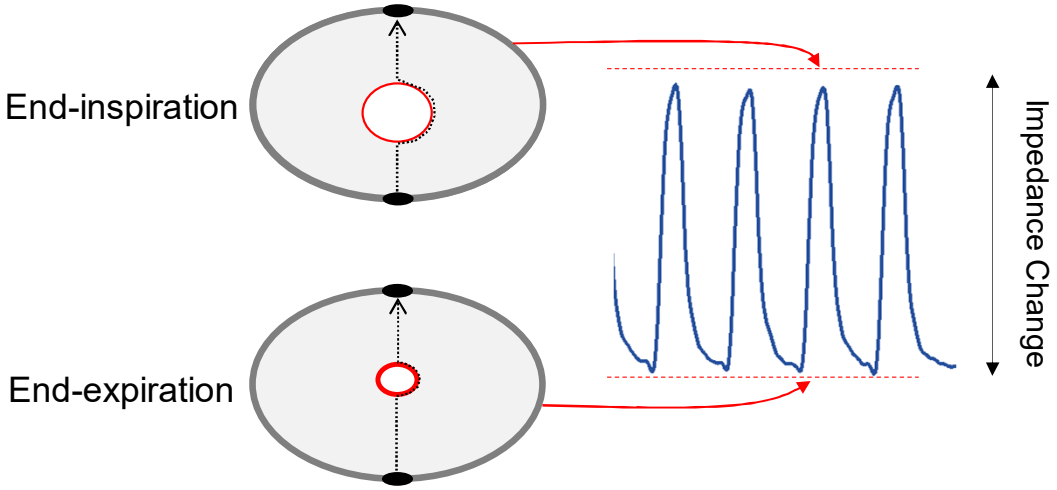


MC Bachmann, C Morais, *et al*. Crit Care, 2018.

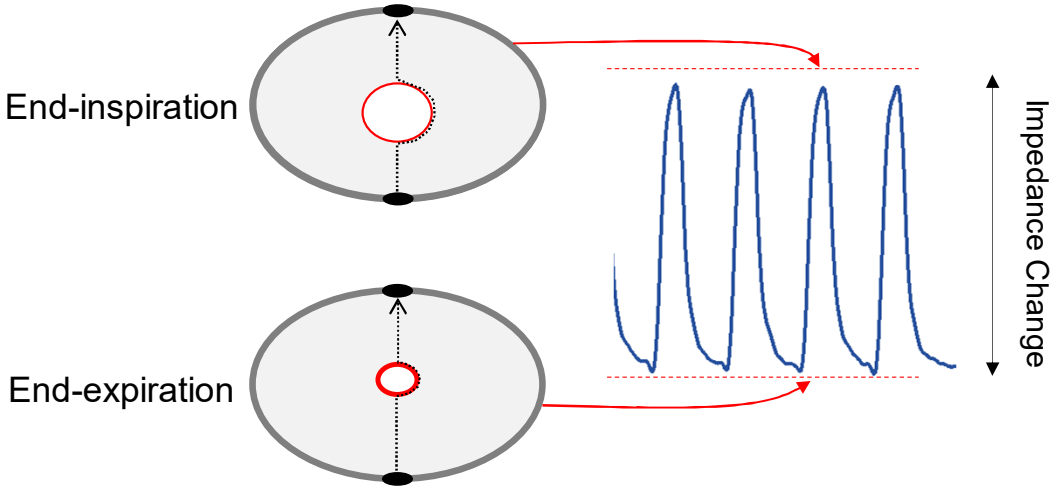
Recommendation for electrode placement:
5th to 6th intercostal spaces at the parasternal line.
(I Frerichs, M Amato, et al. 2016.)

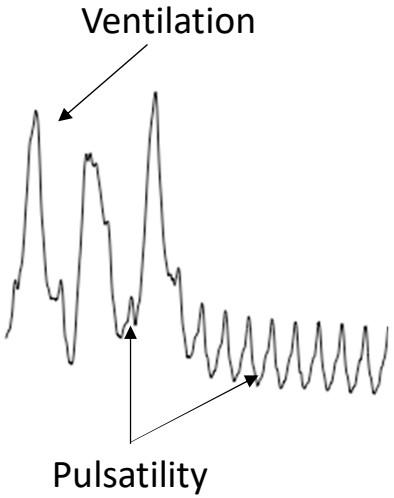


Electrical Impedance Tomography: Basic Principles

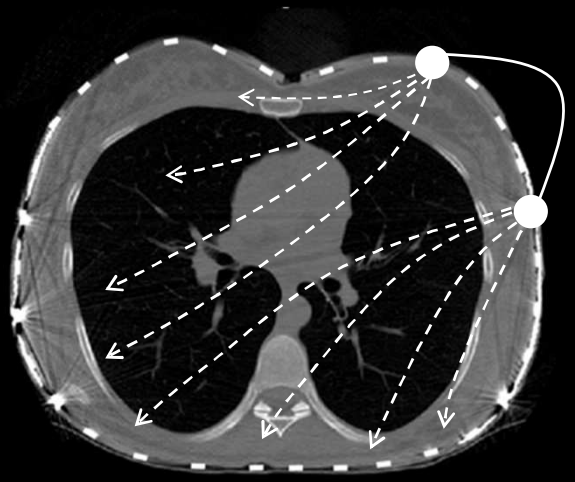


Electrical Impedance Tomography: Basic Principles



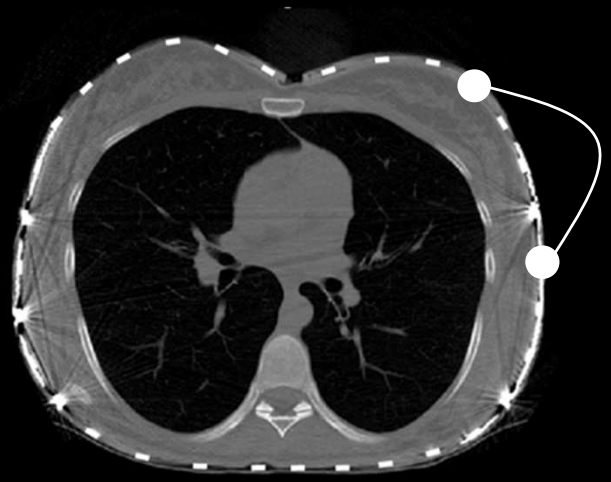


EIT Chest measurements



Electrical current Injection (5 to 12 mA)

EIT Chest measurements



EIT Chest measurements

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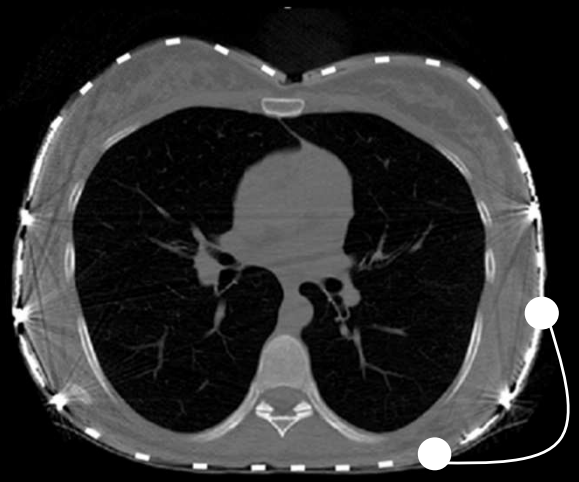

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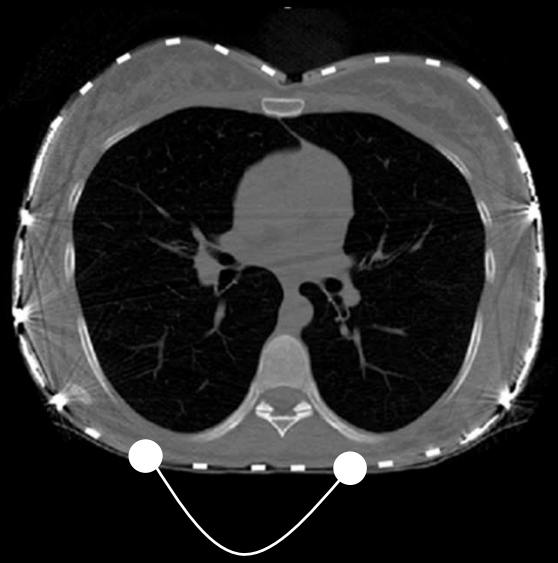

EIT Chest measurements

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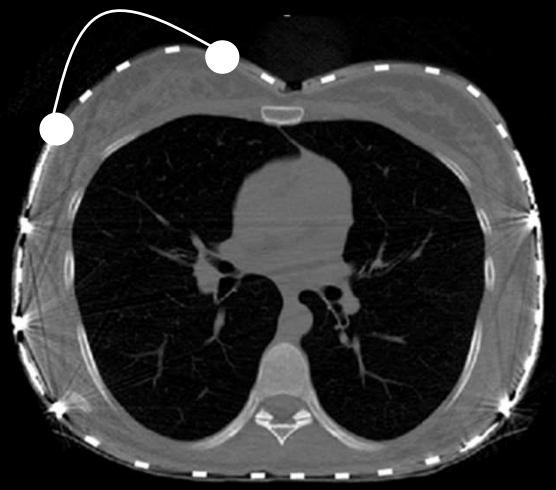
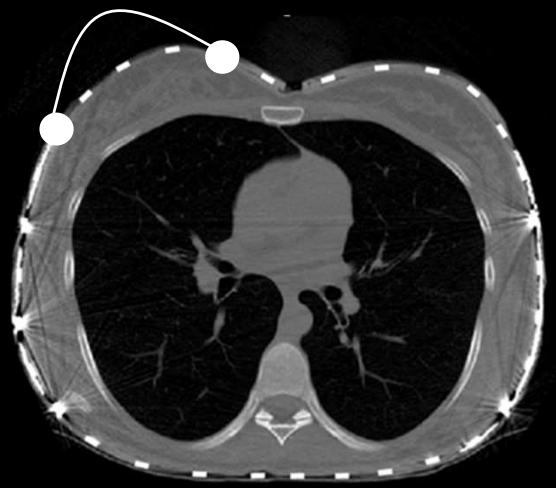
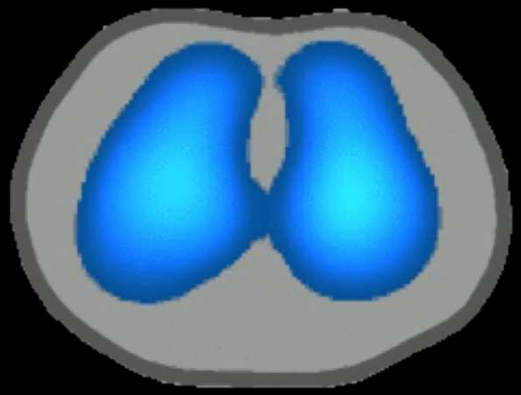


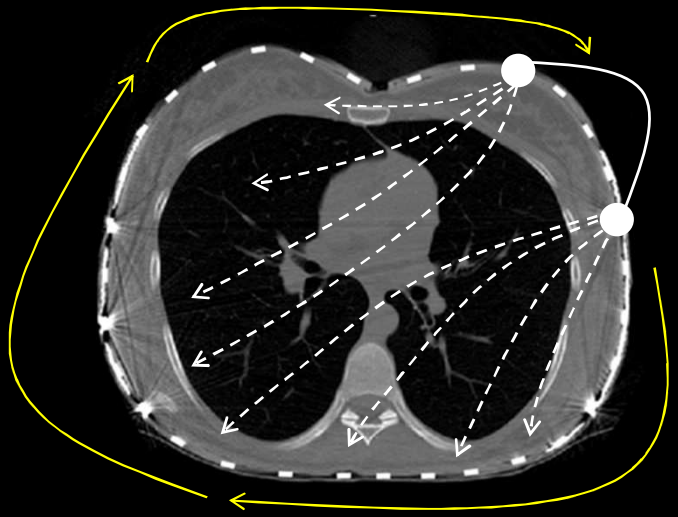
EIT Chest measurements



EIT Image

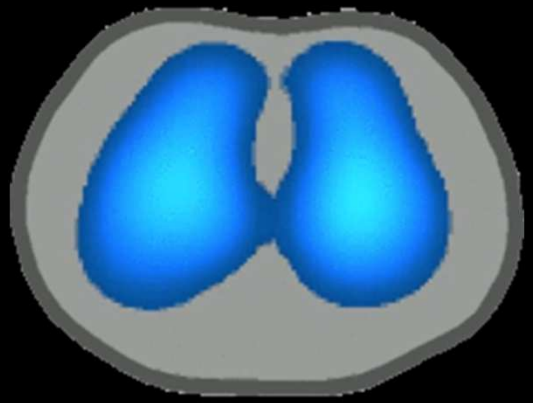


EIT Chest measurements



Scan rate ~
50Hz

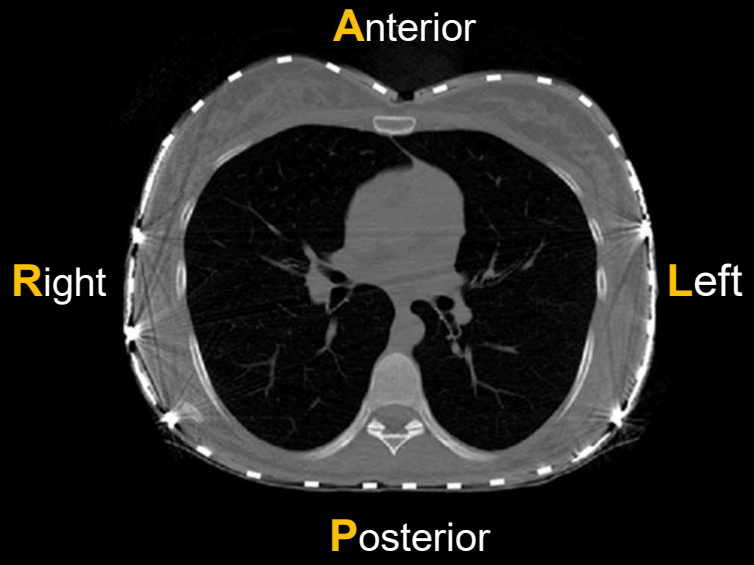
EIT Image



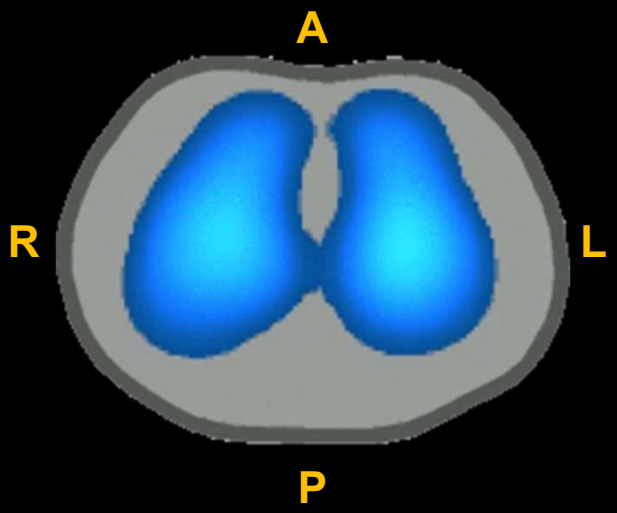
Method with high temporal resolution.

EIT Chest measurements

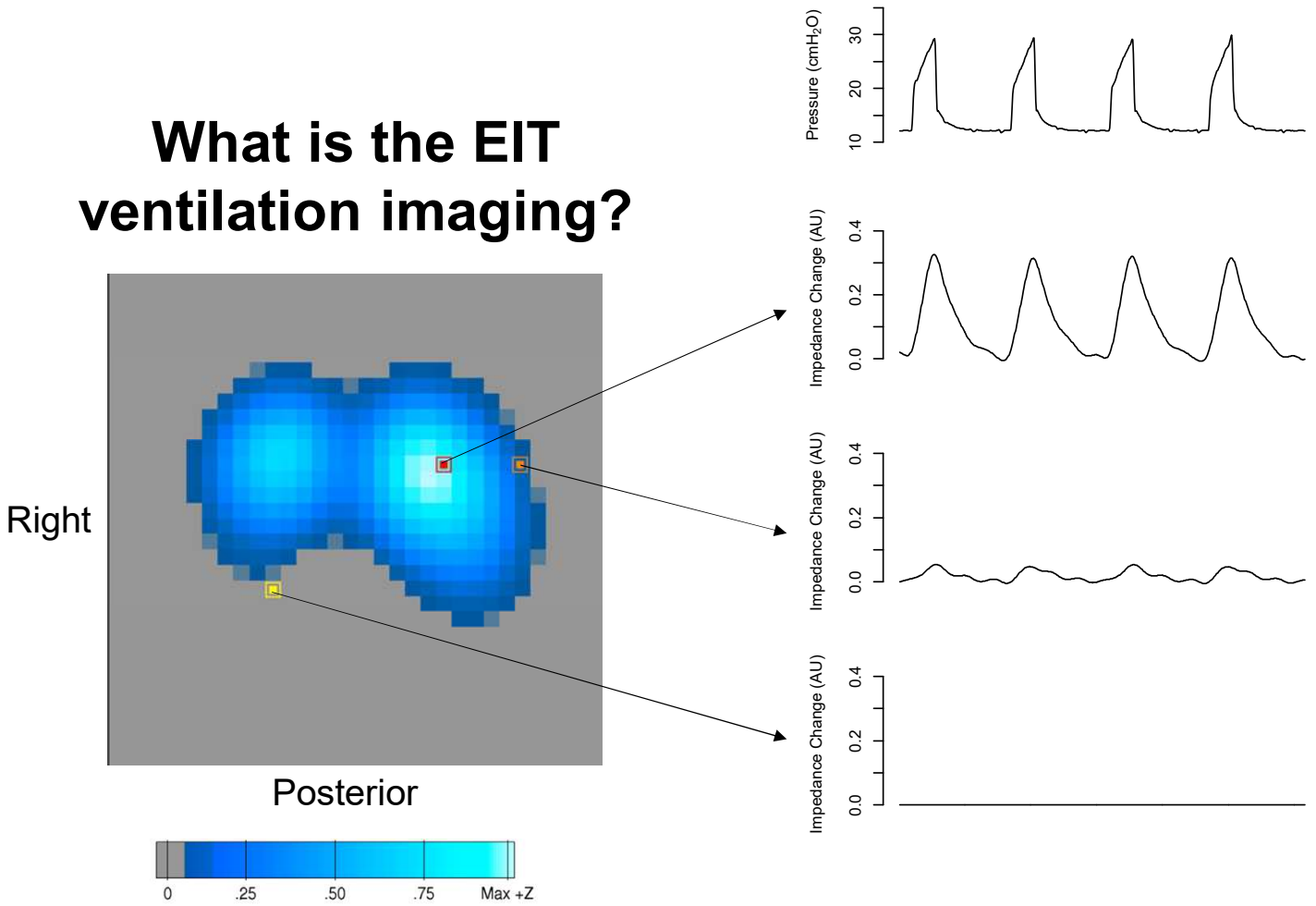
CT Image



EIT Image

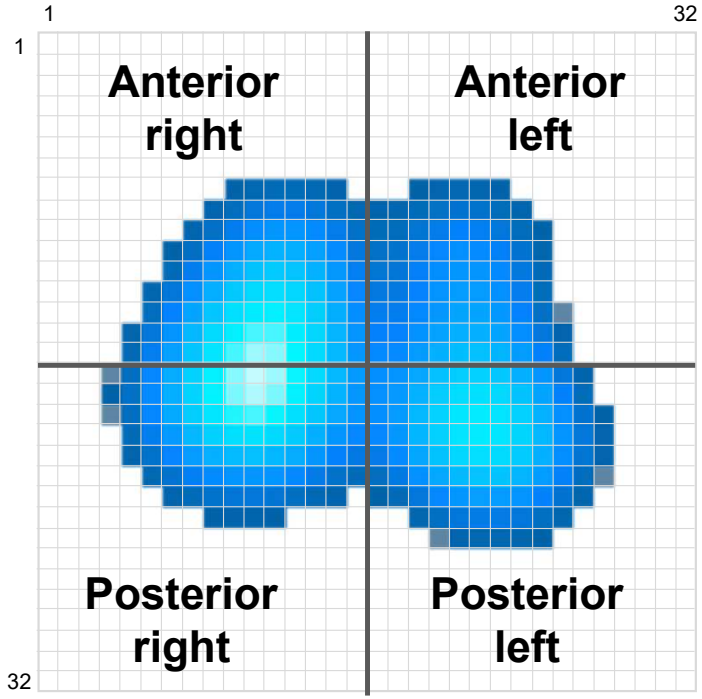


What is the EIT ventilation imaging?

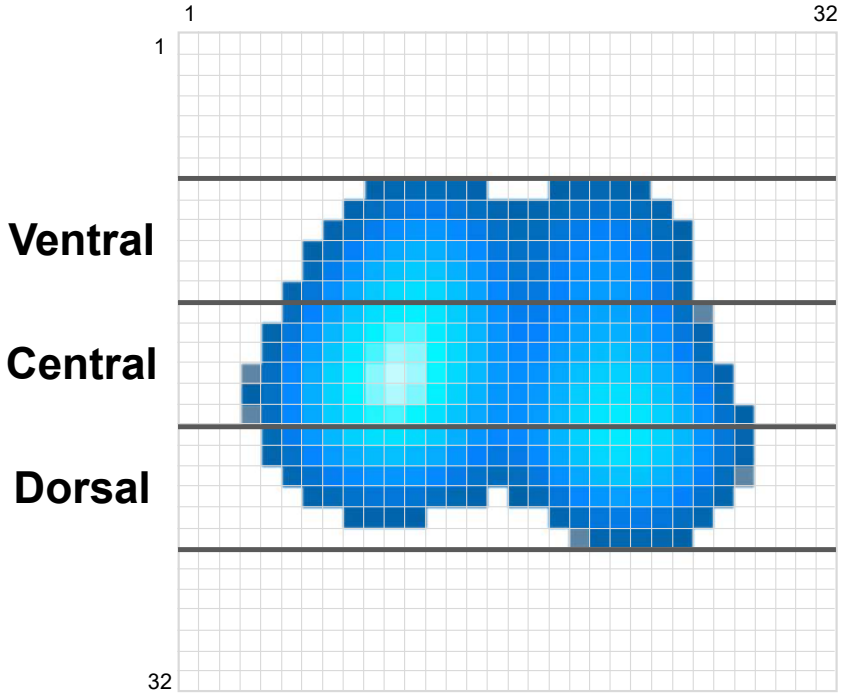


Types of ROIs to characterize the distribution of ventilation

Image quadrants



Multiple layers



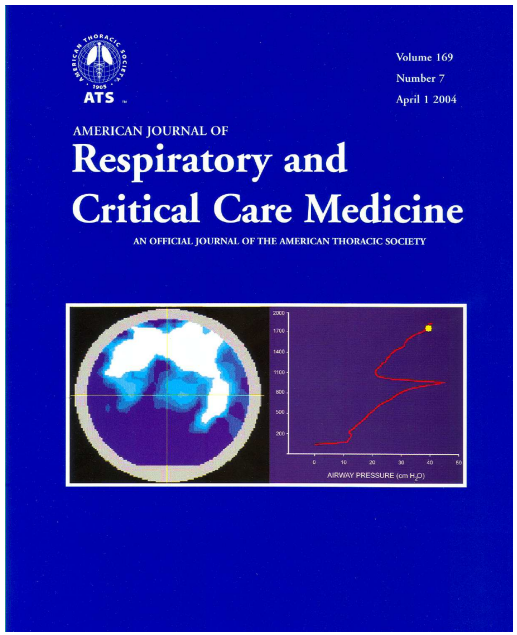
Validations

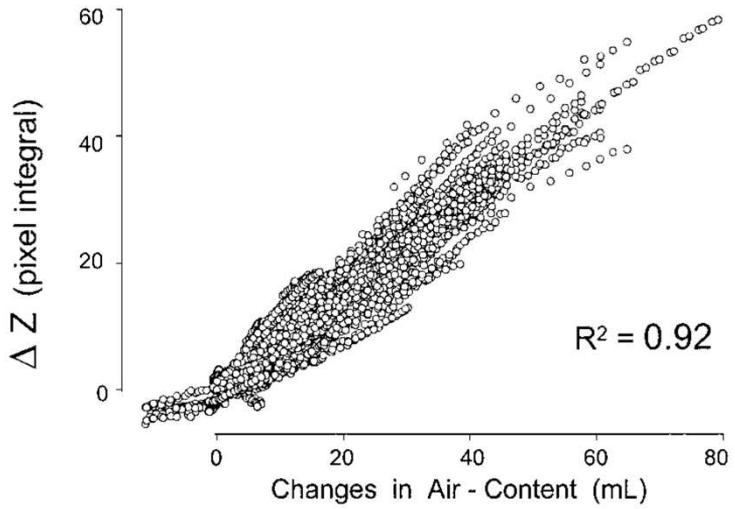
Imbalances in Regional Lung Ventilation

A Validation Study on Electrical Impedance Tomography

Josué A. Victorino, João B. Borges, Valdelis N. Okamoto, Gustavo F. J. Matos, Mauro R. Tucci, Maria P. R. Caramez, Harki Tanaka, Fernando Suarez Sipmann, Durval C. B. Santos, Carmen S. V. Barbas, Carlos R. R. Carvalho, and Marcelo B. P. Amato

Respiratory ICU, Hospital das Clínicas, Pulmonary Department; General ICU, Hospital das Clínicas, Emergency Clinics Division; Radiology Department, Hospital das Clínicas, University of São Paulo, São Paulo, Brazil; and Department of Intensive Care, Fundación Jiménez Díaz, Madrid, Spain





Imbalances in Regional Lung Ventilation

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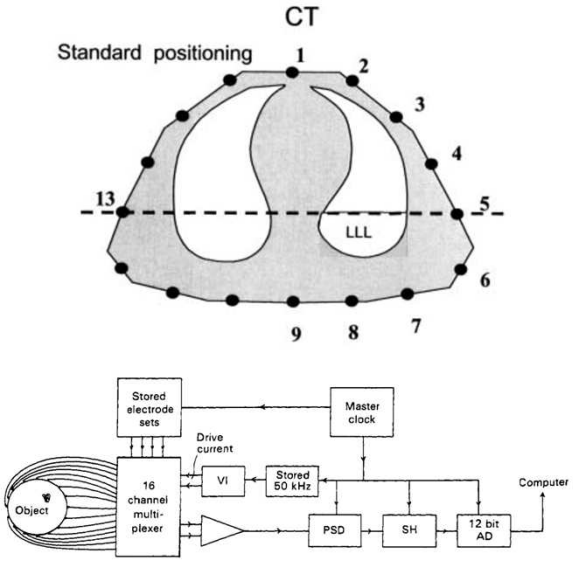
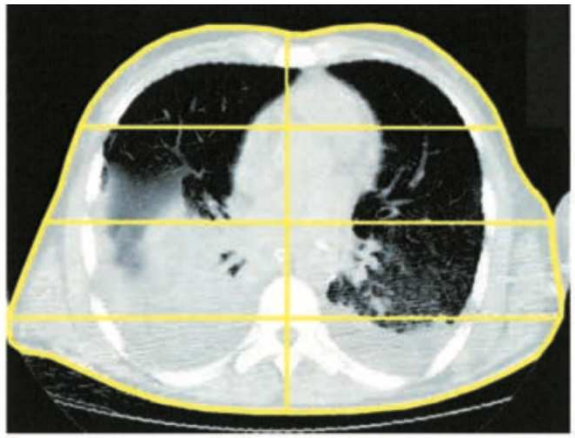
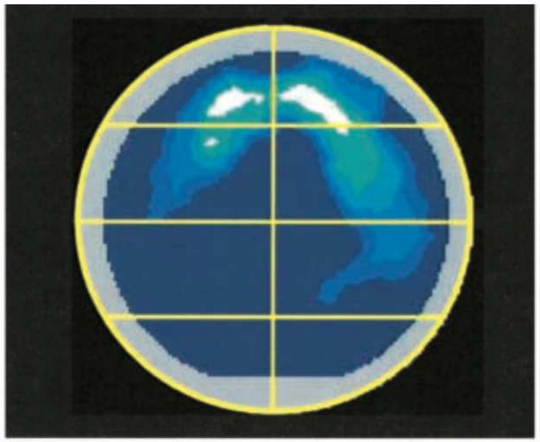


Figure 2. A block diagram of the Sheffield data collection system. This is explained in the text.

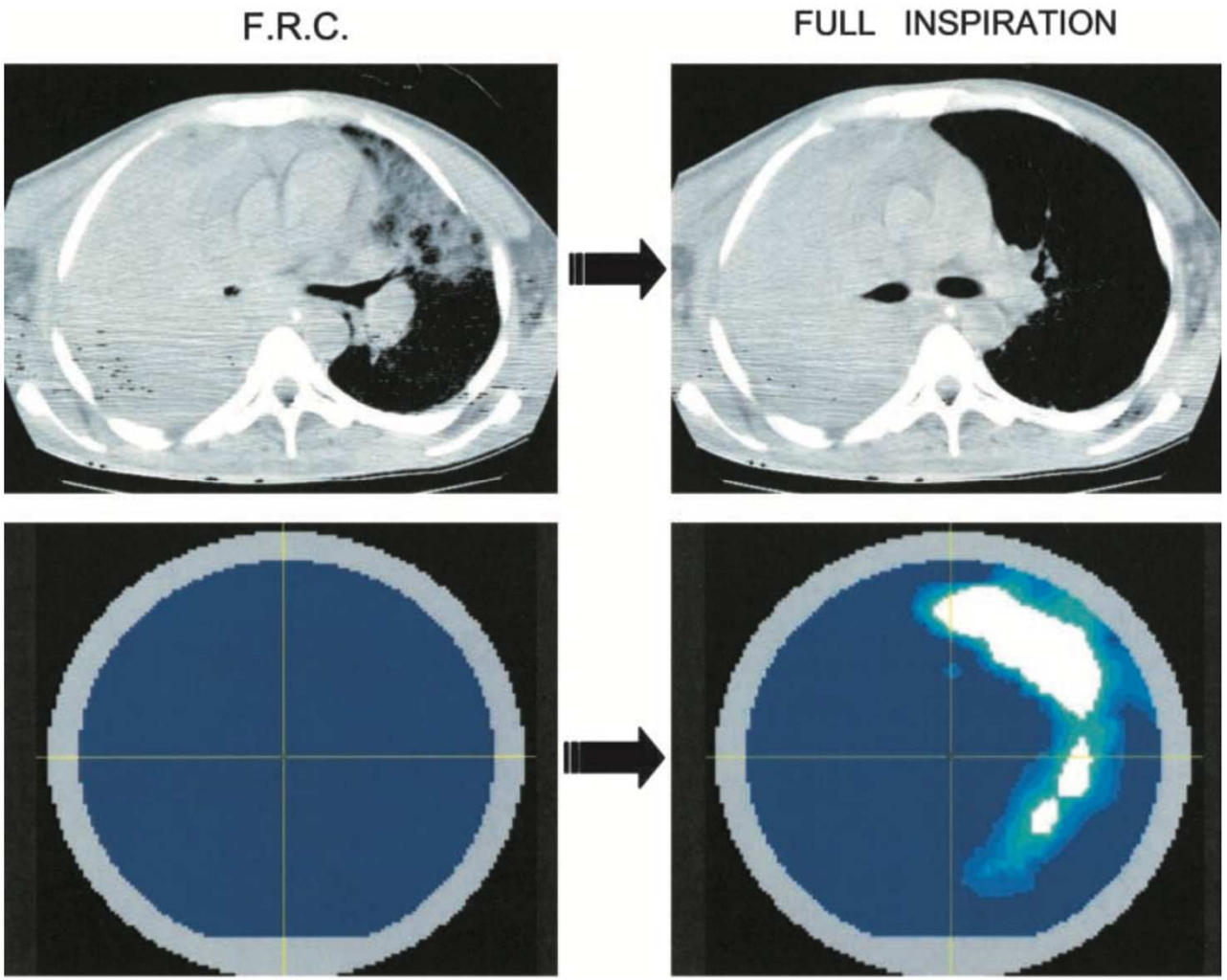


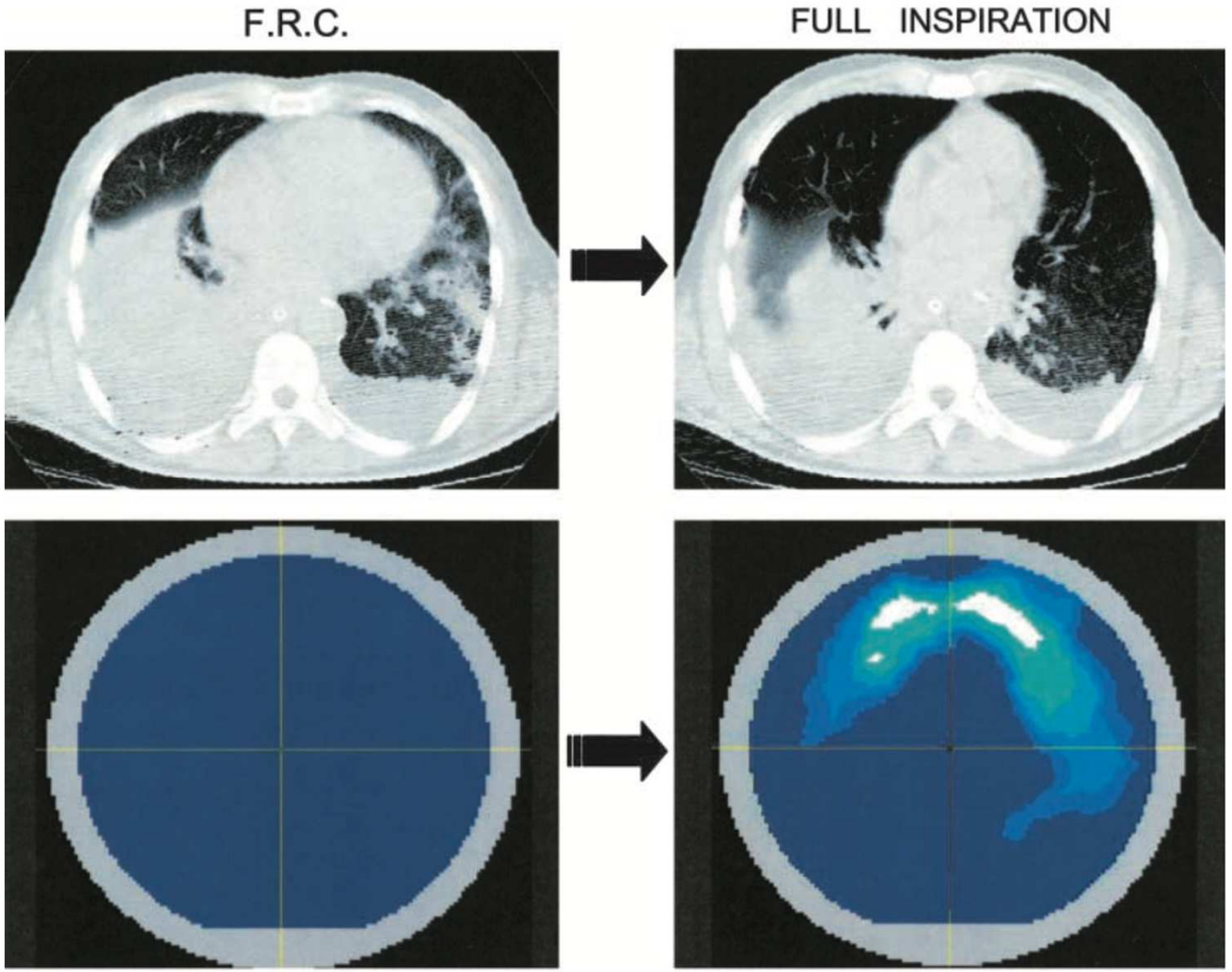
CT

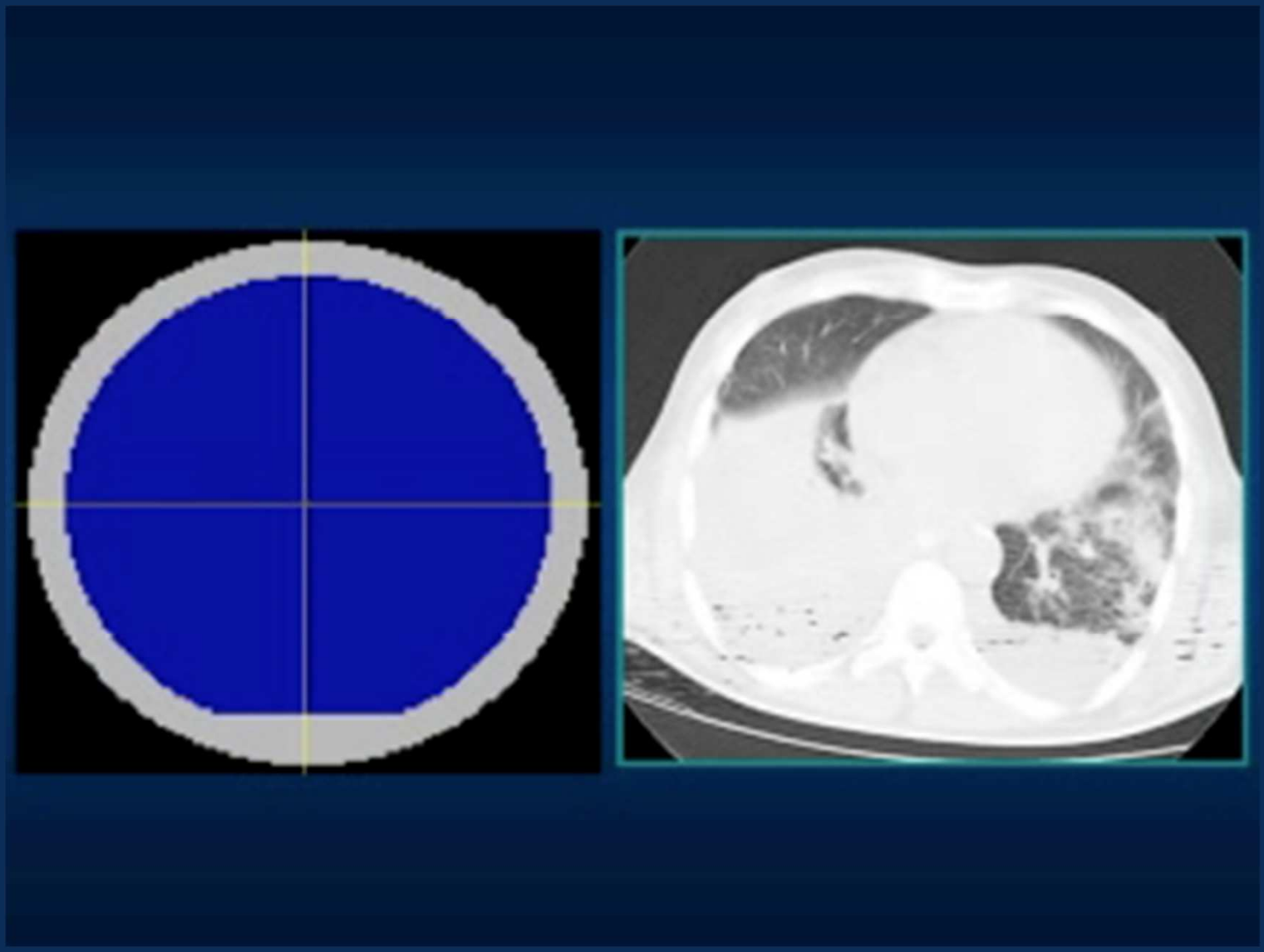


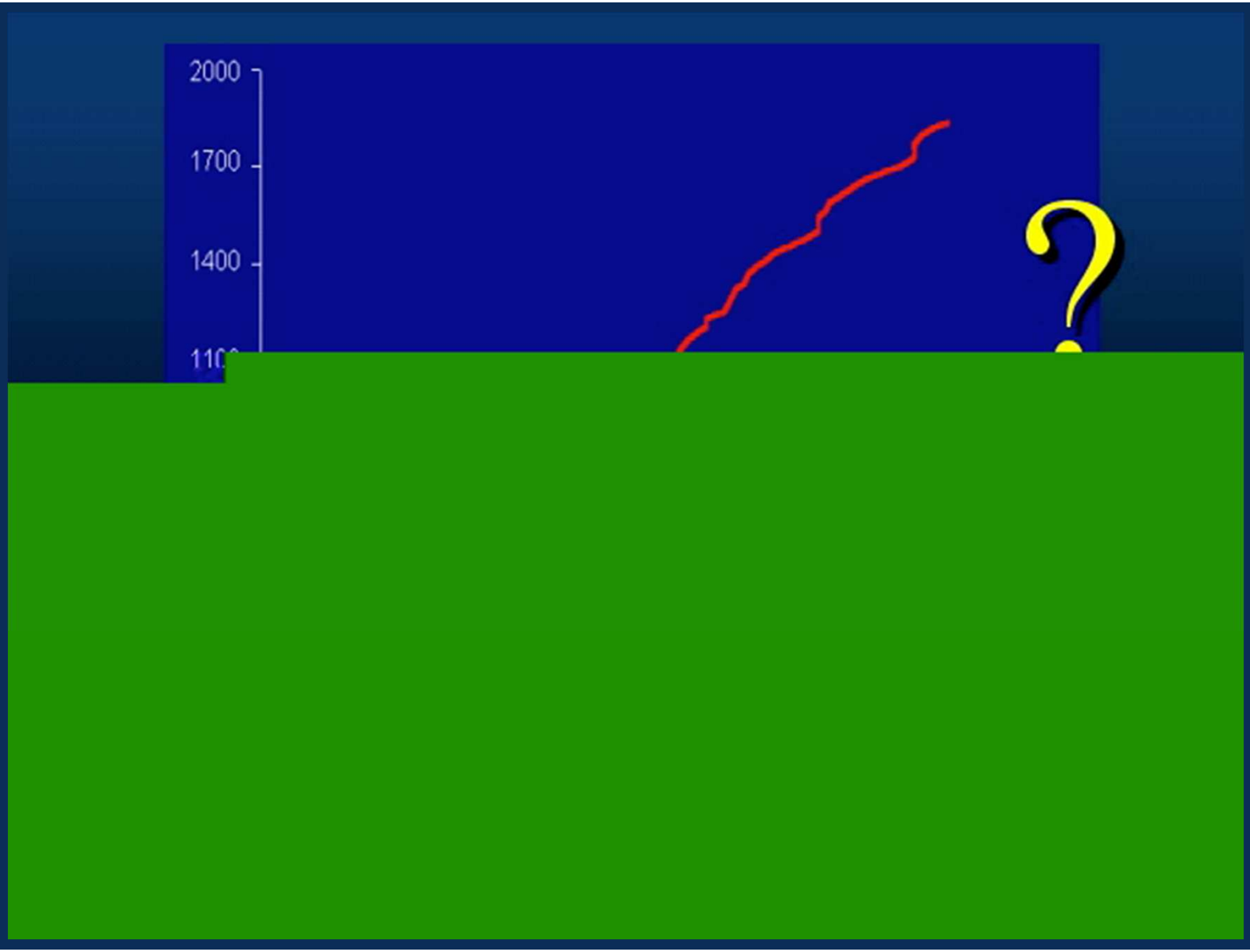
EIT

Sheffield EIT system (16 channels)

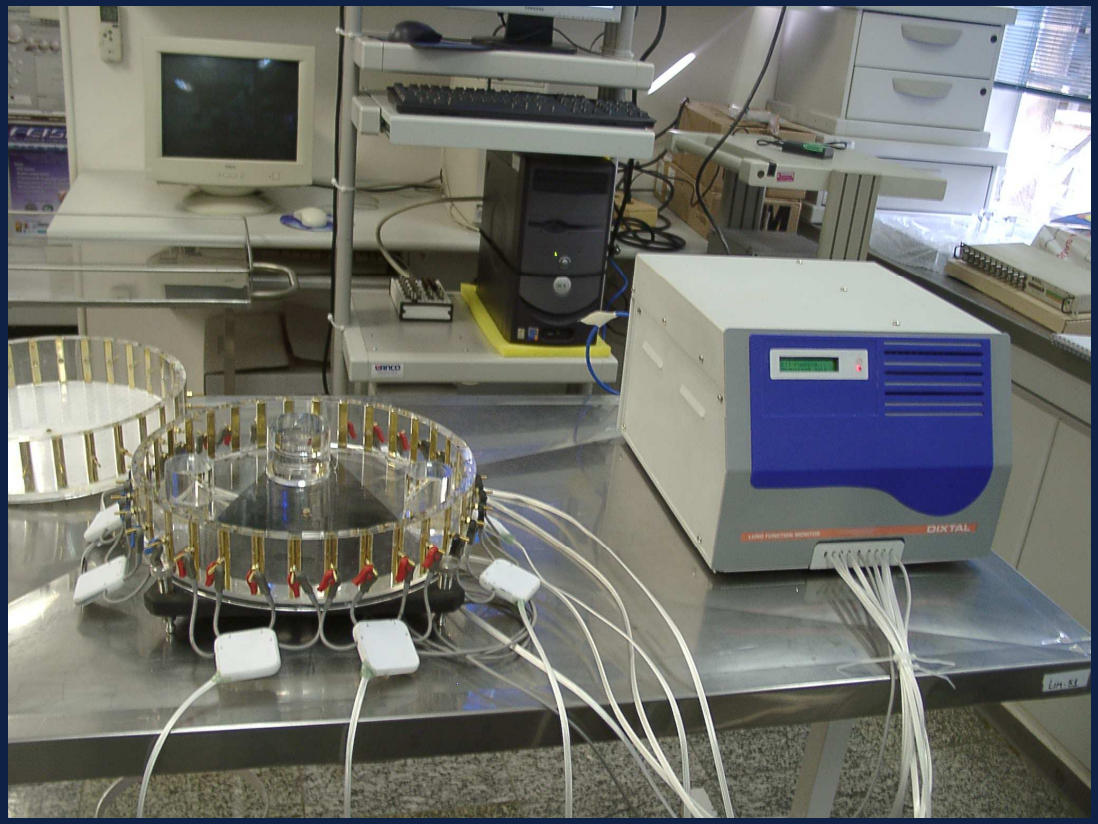

F.R.C.
FULL INSPIRATION


F.R.C.
FULL INSPIRATION




2000
1700
1400
?

University of São Paulo - (Brazil)

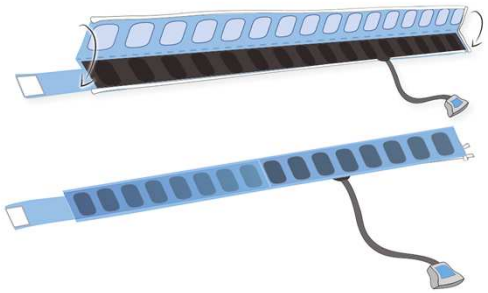


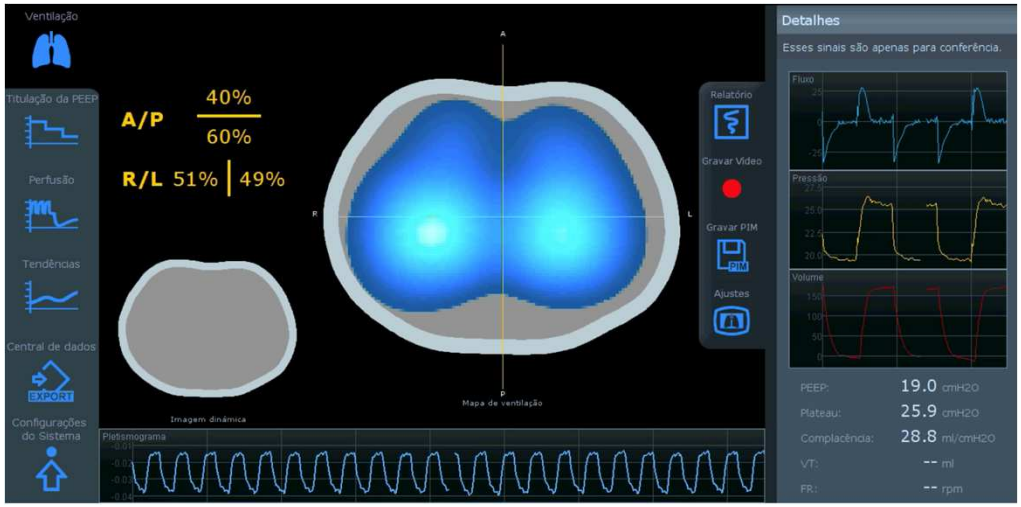
University of São Paulo - (Brazil)
Animal Facility/LIM09

Respiratory ICU / FMUSP, Brazil (2004)

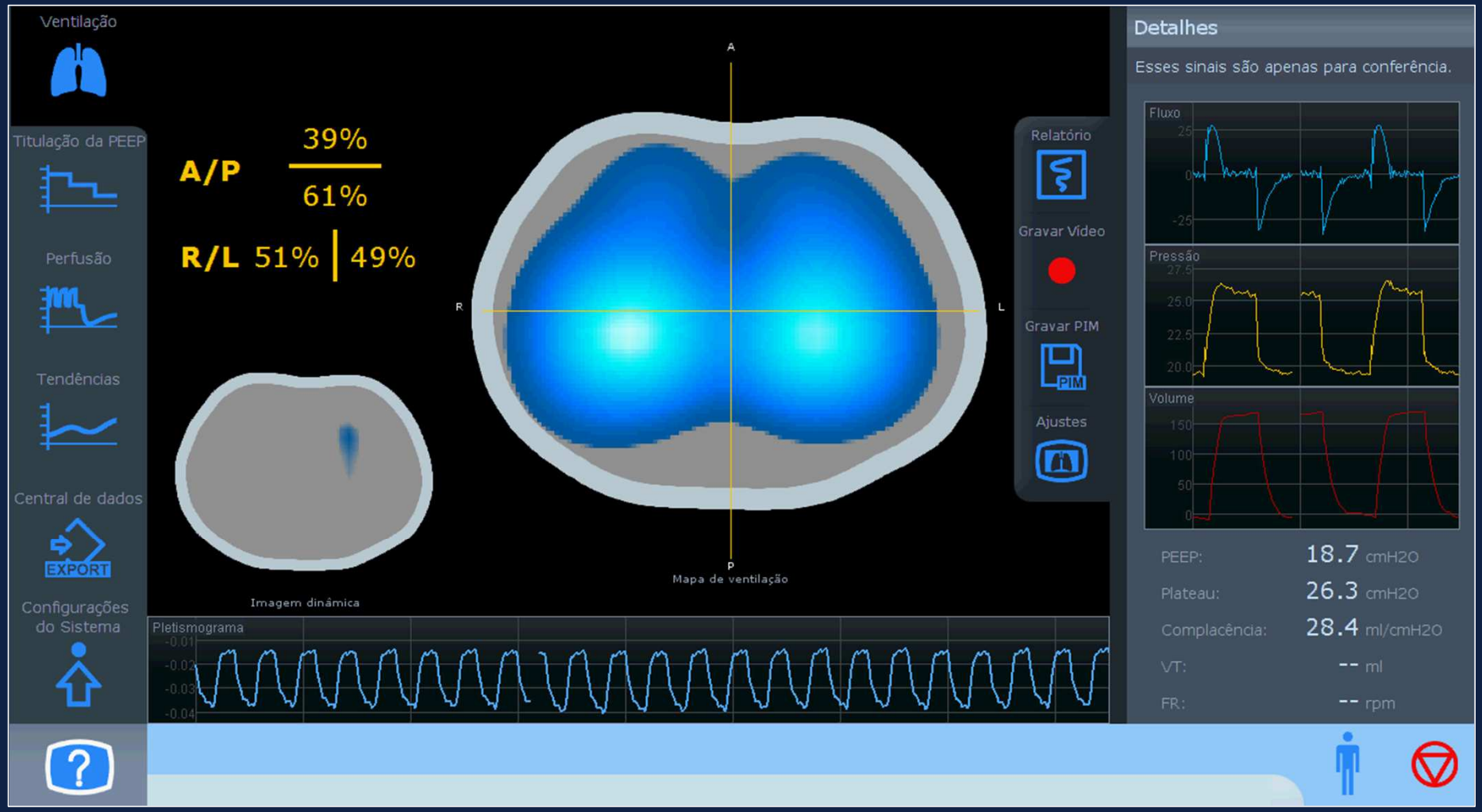
State of Technology

Enlight 2100
TIMPEL MEDICAL (32 electrodes)

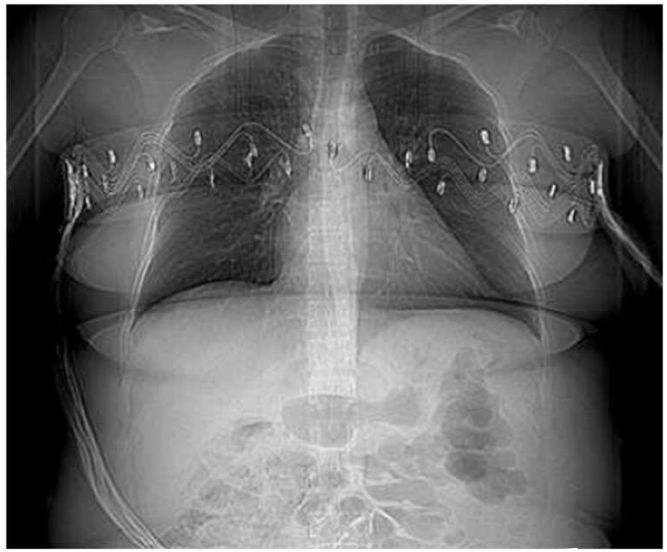


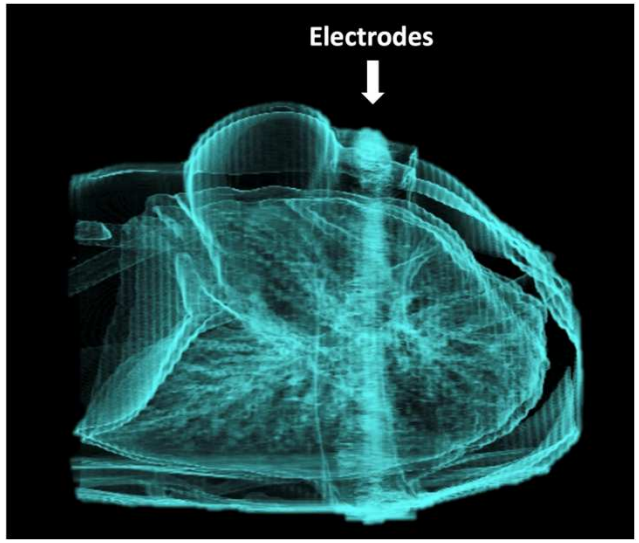


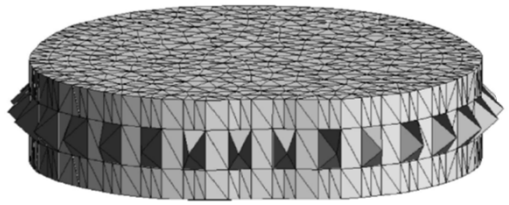
Enlight 2100 – TIMPEL MEDICAL



Validações da tomografia de impedância elétrica







15 cm

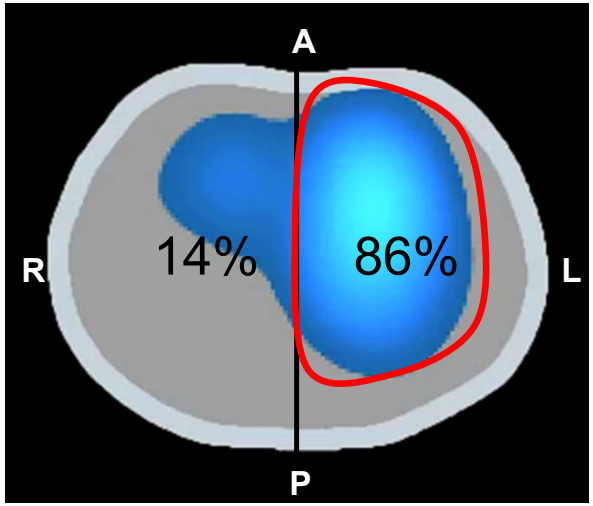
Rattes, C. PhD Thesis. 2018

Summary of validation studies

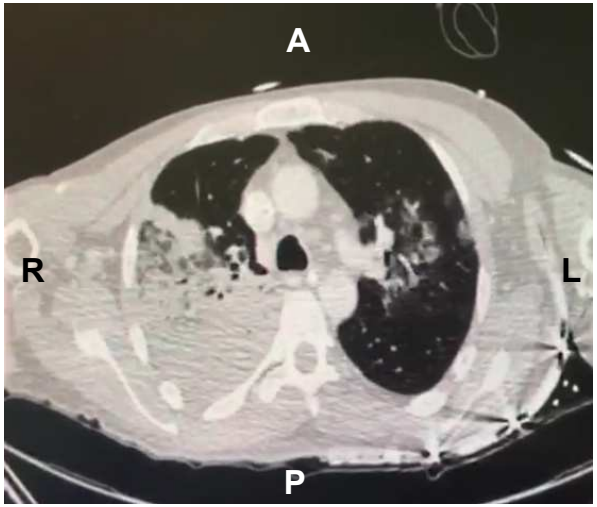
Bias and limmits of agreement

1. J Hinz, et al. 2004 (ROIs: 32 ventral-dorsal): Bias ≈ 0 %, ULA <2%, LLA < -2%
2. **J Victorino, et al. 2004** (ROIs: Anterior-Posterior, quadrants): **Bias = 0%, ULA = 10%, LLA = -10%.**
3. JC Richard, et al. 2009 (ROIs: Anterior-Posterior): Bias = 0.4 ml, ULA = 29.08 mL, LLA = -29.1ml.
4. G Elke, et al. 2013 (ROIs: 32 ventral-dorsal): Bias = 0.06% %, ULA = 2.2% mL, LLA = -2%
5. B Hentze, et al. 2018 (ROIs: 32 ventral-dorsal): Bias = 0 %, ULA = 1.4 %, LLA = -1.4%
6. **C Rattes, et al. 2018** (ROIs: Anterior-Posterior): **Bias = 0.8%, ULA = 10.9%, LLA = -9.2%.**
7. SD Reinartz, et al. 2019 (ROIs: UR, UL, LR, LL): Bias ≈0 %, ULA ≈7%, LLA ≈-7%.

EIT image

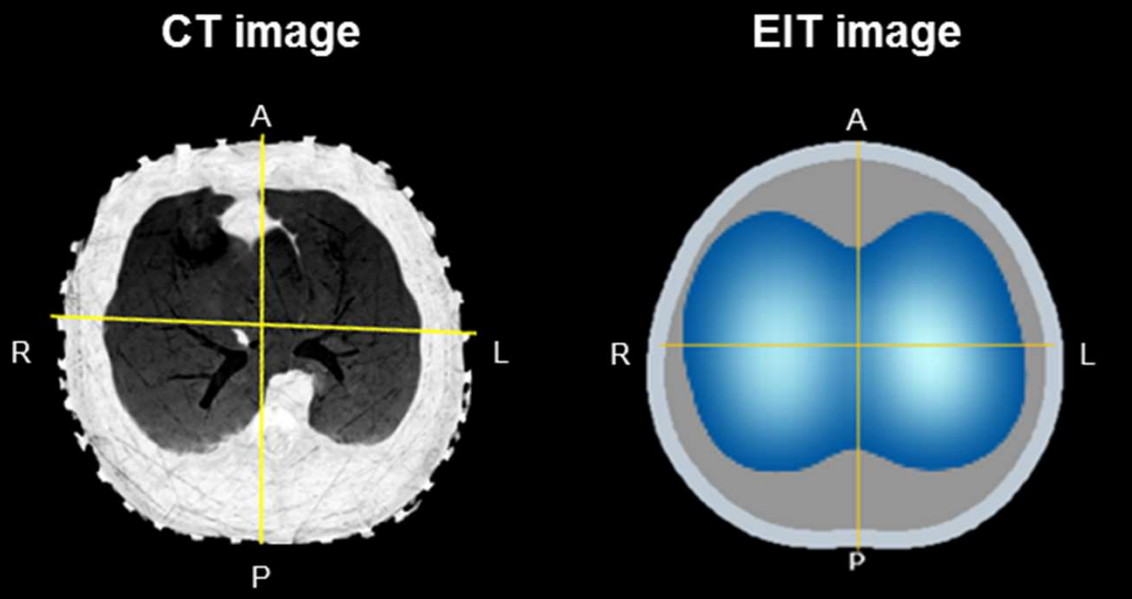


CT image



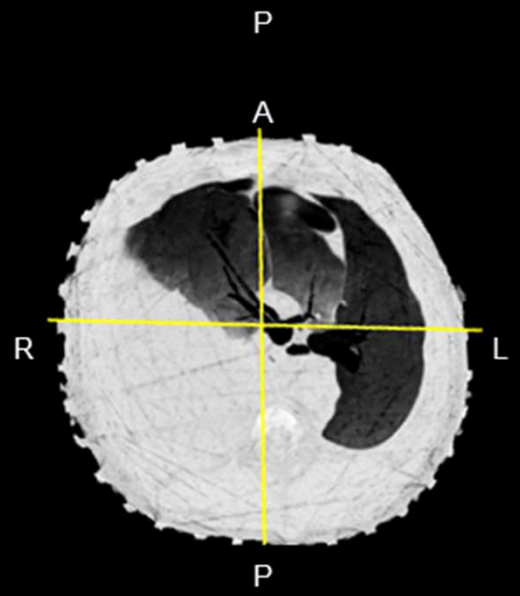
C Bachmann, C Morais, et al. *et al.* Crit Care 2018.

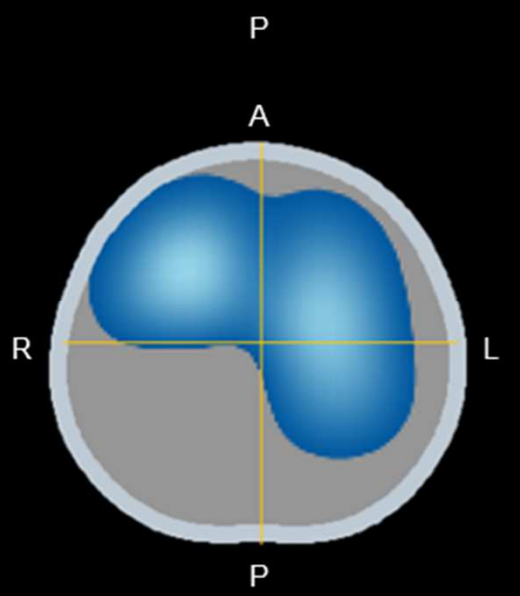
Bilateral ventilation



Functional lung size = 100%

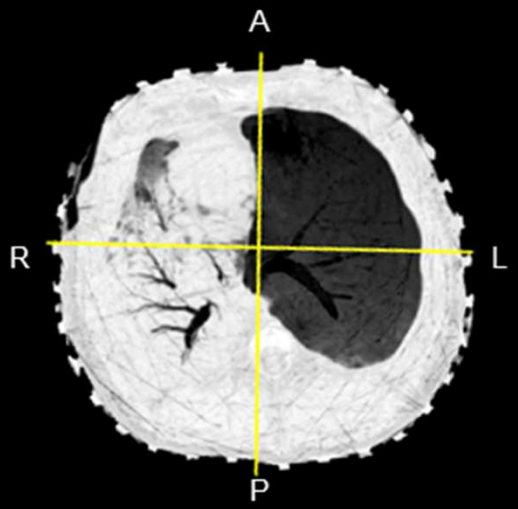
Pleural effusion
(Lower Right)

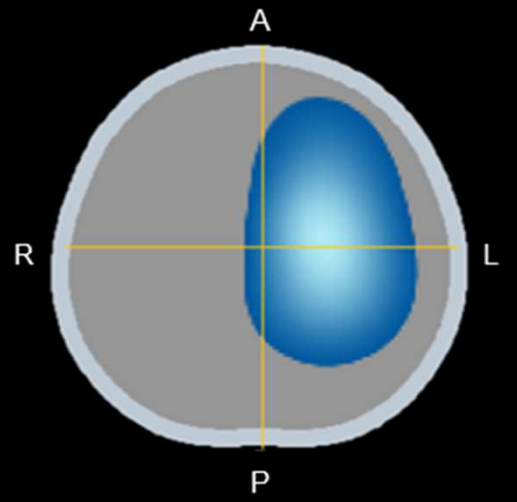




Functional lung size = 75%

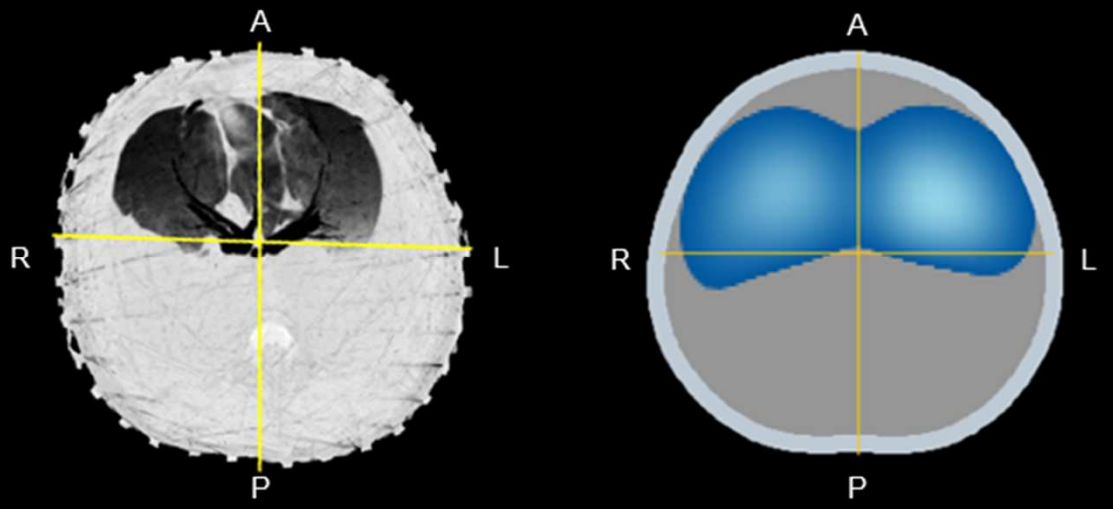
Selective intubation
(Left Main Bronchus)





Functional lung size = 50%

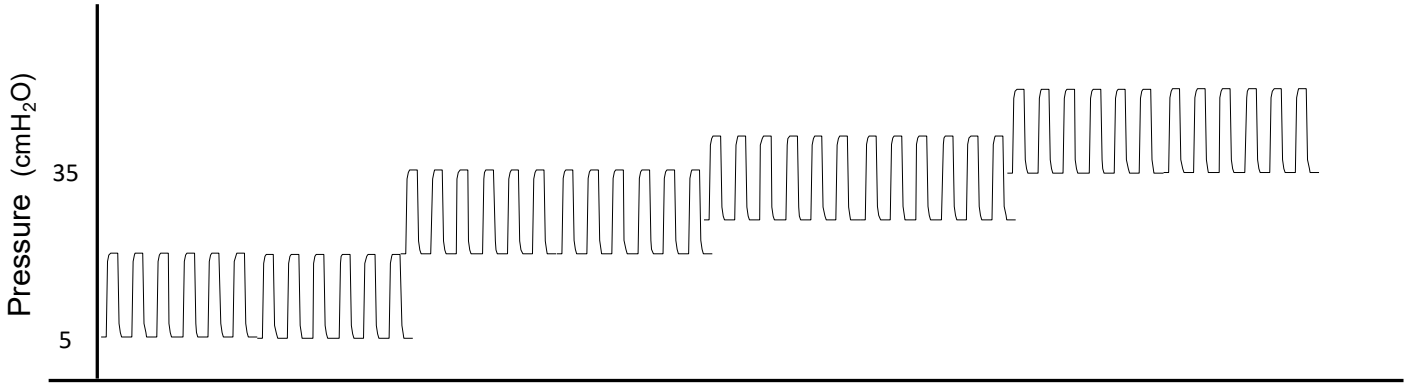
Bilateral pleural Effusion (Supine)

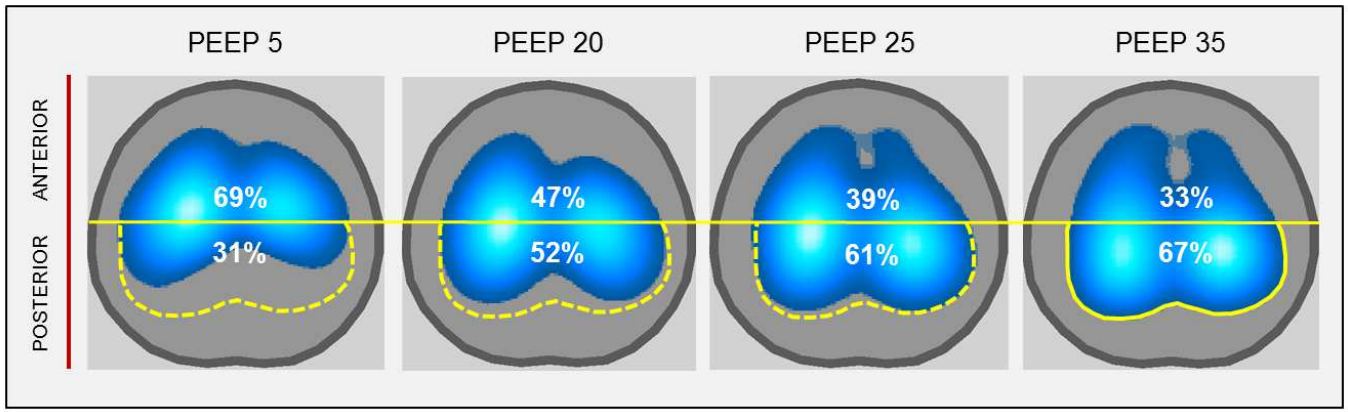


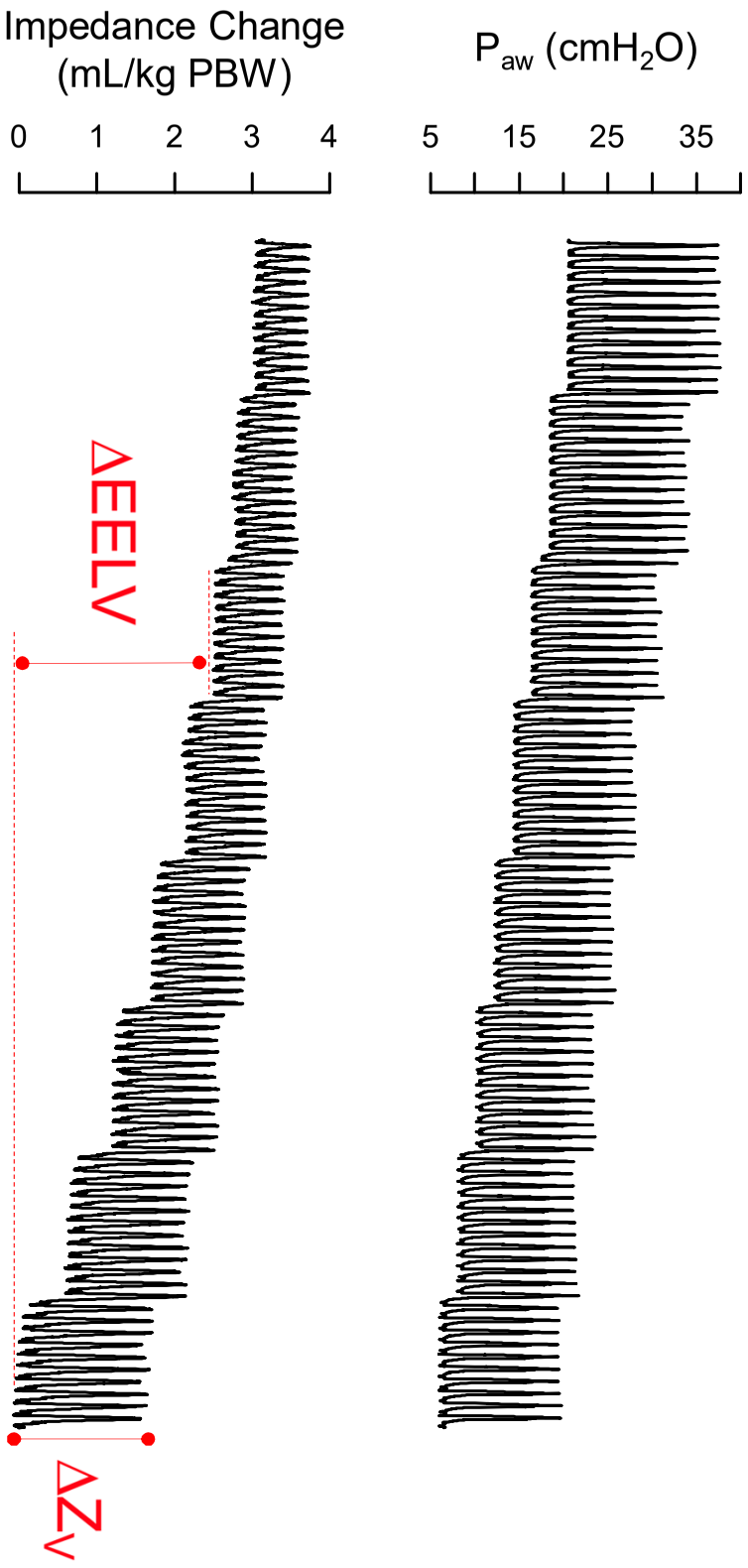
Functional lung size = 50%

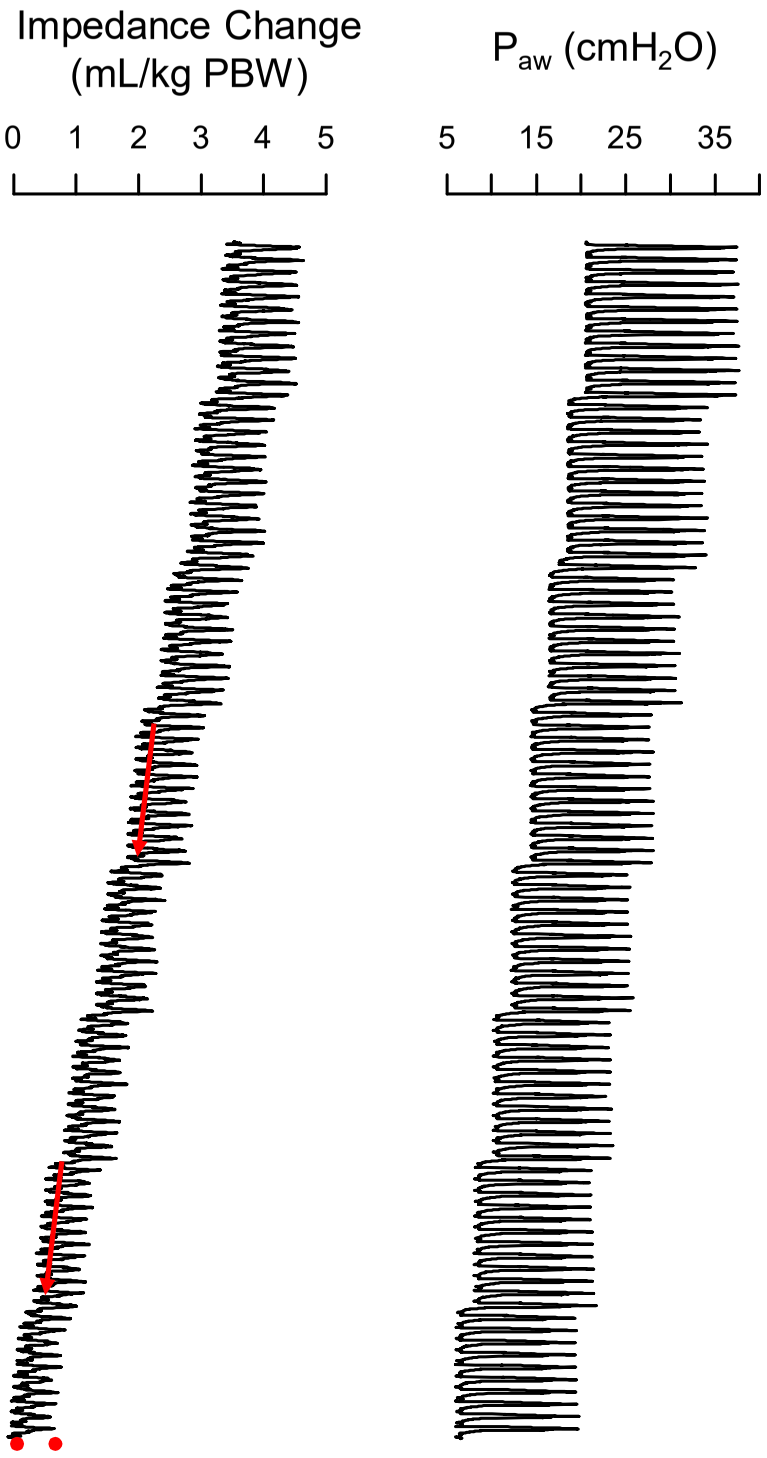
Examples of clinical use of ventilation image and plethysmogram

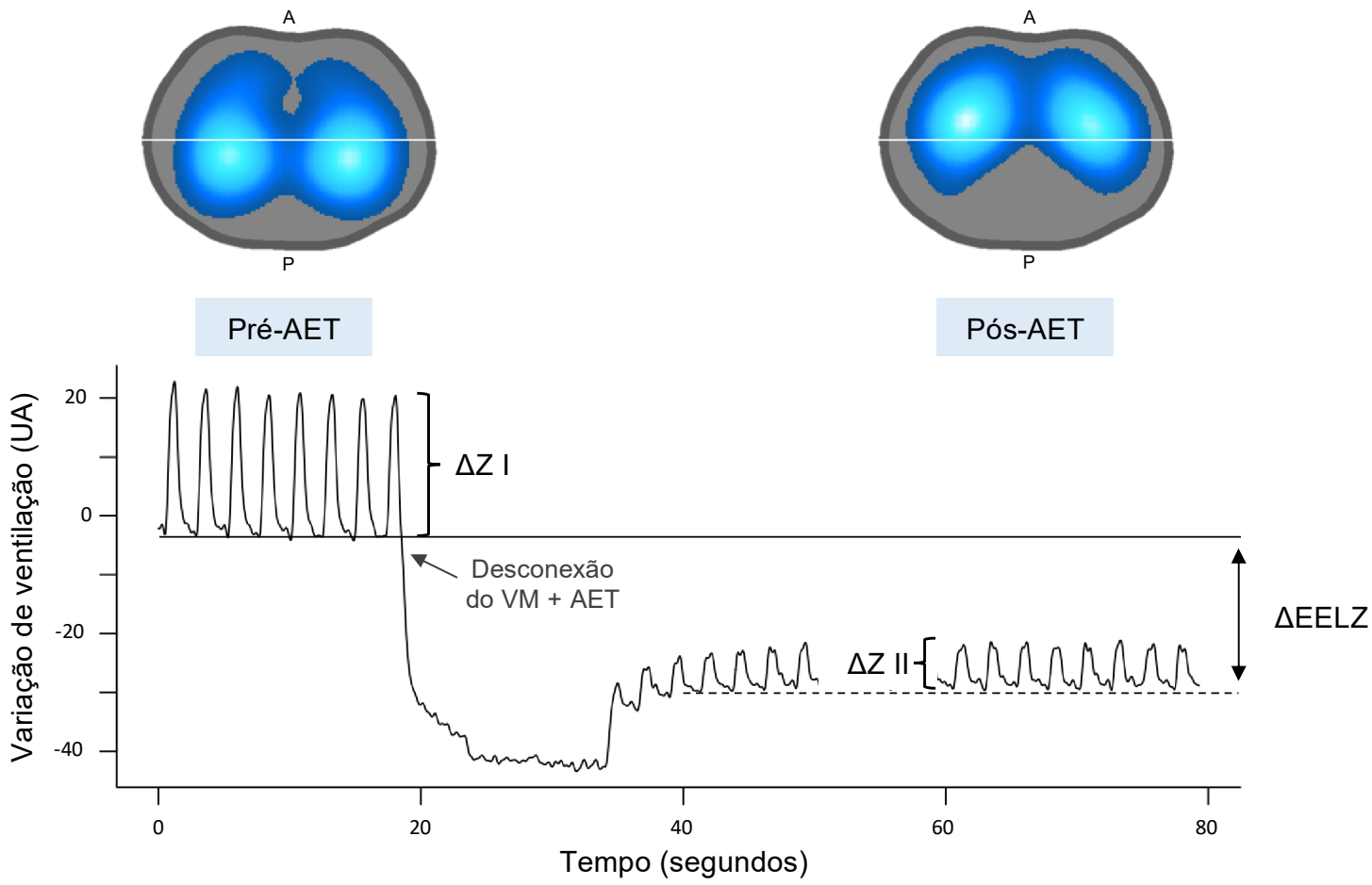
Ventilation Distribution During PEEP Trial





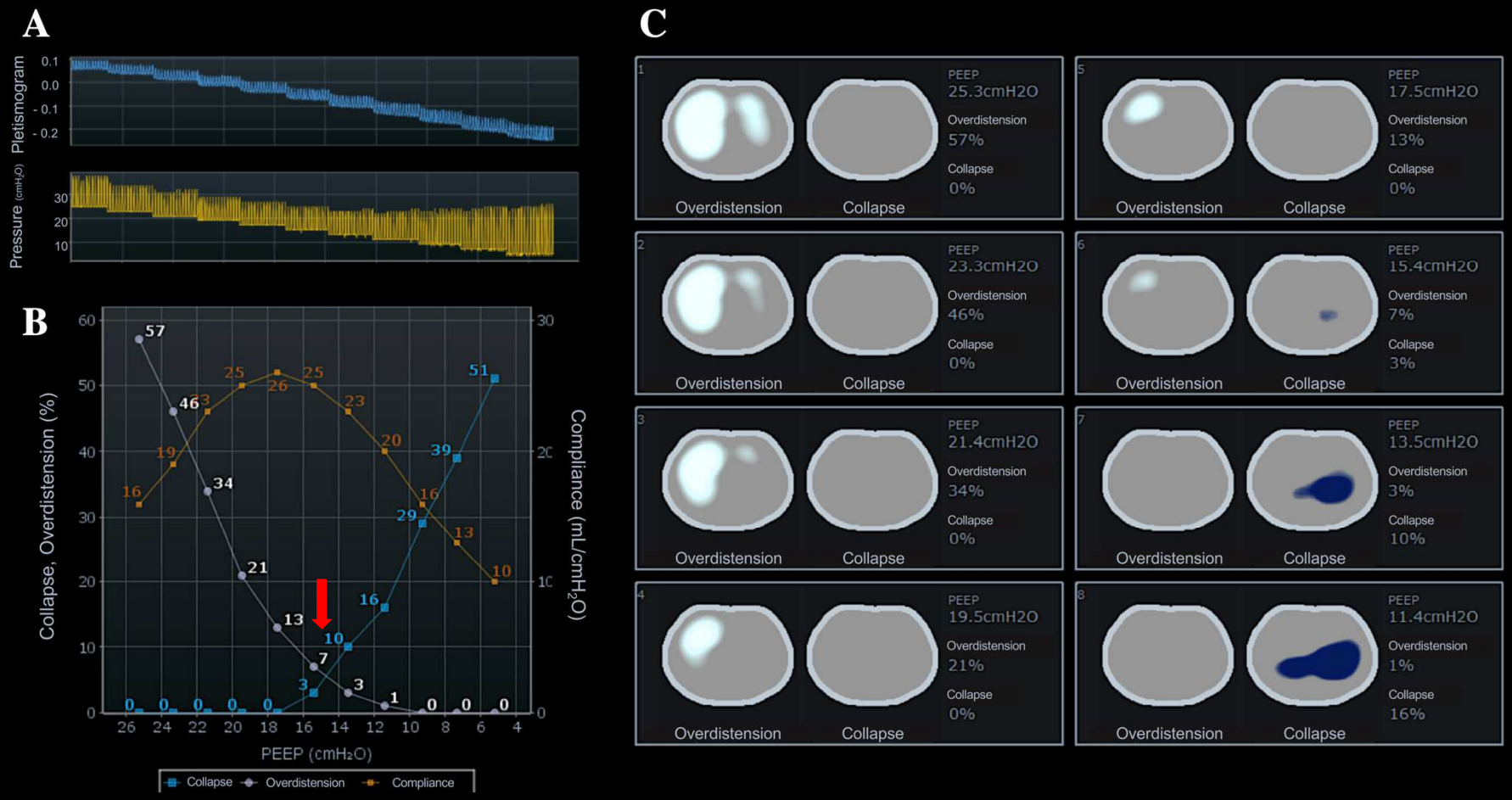

Impedance Change
(mL/kg PBW)
0
1
2
3
4
P_{aw} (cmH_2O)
5
15
25
35
ΔEELV
ΔZv


Impedance Change
(mL/kg PBW)
0 1 2 3 4 5
P_{aw} (cmH_2O)
5 15 25 35


A
P
A
P
Pré-AET
Pós-AET
Variação de ventilação (UA)
20
0
-20
-40
ΔZ I
Desconexão
do VM + AET
ΔZ II
ΔEELZ
0
20
40
60
80
Tempo (segundos)

Estimation of lung collapse and overdistension

PEEP Titration Guided by EIT

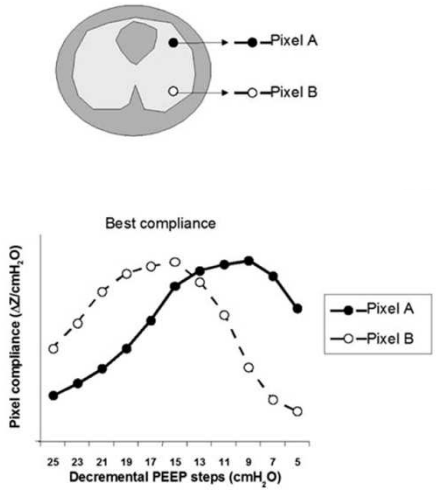


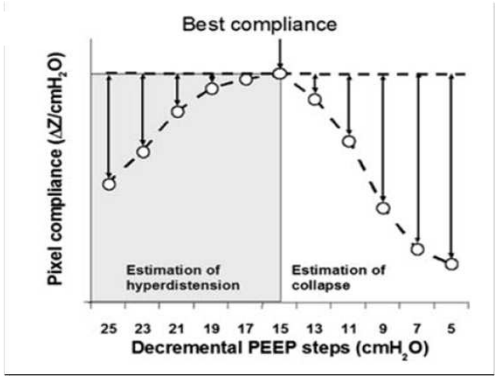
Intensive Care Med (2009) 35:1132–1137
DOI 10.1007/s00134-009-1447-y

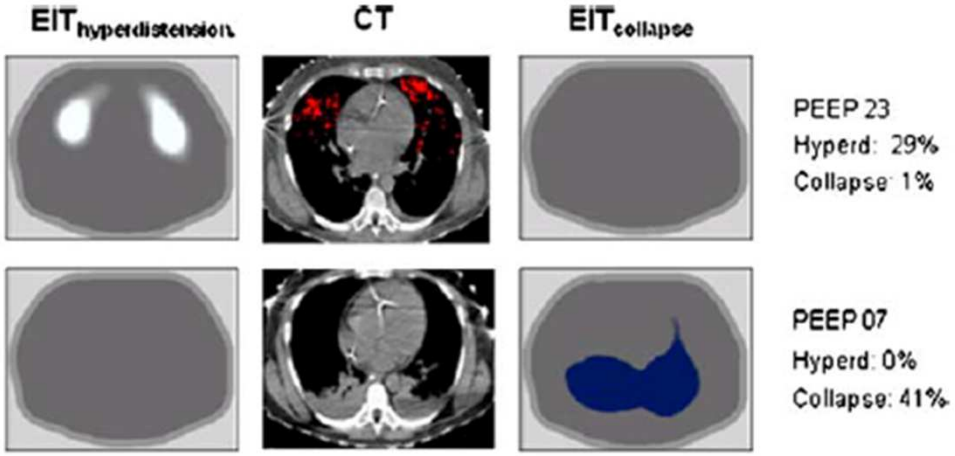
PHYSIOLOGICAL AND TECHNICAL NOTES

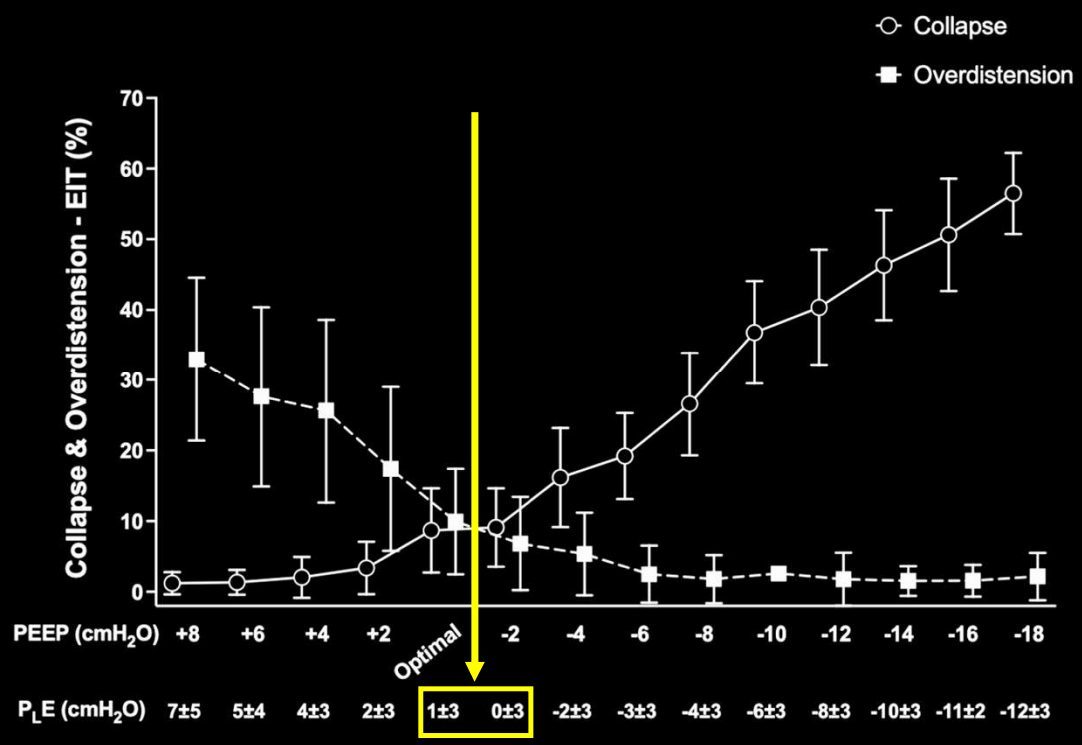
Eduardo L. V. Costa
João Batista Borges
Alexandre Melo
Fernando Suarez-Sipmann
Carlos Toufen Jr
Stephan H. Bohm
Marcelo B. P. Amato

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









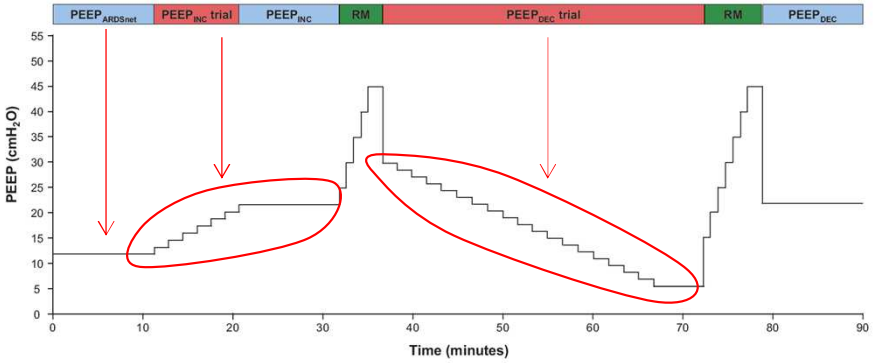
ANESTHESIOLOGY 2019; 130:791–803

ANESTHESIOLOGY

Lung Recruitment in Obese Patients with Acute Respiratory Distress Syndrome

Jacopo Fumagalli, M.D., Roberta R. S. Santiago, M.D., Ph.D., Maddalena Teggia Droghi, M.D., Changsheng Zhang, M.D., Ph.D., Florian J. Fintelmann, M.D., Fabian M. Troschel, Cand. Med., Caio C. A. Morais, R.R.T., Ph.D., Marcelo B. P. Amato, M.D., Ph.D., Robert M. Kacmarek, R.R.T., Ph.D., Lorenzo Berra, M.D., on behalf of the Lung Rescue Team Investigators*

ANESTHESIOLOGY 2019; 130:791–803



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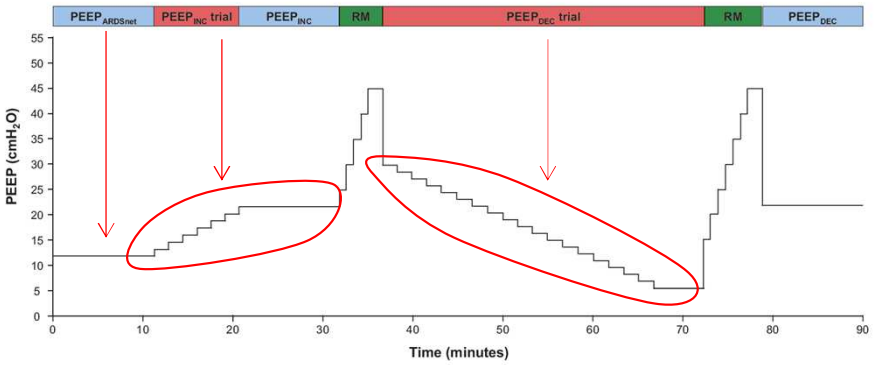
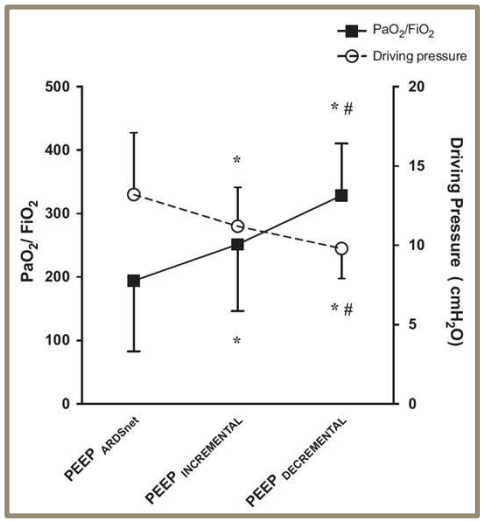
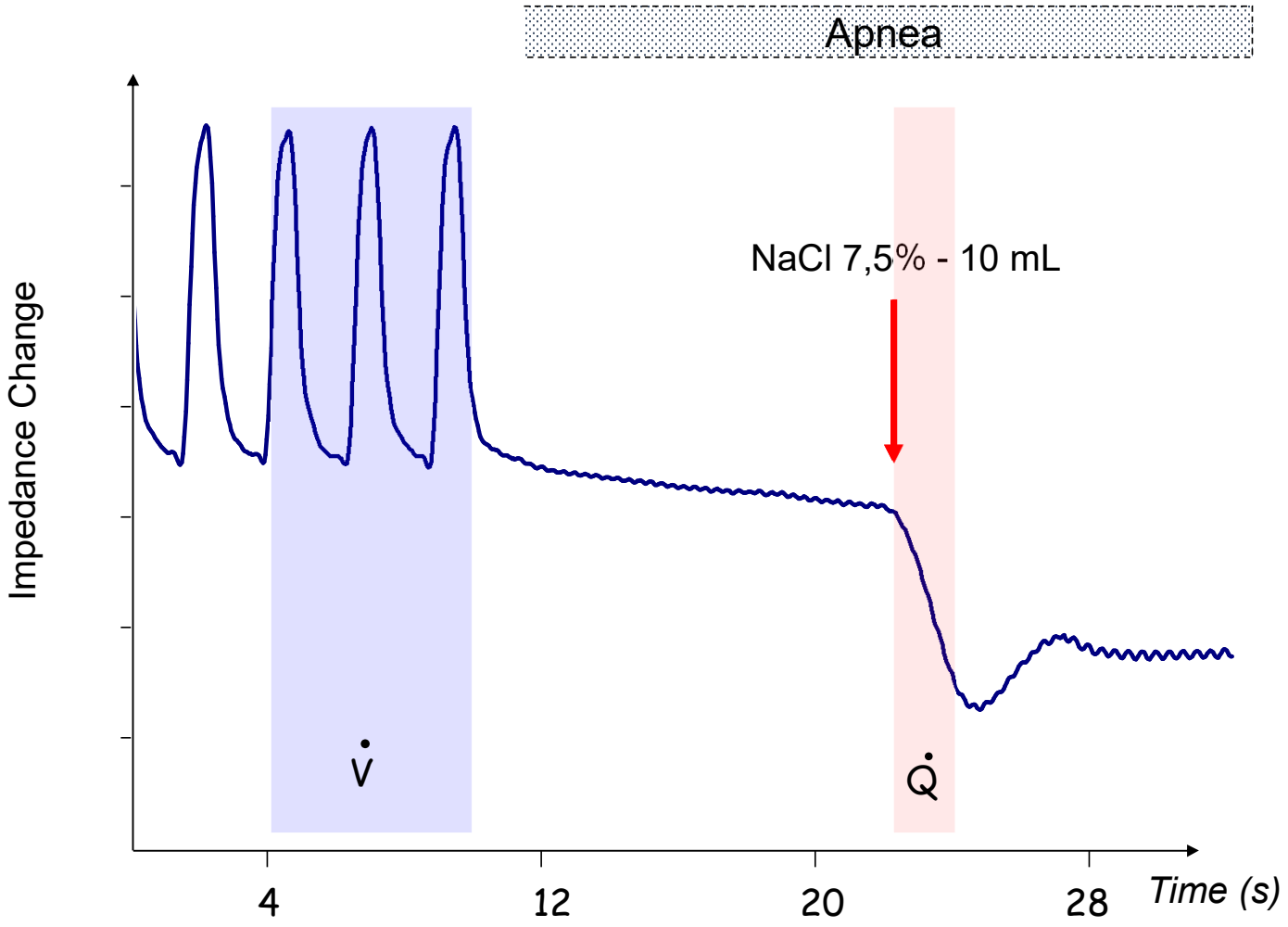


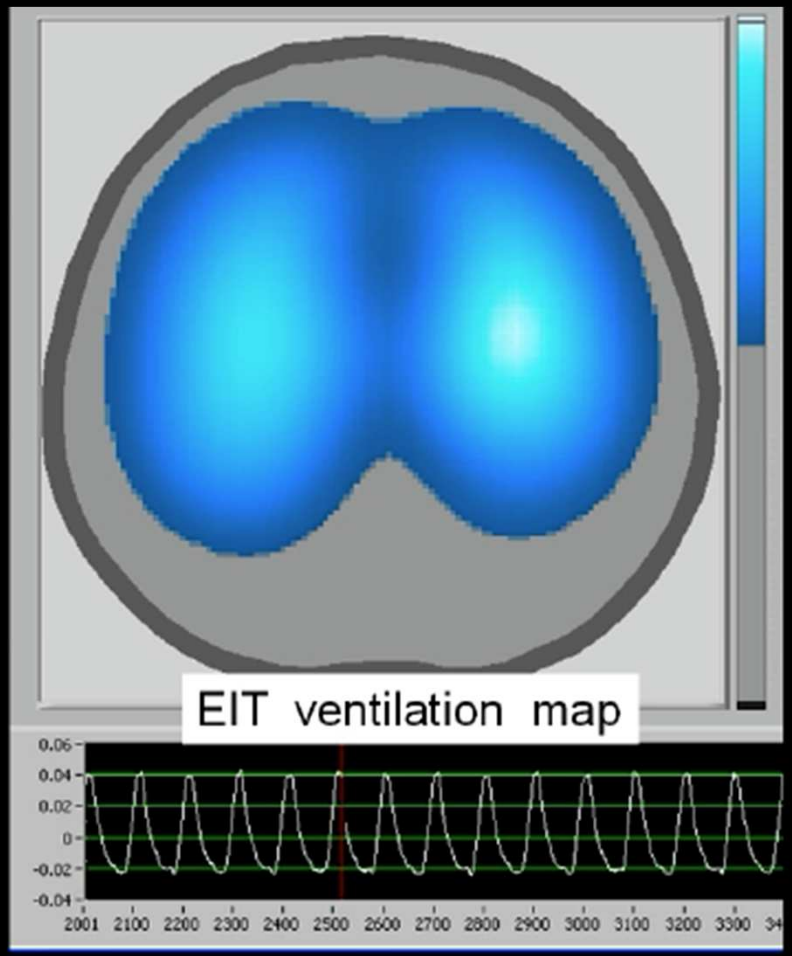
	PEEP ARDSnet	PEEP INCREMENTAL	PEEP DECREMENTAL
PEEP, cm H_2O	13 ± 1	22 ± 3*	21 ± 4*
P-plat, cm H_2O	26 ± 4	33 ± 4*	31 ± 4*
Driving pressure, cm H_2O	13 ± 4	11 ± 2*	10 ± 2*§
P_LE, cm H_2O	–5 ± 5	1 ± 4*	1 ± 4*



Regional lung perfusion estimated by EIT

EIT Perfusion – Basic Concept

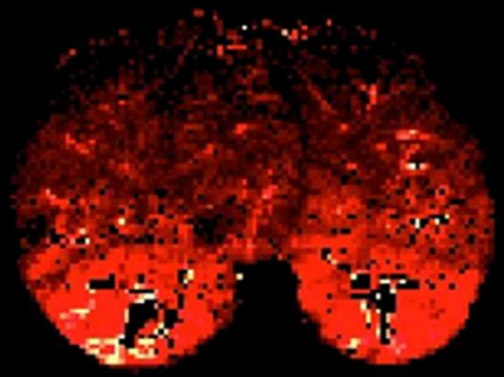



EIT ventilation map
0.06
0.04
0.02
0
-0.02
-0.04
2001 2100 2200 2300 2400 2500 2600 2700 2800 2900 3000 3100 3200 3300

Swan Ganz catheter deflated

Control

Perfusion- Dynamic CT



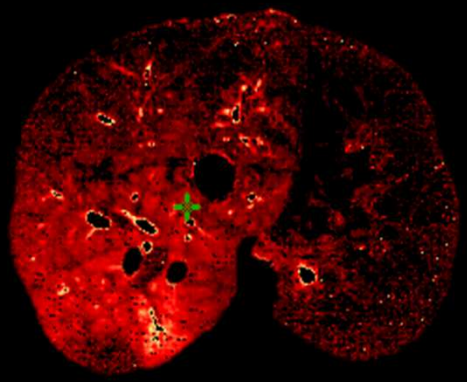
Perfusion EIT

BERALDO, MA. POSTDOCTORAL RESEARCH DATA
UNIVERSITY OF SAO PAULO, SCHOOL OF MEDICINE

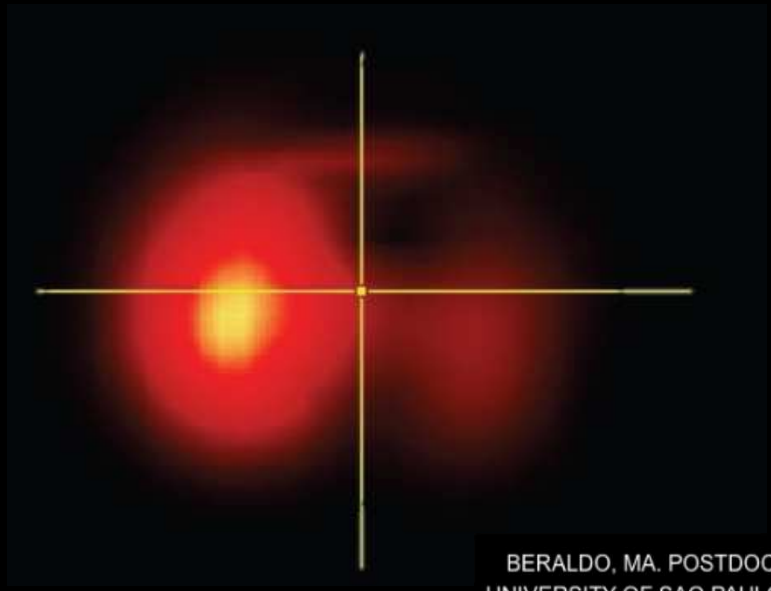
Swan Ganz catheter inflated at the left pulmonary artery

Inflated volume = 1.5 mL

Perfusion- Dynamic CT



Perfusion EIT



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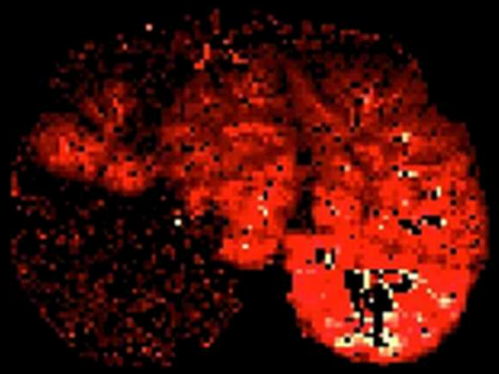
UNIVERSITY OF SAO PAULO, SCHOOL OF MEDICINE

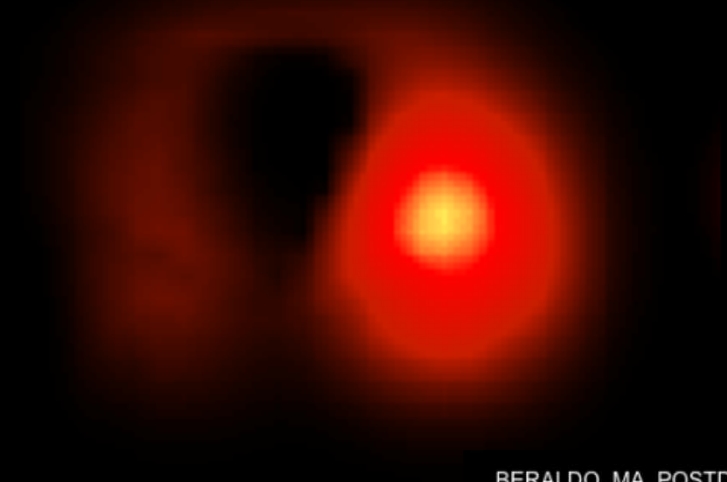
Swan Ganz catheter inflated at the right pulmonary artery

Inflated volume = 1.5 mL

Perfusion- Dynamic CT



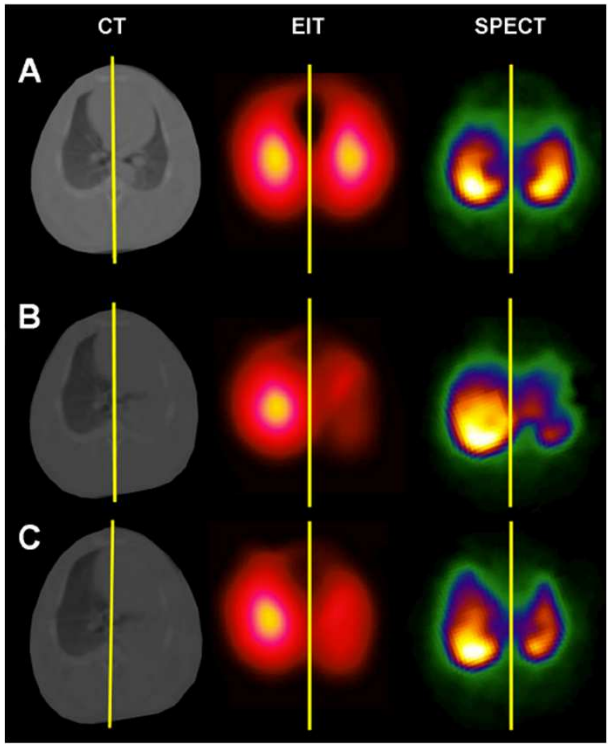
Perfusion EIT

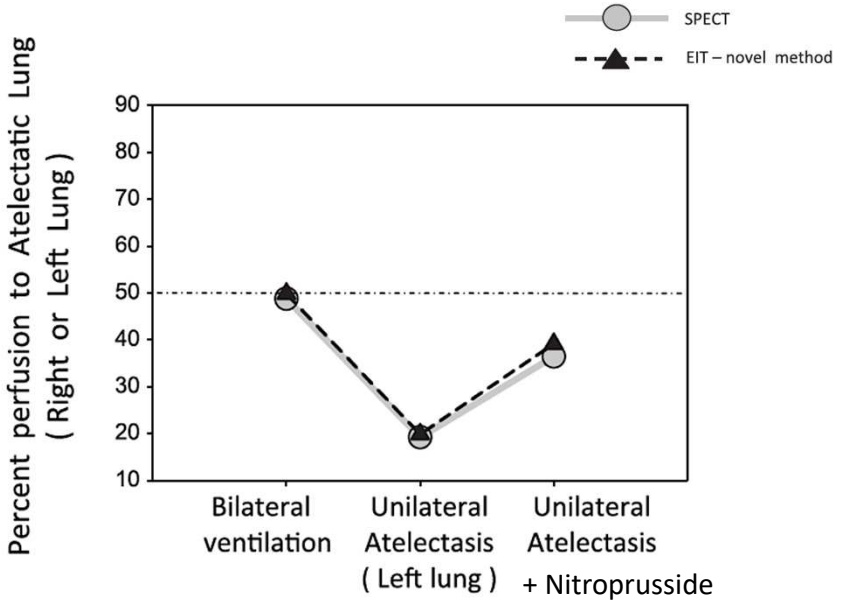


BERALDO, MA. POSTDOCTORAL RESEARCH DATA
UNIVERSITY OF SAO PAULO, SCHOOL OF MEDICINE

Regional lung perfusion estimated by electrical impedance tomography in a piglet model of lung collapse

João Batista Borges,[1,8] Fernando Suarez-Sipmann,[1,2] Stephan H. Bohm,[3] Gerardo Tusman,[4] Alexandre Melo,[5] Enn Maripuu,[6] Mattias Sandström,[6] Marcelo Park,[7] Eduardo L. V. Costa,[8,9] Göran Hedenstierna,[10] and Marcelo Amato[8]





J Appl Physiol 112: 225–236, 2012.

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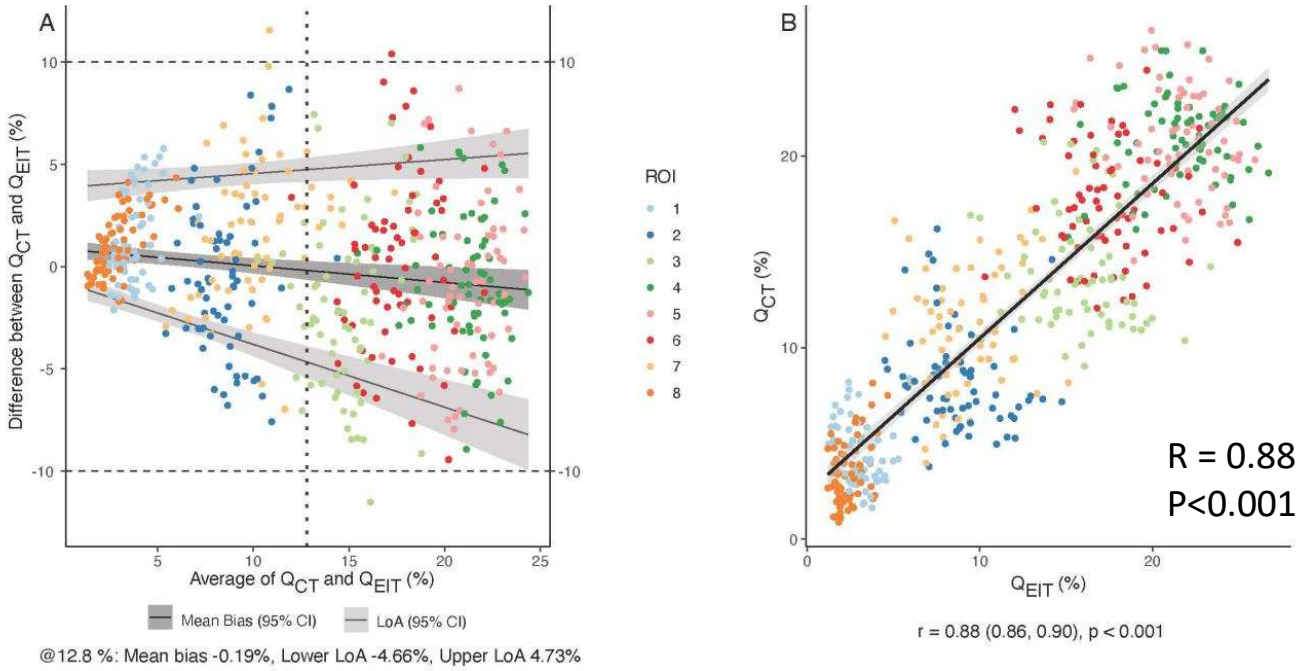
Critical Care Medicine | October 2023

Electrical Impedance Tomography Identifies Evolution of Regional Perfusion in a Porcine Model of Acute Respiratory Distress Syndrome

Kevin T. Martin, M.D.; Yi Xin, Ph.D.; Timothy G. Gaulton, M.D.; Marcus Victor, Ph.D.; Roberta R. Santiago, M.D., Ph.D.; Taehwan Kim; Caio C. A. Morais, Ph.D.; Aubrey A Kazimi, B.A.; Marc Connell, M.S.; Sarah E. Gerard, Ph.D.; ... Show more



Examples of clinical use combining ventilation and perfusion imaging

Clinical Case:

66-yr-old man with COVID-19 - related ARDS, with progressive deterioration in gas exchange (P/F ratio-day 6 = 120 mmHg)

- D-dimer > 10 000 ng ml^{-1}
- Echo: RVSP > 35 mmHg
- Dead space = 66%
- PEEP= 14 cmH_2O (ARDSnet table)
- FiO2 = 0.7

F_{iO2}	0.3	0.4	0.4	0.5	0.5	0.6	0.7	0.7	0.7	0.8	0.9	0.9	0.9	1.0	1.0	1.0	1.0
PEEP	5	5	8	8	10	10	10	12	14	14	14	16	18	18	20	22	24

Safaee Fakhr, et al. BJA 2020

Clinical Case:

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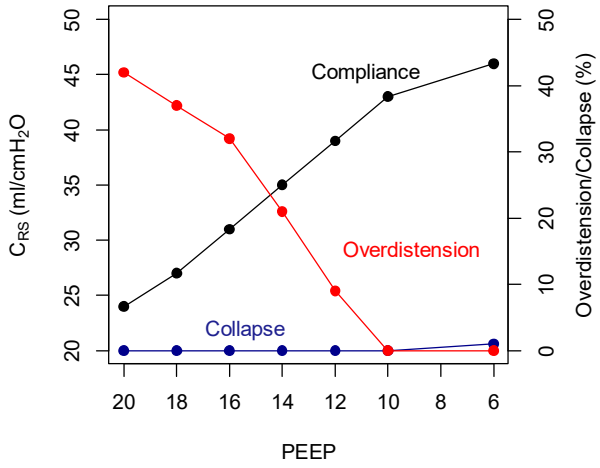
Decremental PEEP Trial



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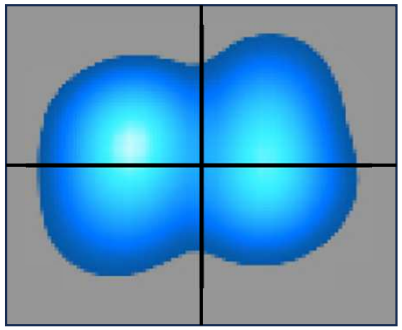
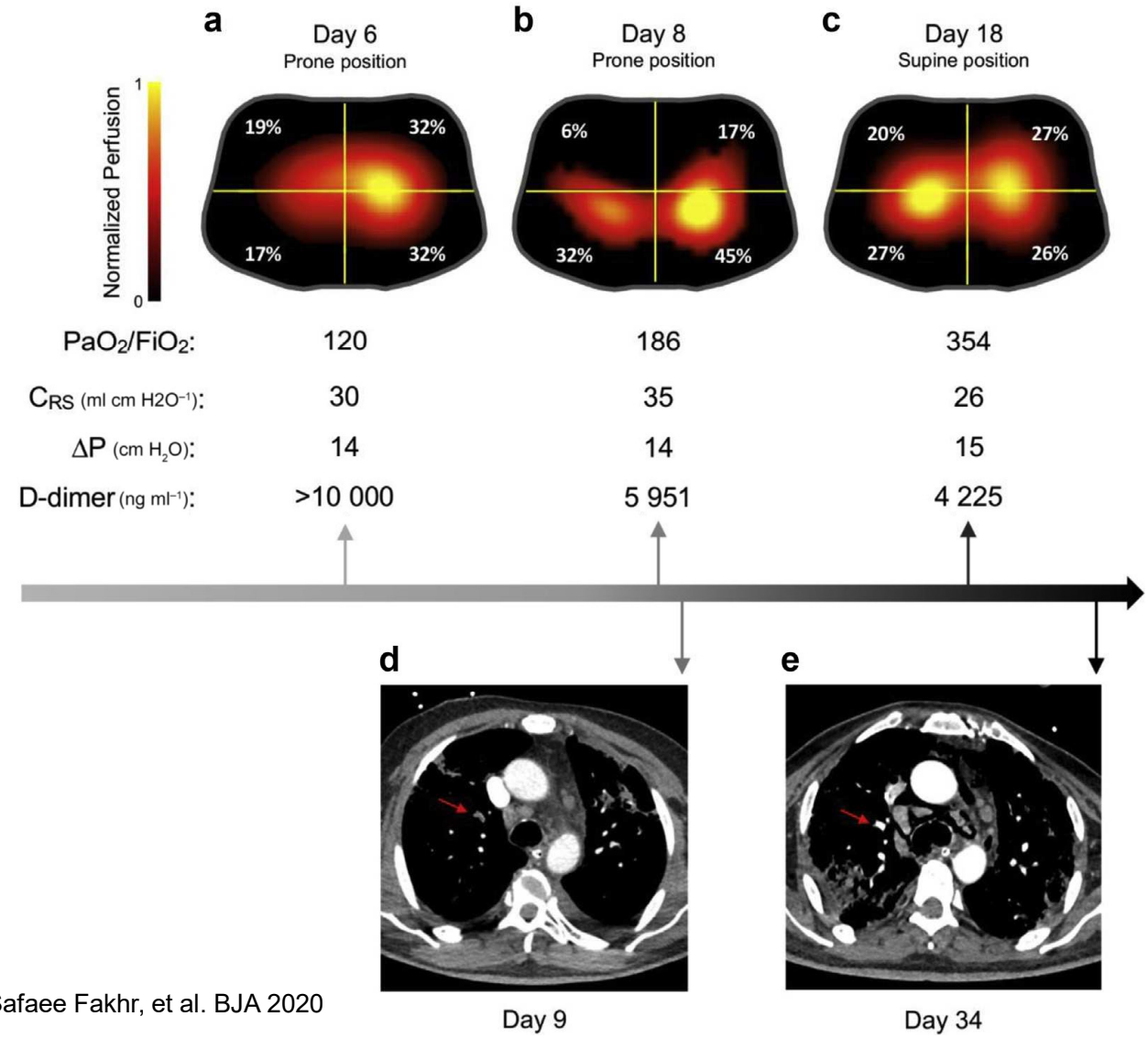
Ventilation Image





Safaee Fakhr, et al. BJA 2020

EIT - Take Home Points:

- EIT is a clinical tool for real-time monitoring of lung ventilation and perfusion distribution.

- EIT can help optimize mechanical ventilation settings to improve lung function.

Suggested reading:

Critical Care

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Electrical impedance tomography in acute respiratory distress syndrome

M Consuelo Bachmann, Caio Morais, Guillermo Bugedo, Alejandro Bruhn, Arturo Morales, João B Borges, Eduardo Costa & Jaime Retamal

Critical Care **22**, Article number: 263 (2018) | Cite this article

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Chest Electrical Impedance Tomography

Part 1: Principles and validation

Caio C. A. Morais, PT

MSc - Respiratory Physiotherapy (UFPE)

PhD - Pulmonology (University of São Paulo)

Postdoctoral fellowship at Massachusetts General Hospital/HMS