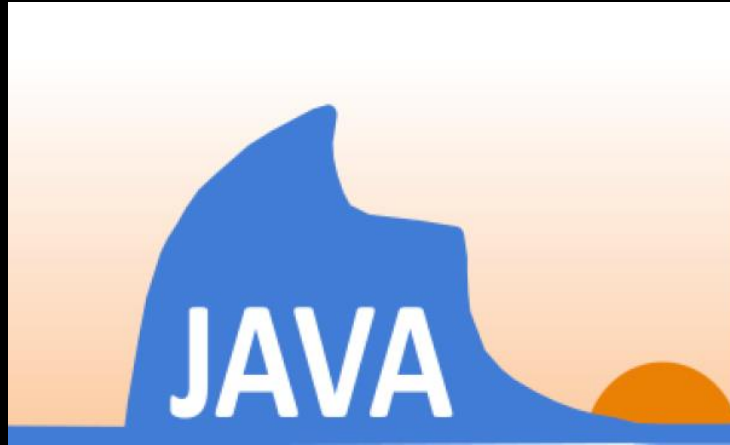




Monitorage de la ventilation par tomographie en impédance électrique (EIT)

Alain Mercat



Conflits d'intérêts

- Financement de travaux de recherche
 - Covidien (PAV+)
 - General Electric (CRF/SDRA)
 - Maquet (NAVA)
 - Fisher-Paykel (Optiflow)
- Brevet
 - General Electric (EELV/PEEP/recrutement)
- Exposés lors de congrès
 - Covidien
 - Alung technologies
- Activité d'expertise
 - Faron Pharmaceuticals
 - Air Liquide Medical Systems

Historique



LB Isborn. Auxerre To Day. December 1957

Impédance électrique ?

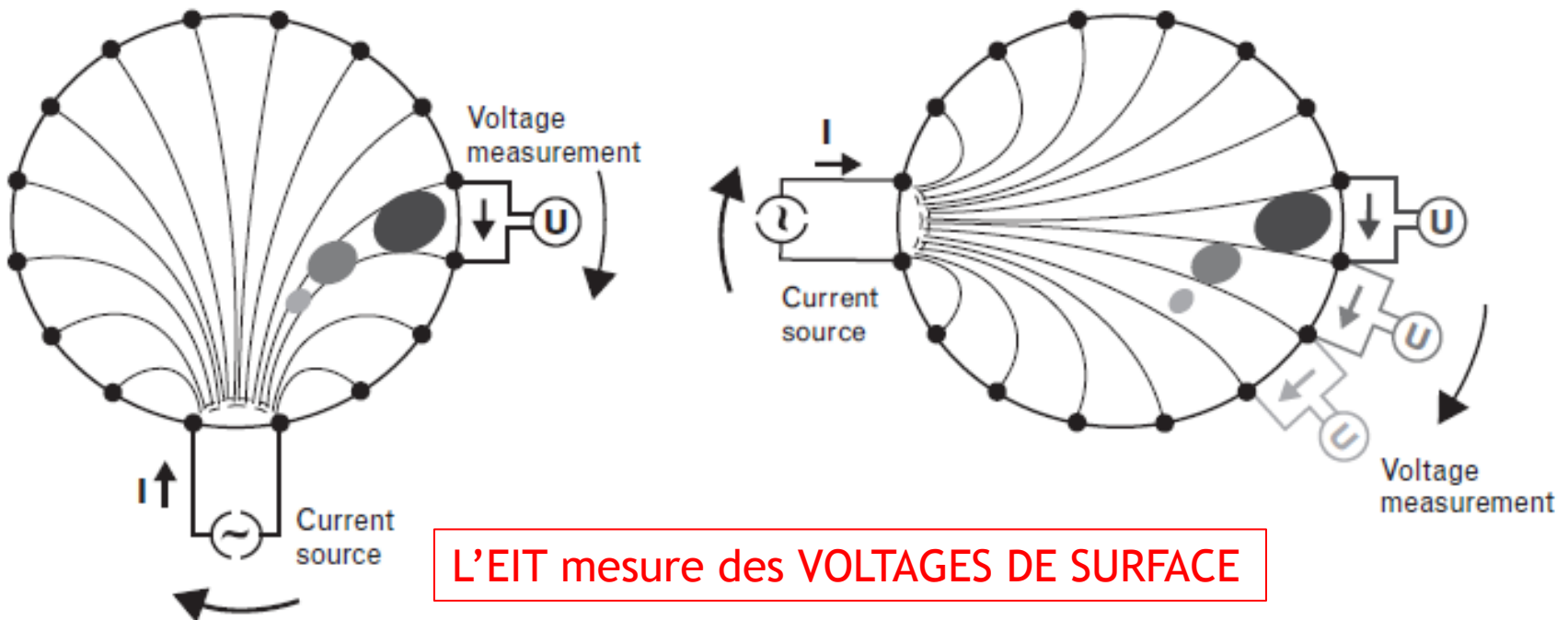
- L'impédance (Z) relie la résistivité d'un circuit électrique à l'intensité d'un courant alternatif qui le parcourt.
- Unité : Ohms (Ω)
- Dépend de la composition de l'objet analysé (résistivité)
- Variations dynamiques d'Impédance du thorax :
 - Ventilation
 - Perfusion pulmonaire

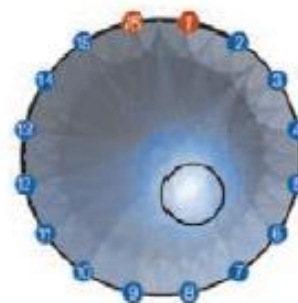
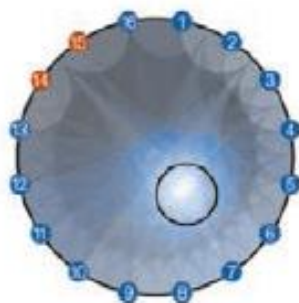
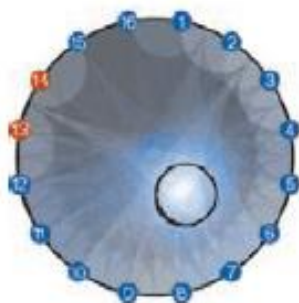
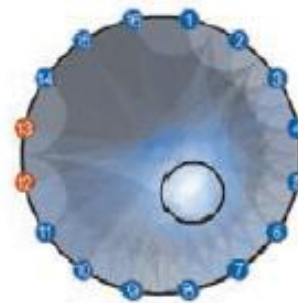
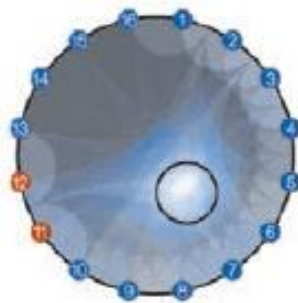
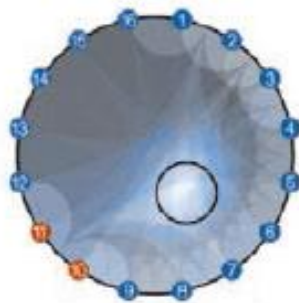
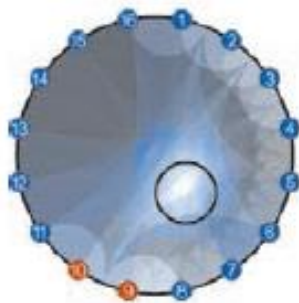
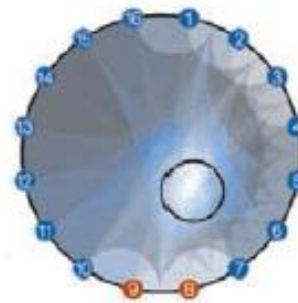
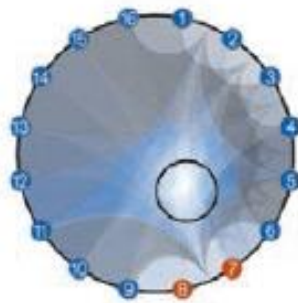
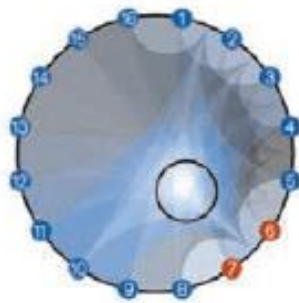
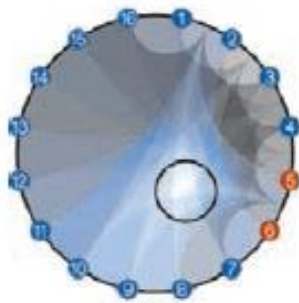
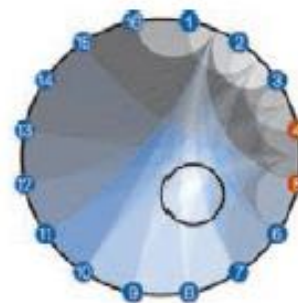
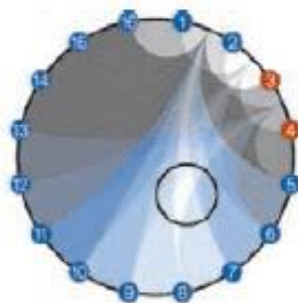
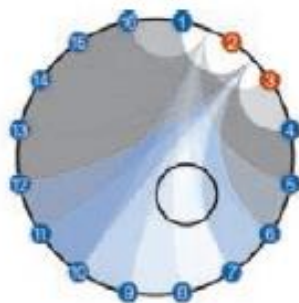
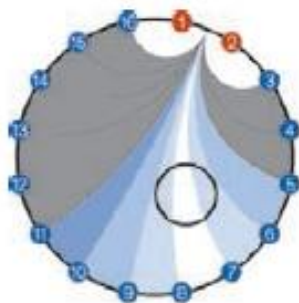
Table 1. Resistivity of different tissues (21)

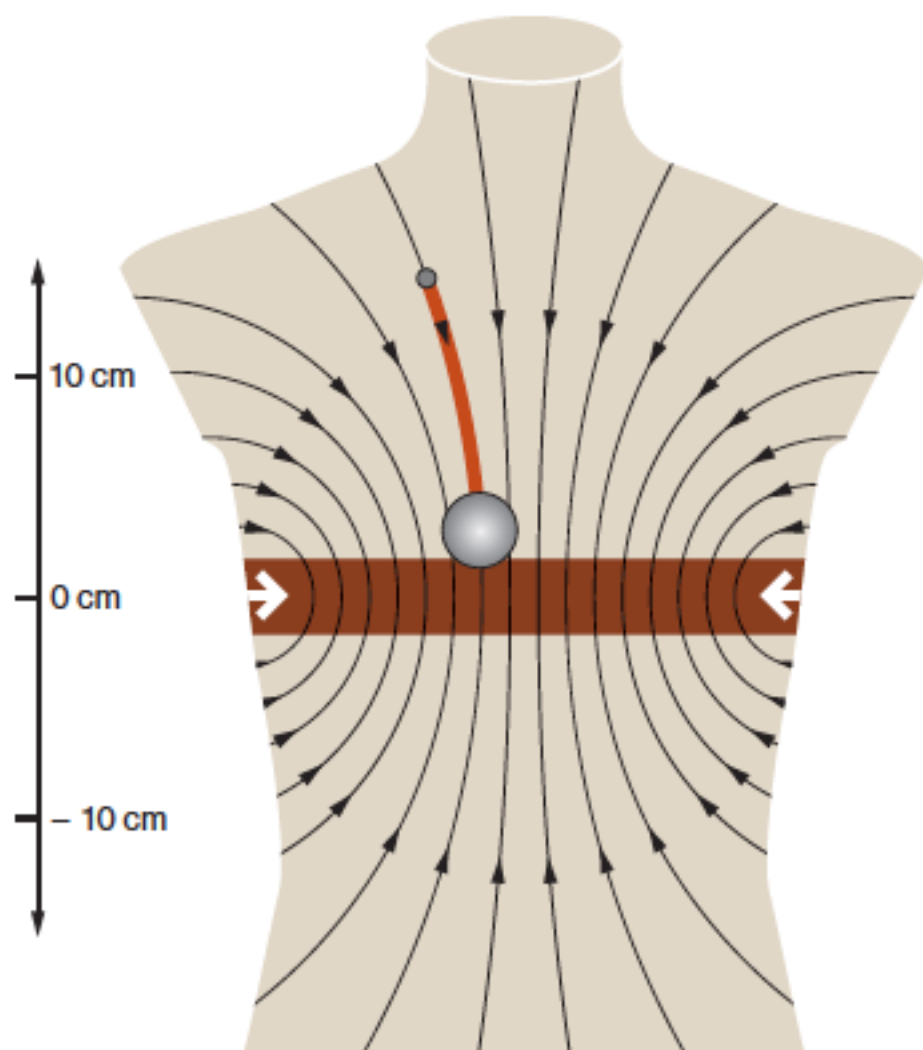
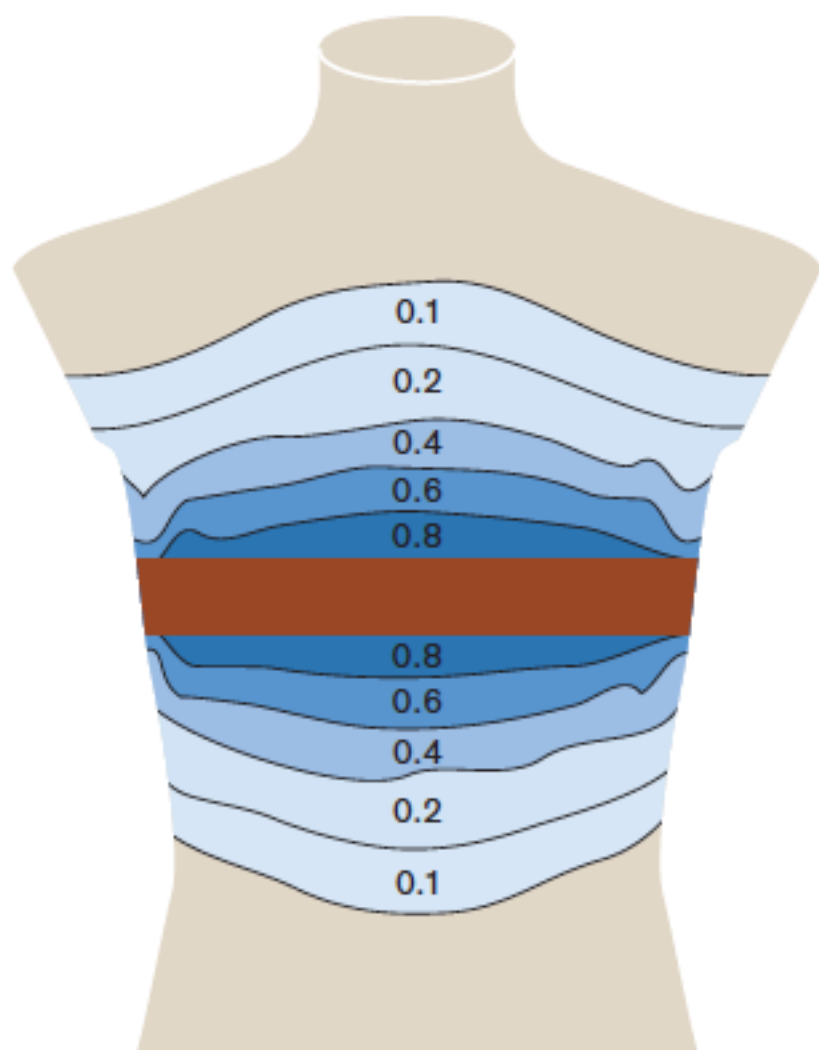
Tissue	Resistivity (ρ , Ωm)
Blood	1.5
Heart	1.6–4.3
Lung (expiration)	7.2
Lung (inspiration)	23.6
Fat	27.2

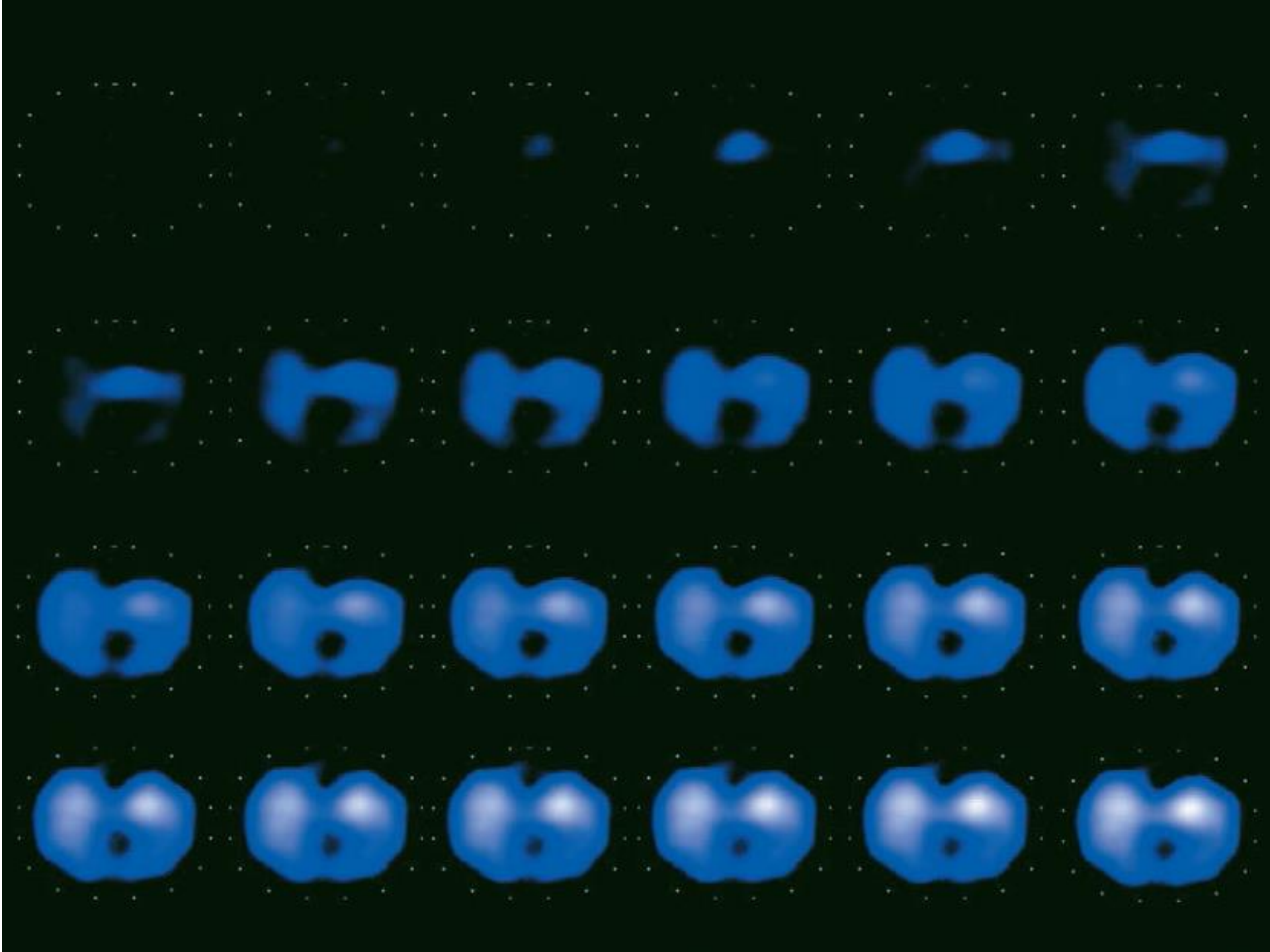
Tomographie en Impédance Electrique

- 16 ou 32 électrodes tout autour du thorax
- Injection d'un courant alternatif de faible amplitude (5 mA) par une paire d'électrodes
- Mesure ddp correspondante par les 15 autres paires d'électrodes.
- Rotation rapide autour du thorax (13 Hz): 1 mesure de ddp toutes les 77 msec
- 1 cycle complet génère une image (un tomogramme)









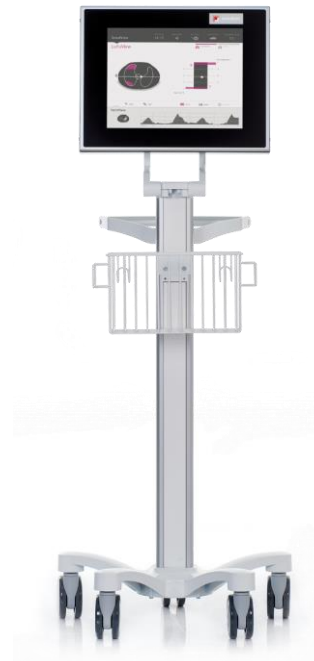
Systèmes disponibles



Dräger
Pulmovista



Timpel
Enlight 1800

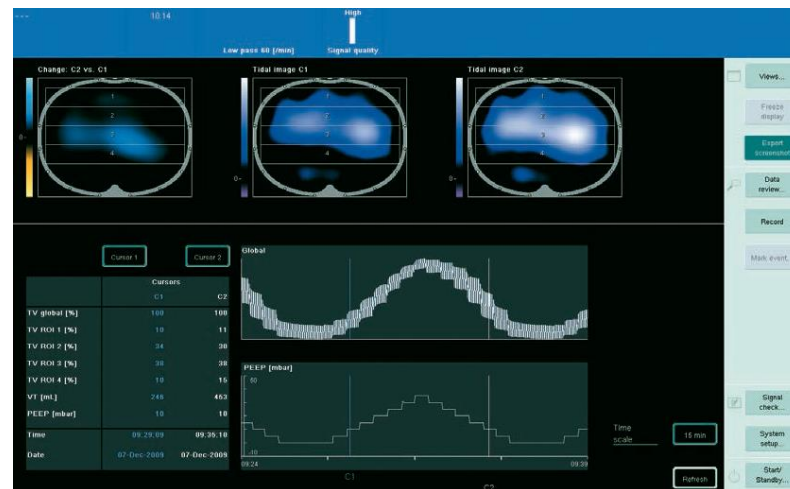
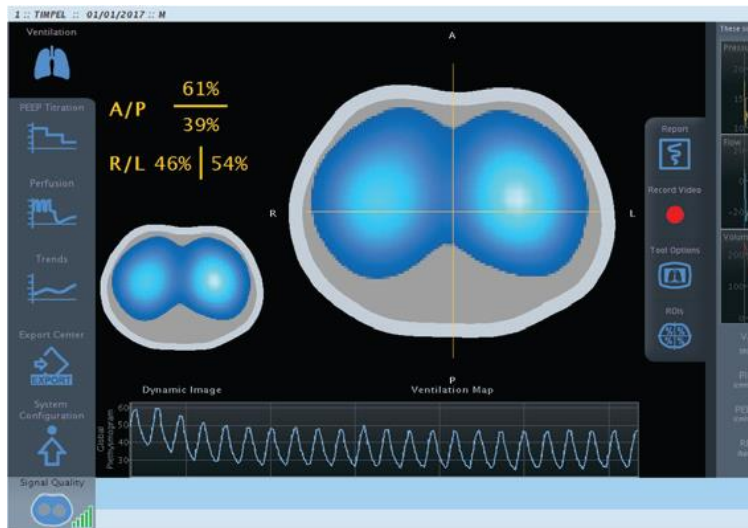


Swisstom
BB2

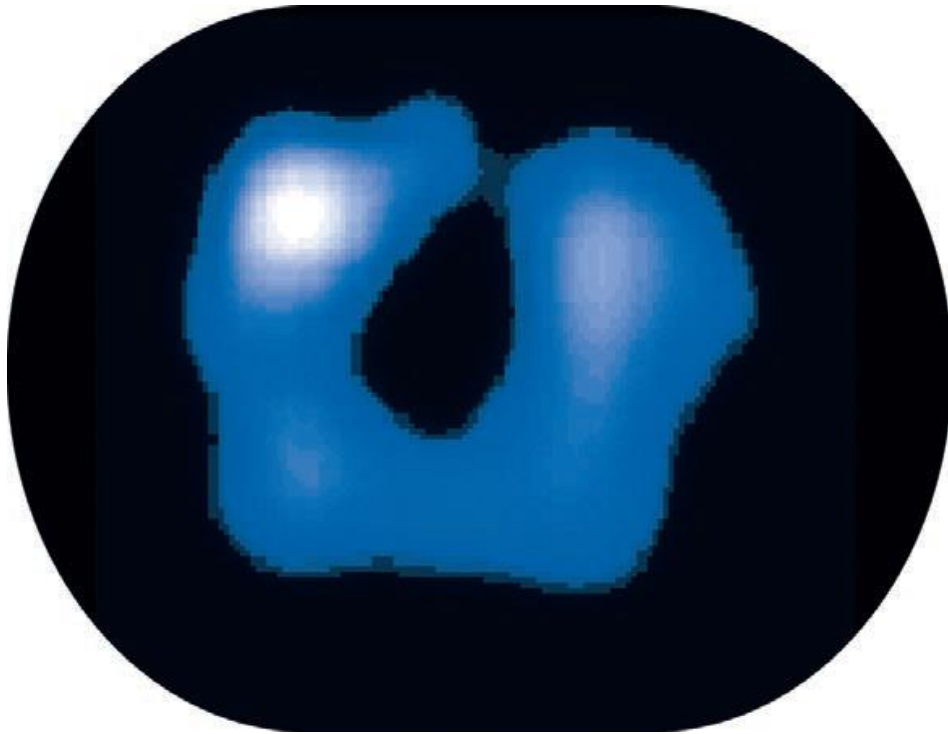


Löwenstein
Elisa 800 VIT





Faible résolution spatiale

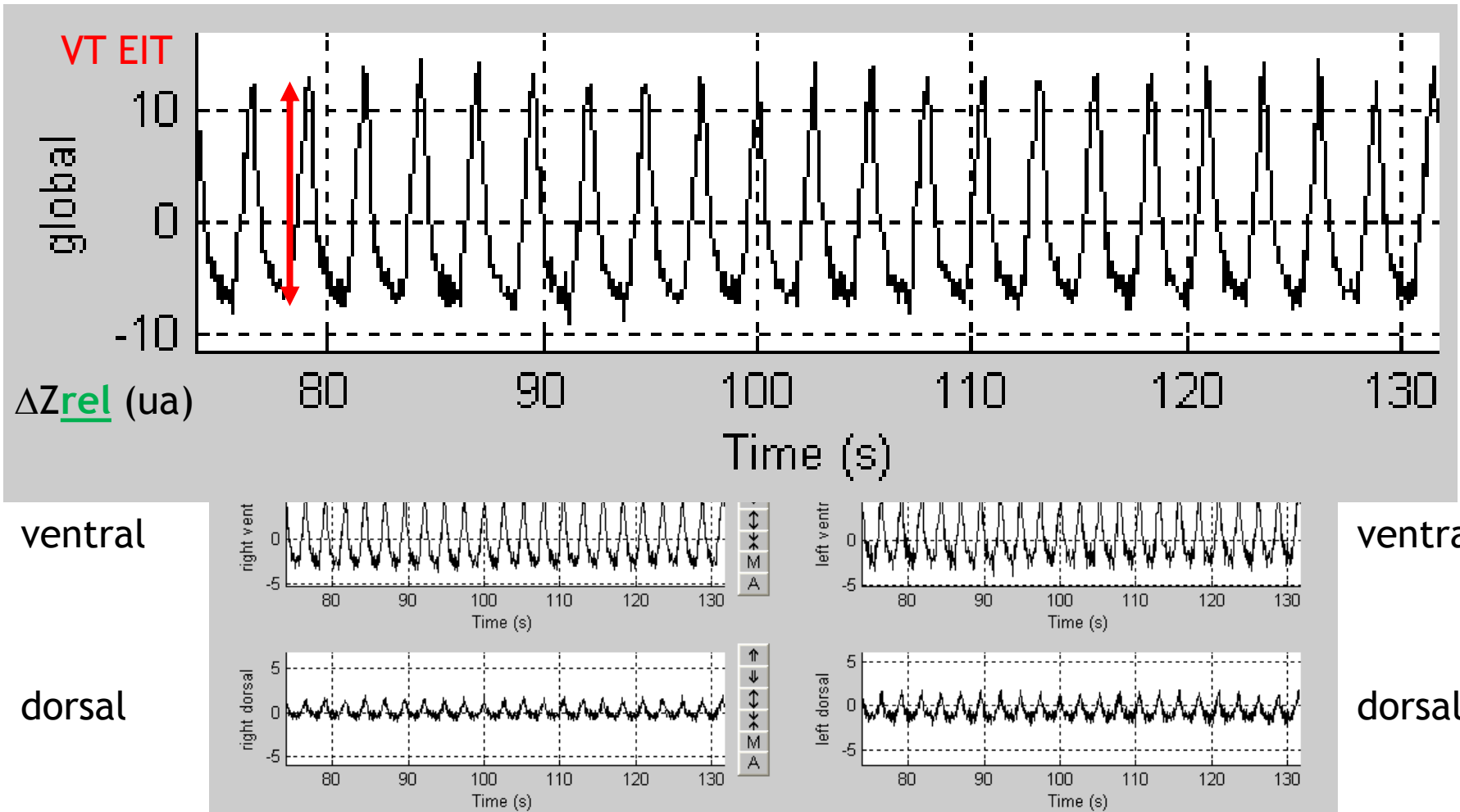


**Matrice
32 x 32
=1024 pixels
Réduits à 912
car représentation
circulaire (cylindre)
du thorax**

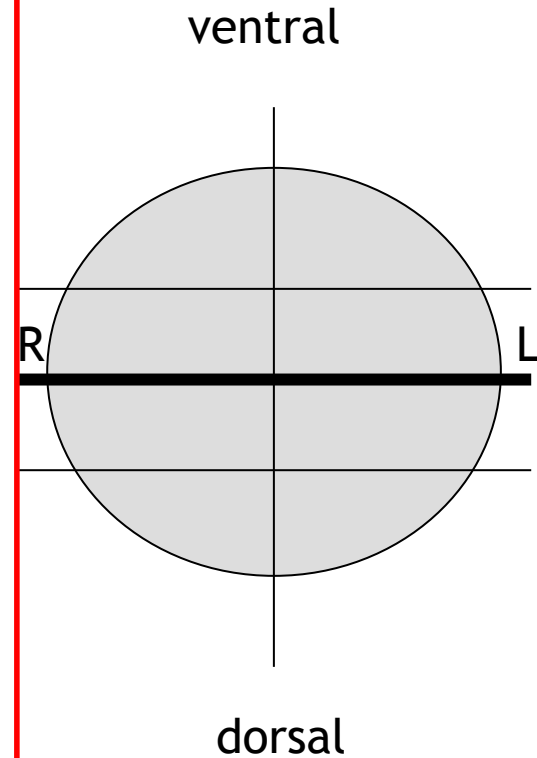
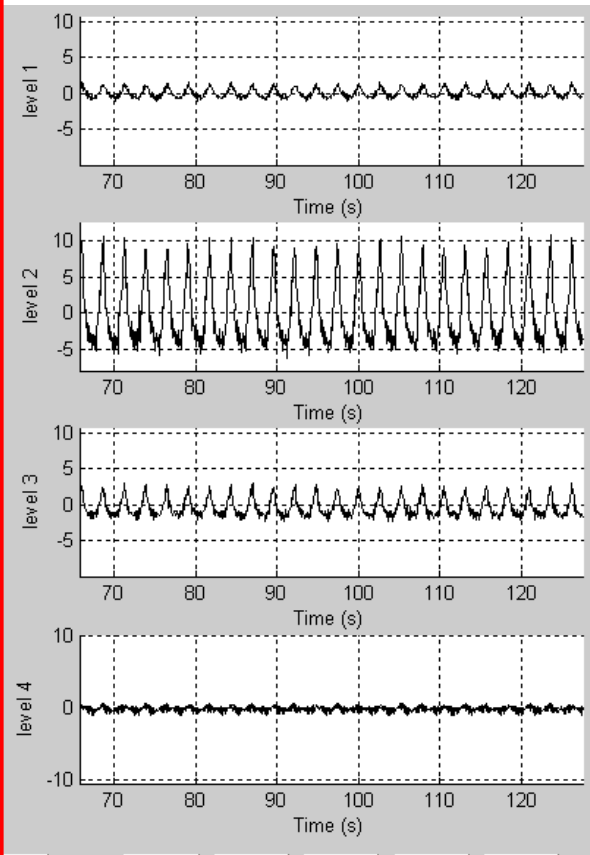
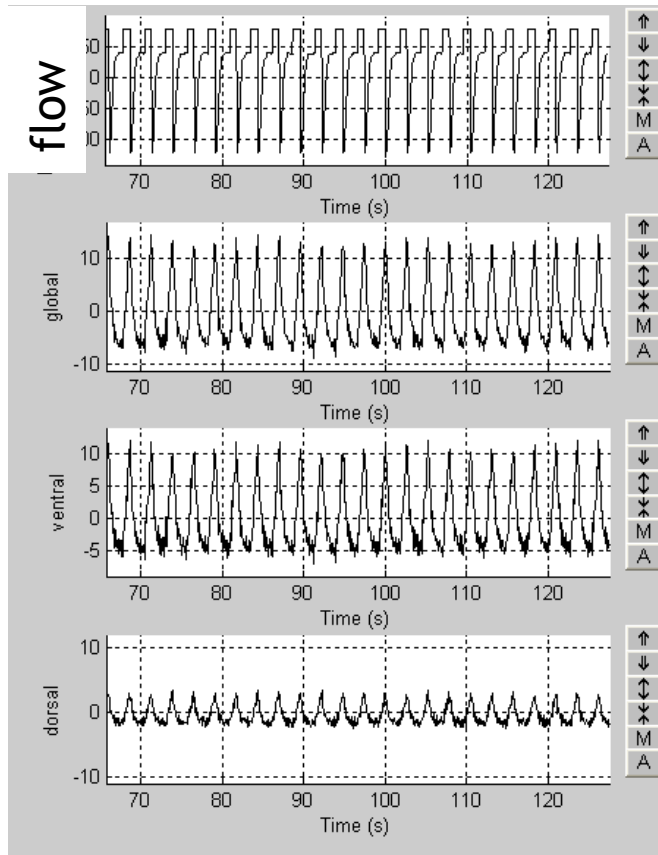
- 1 voxel : 10 – 20 cm³ (scanner, matrice 512 x 512, 1 voxel = 0,15 mm³)

Forte résolution temporelle → Ventilation

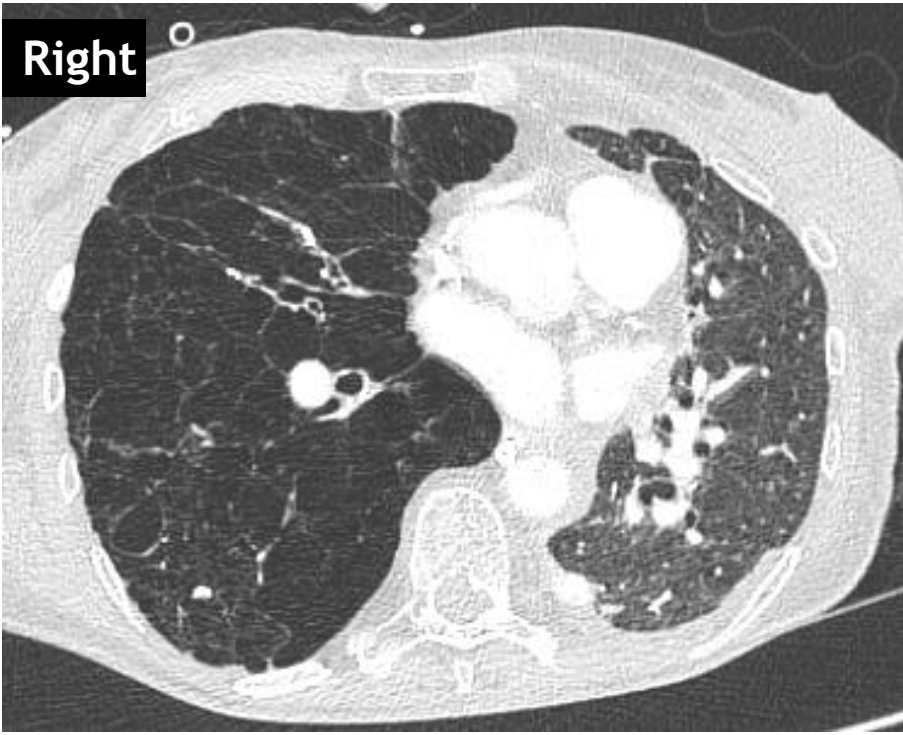
RELATIVEMENT A UNE SITUATION DE REFERENCE



Ventilation régionale

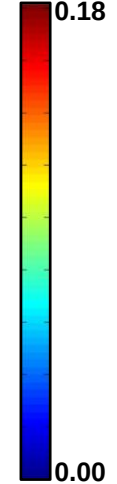
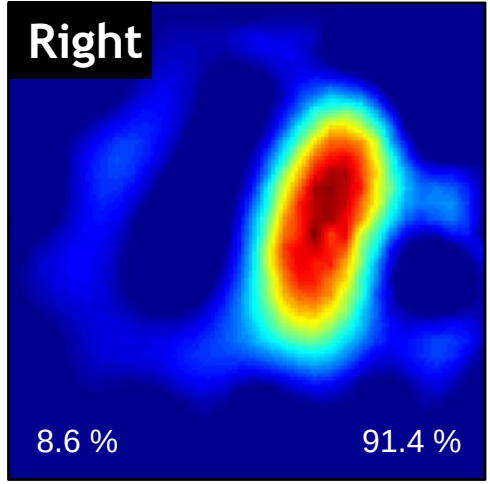
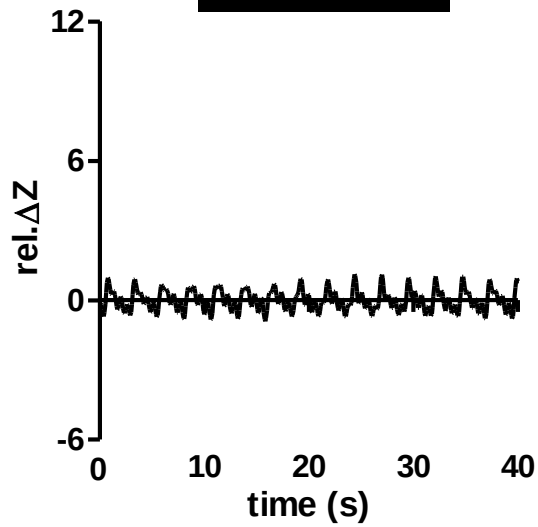


A

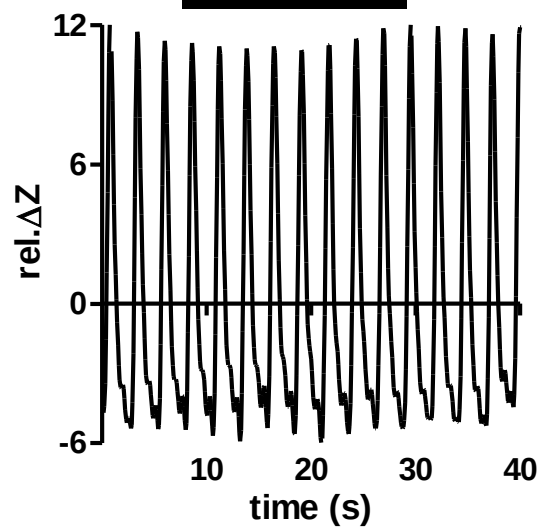


B

Right lung

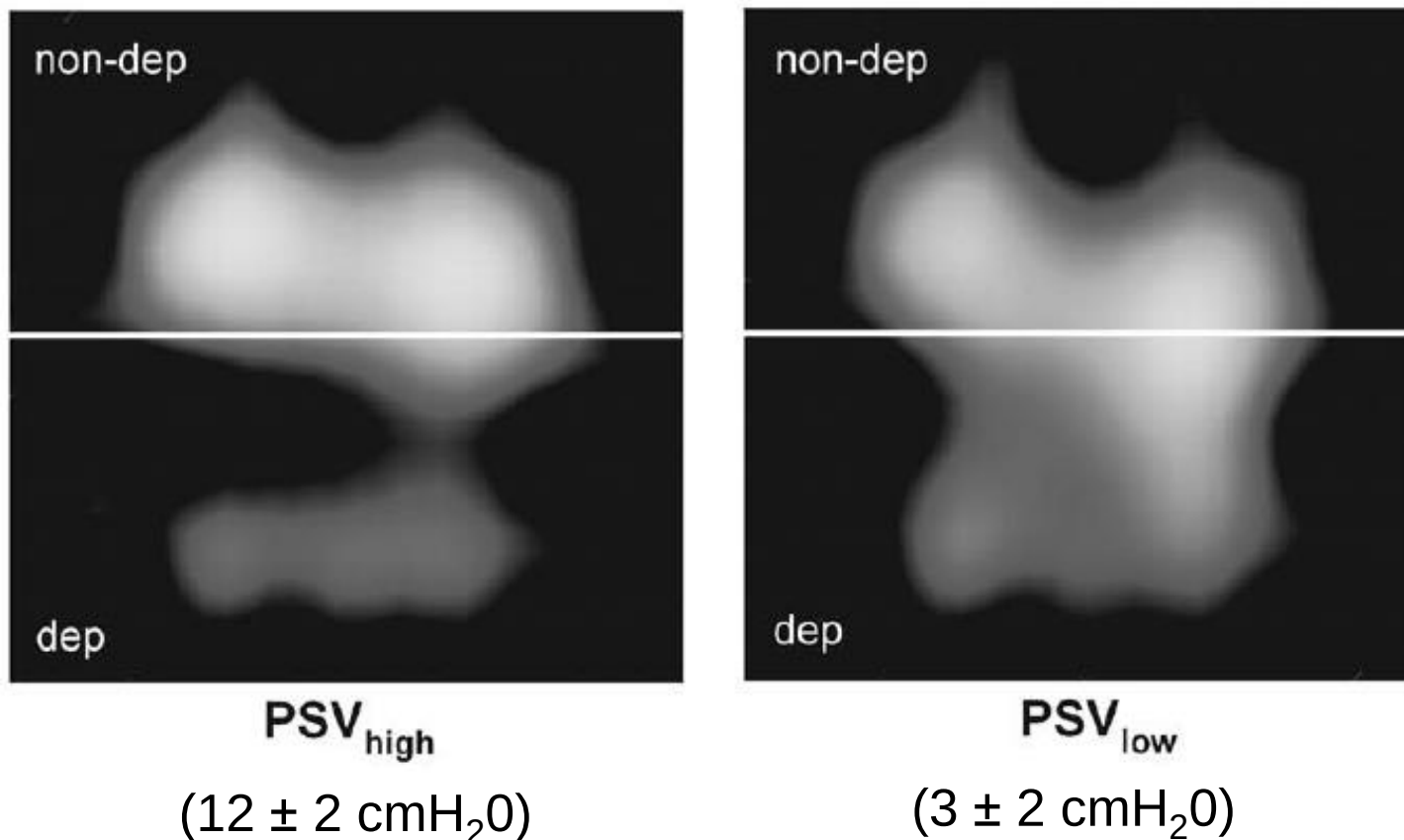


Left lung

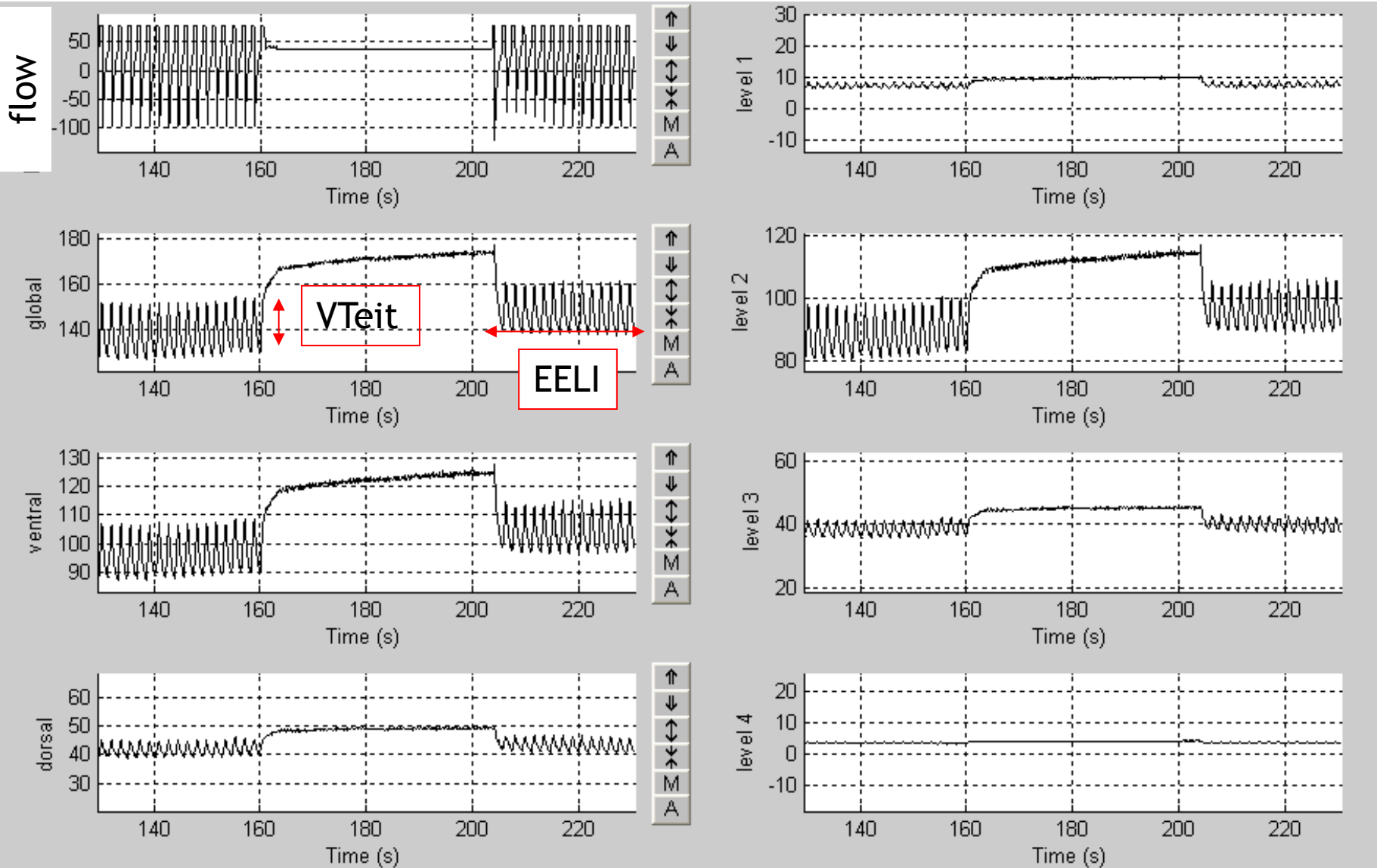


Topographic Distribution of Tidal Ventilation in Acute Respiratory Distress Syndrome: Effects of Positive End-Expiratory Pressure and Pressure Support*

Tommaso Mauri, MD^{1,2}; Giacomo Bellani, MD, PhD^{1,2}; Andrea Confalonieri, MD²;
Paola Tagliabue, MD²; Marta Turella, MD^{1,2}; Andrea Coppadoro, MD¹;
Giuseppe Citerio, MD²; Nicolo' Patroniti, MD^{1,2}; Antonio Pesenti, MD^{1,2}

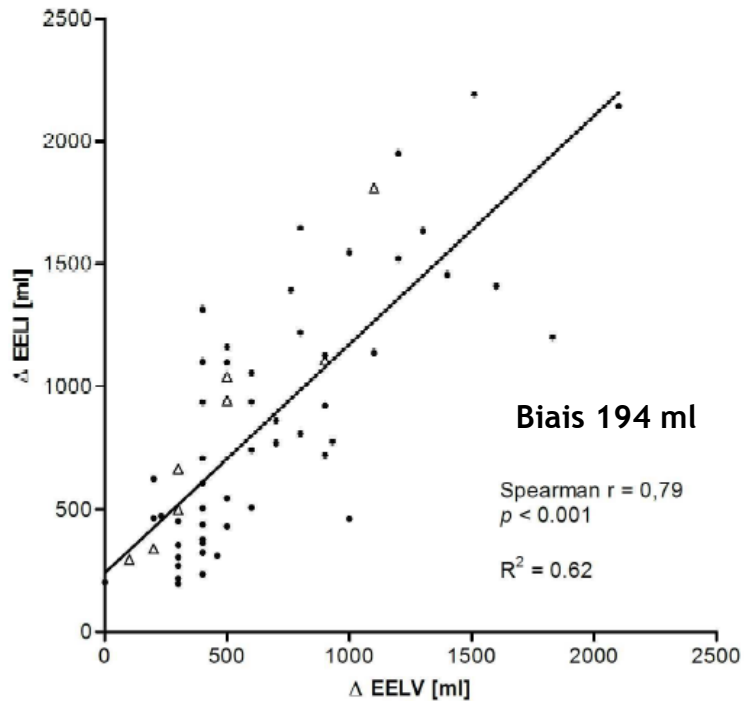


Impédance de fin d'expiration (EELI)

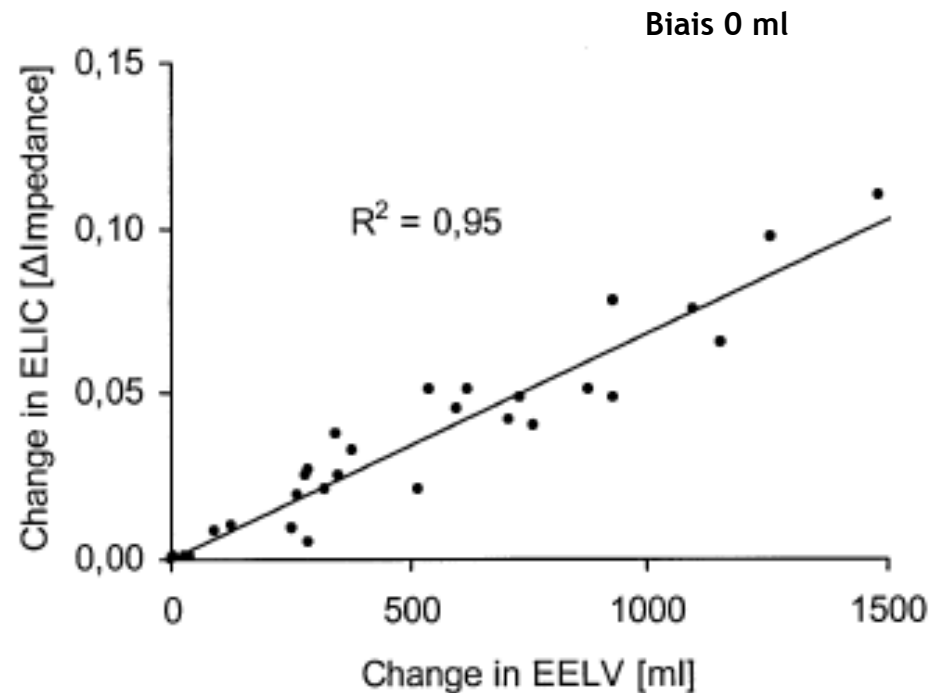


ΔEELI vs ΔEELV (scanner)

Bikker ICM 2009

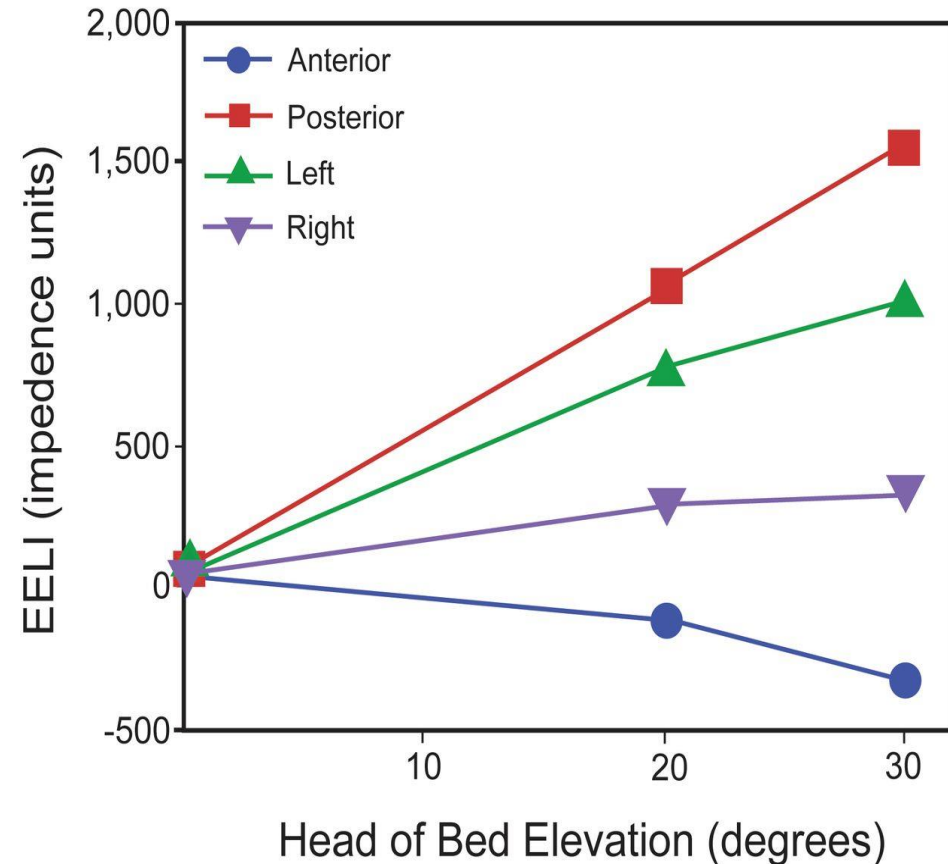
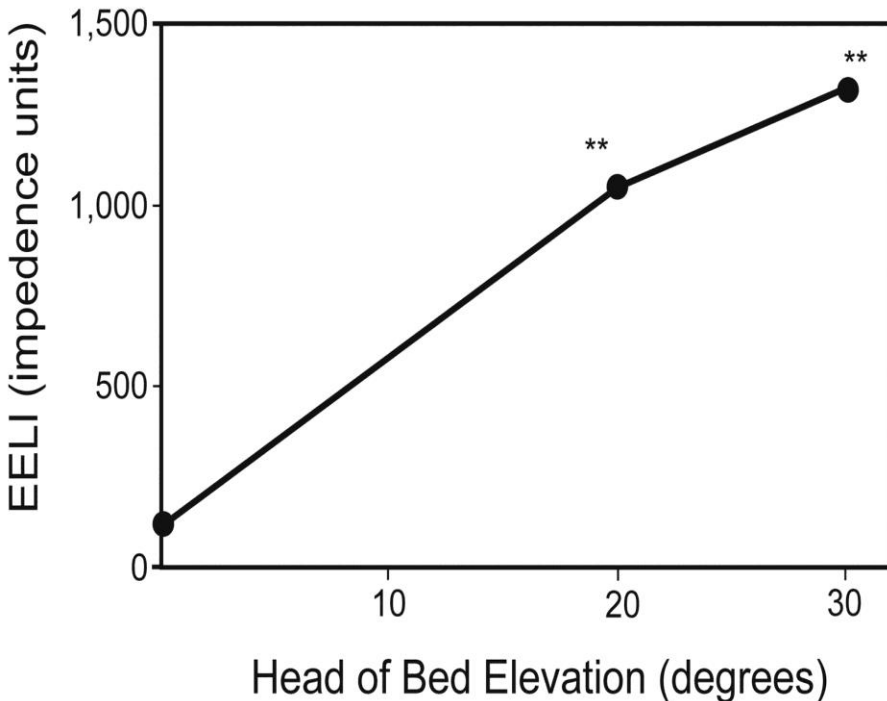


Hinz ICM 2003



EELI et position

20 patients Post-op chirurgie cardiaque
Intubés et ventilés PEP 5 AI 10

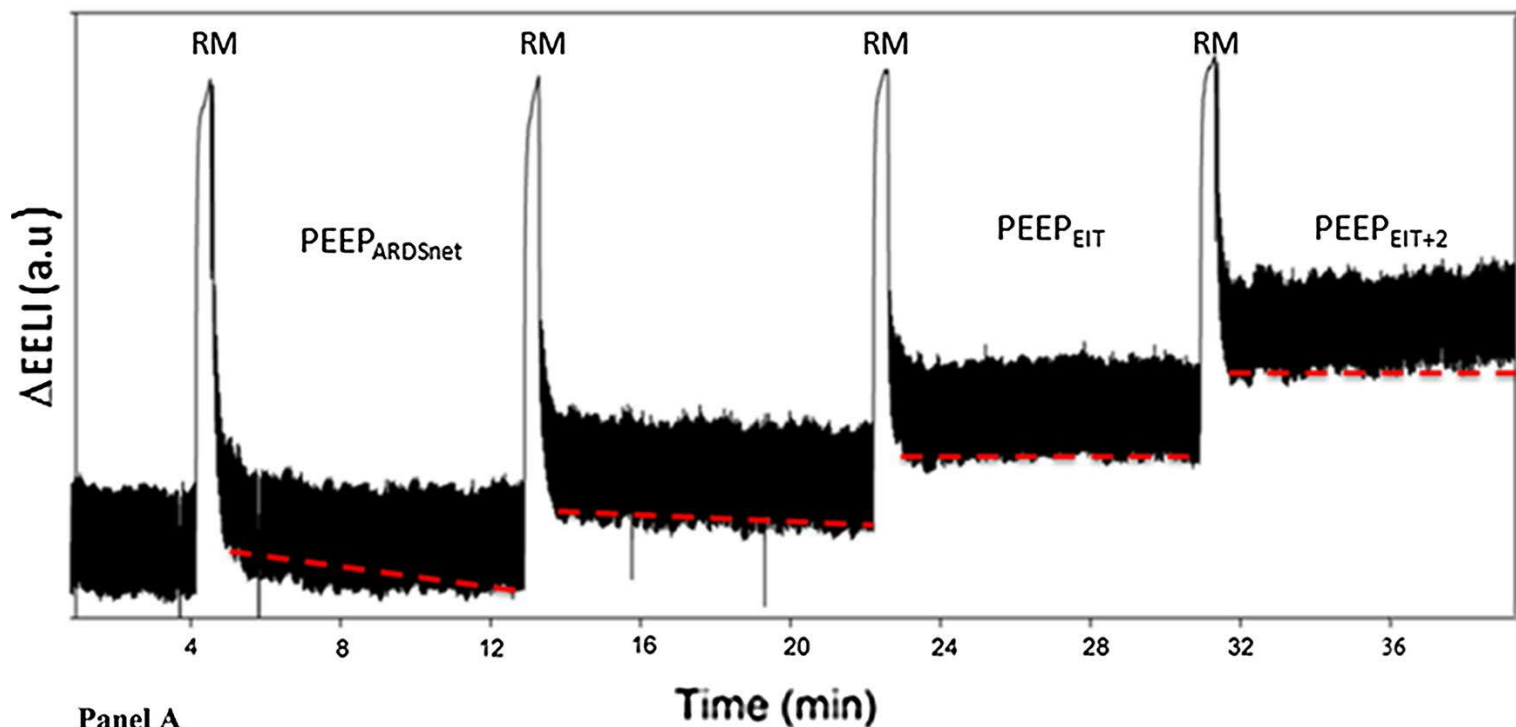


EELI et PEEP



Bedside selection of positive end-expiratory pressure by electrical impedance tomography in hypoxemic patients: a feasibility study

Nilde Eronia¹, Tommaso Mauri^{2,3}, Elisabetta Maffezzini⁴, Stefano Gatti⁴, Alfio Bronco⁴, Laura Alban^{2,3}, Filippo Binda³, Tommaso Sasso^{2,3}, Cristina Marenghi³, Giacomo Grasselli³, Giuseppe Foti^{1,4}, Antonio Pesenti^{2,3} and Giacomo Bellani^{1,4*} 





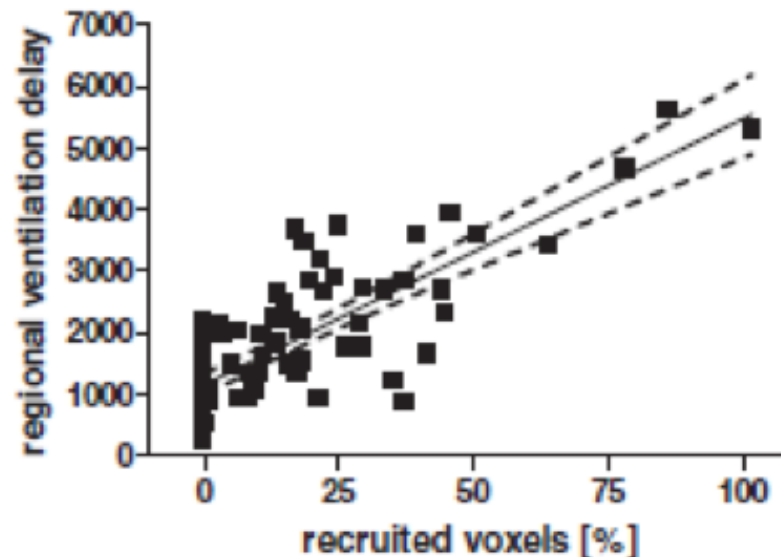
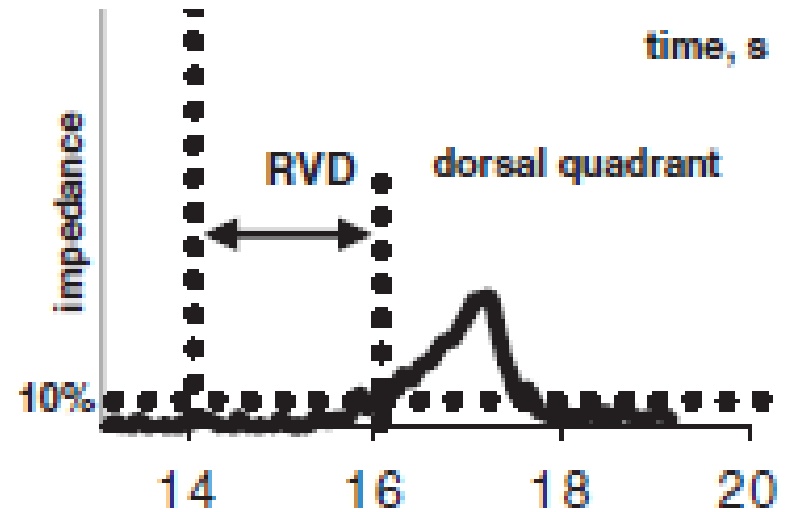
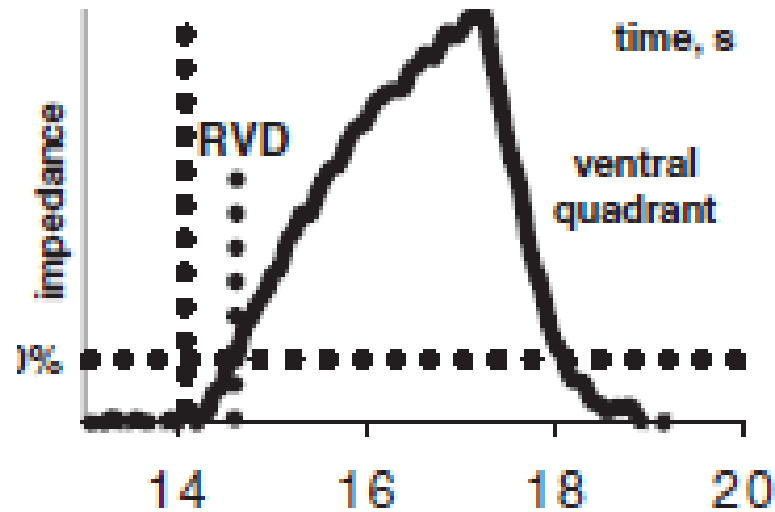
EIT : Quelles informations ?

- Index qui mesurent la distribution régionale de la ventilation
 - VT
 - EELV
- Index qui explorent l'hétérogénéité de la distribution de la ventilation
- Evaluation du potentiel de recrutement (PEEP)
- Index qui évaluent la compliance pulmonaire régionale

Index dérivés de l'EIT

- Tidal impedance variation (TIV) = VT EIT
- Regional ventilatory delay (RVD) = proportion du Ti requis pour atteindre une valeur seuil de DZ
- Global inhomogeneity index (GI)
- Regional Compliance
- Center of ventilation = ITV dorsal/ITV total reflet distribution VT sens ventro-dorsal
- Silent spaces, stretch (développés par Swisstom)
- Ventilation surface area (VSA) = n pixels avec DZ dans une région/n pixels avec DZ sur la totalité de l'échantillon
- ITV index = $\Sigma \text{ITV non-dépendant} / \Sigma \text{dépendant}$. ITV= intra tidal variation entre 8 parties isovolume du VT EIT

RVD → Recrutement alvéolaire



Index global d'inhomogénéité (GI)

GI map shows the amount by which a pixel is aerated more/less than average

$$GI = \frac{\sum |DI_{xy} - DI_{medi}|}{\sum DI_{xy}}$$

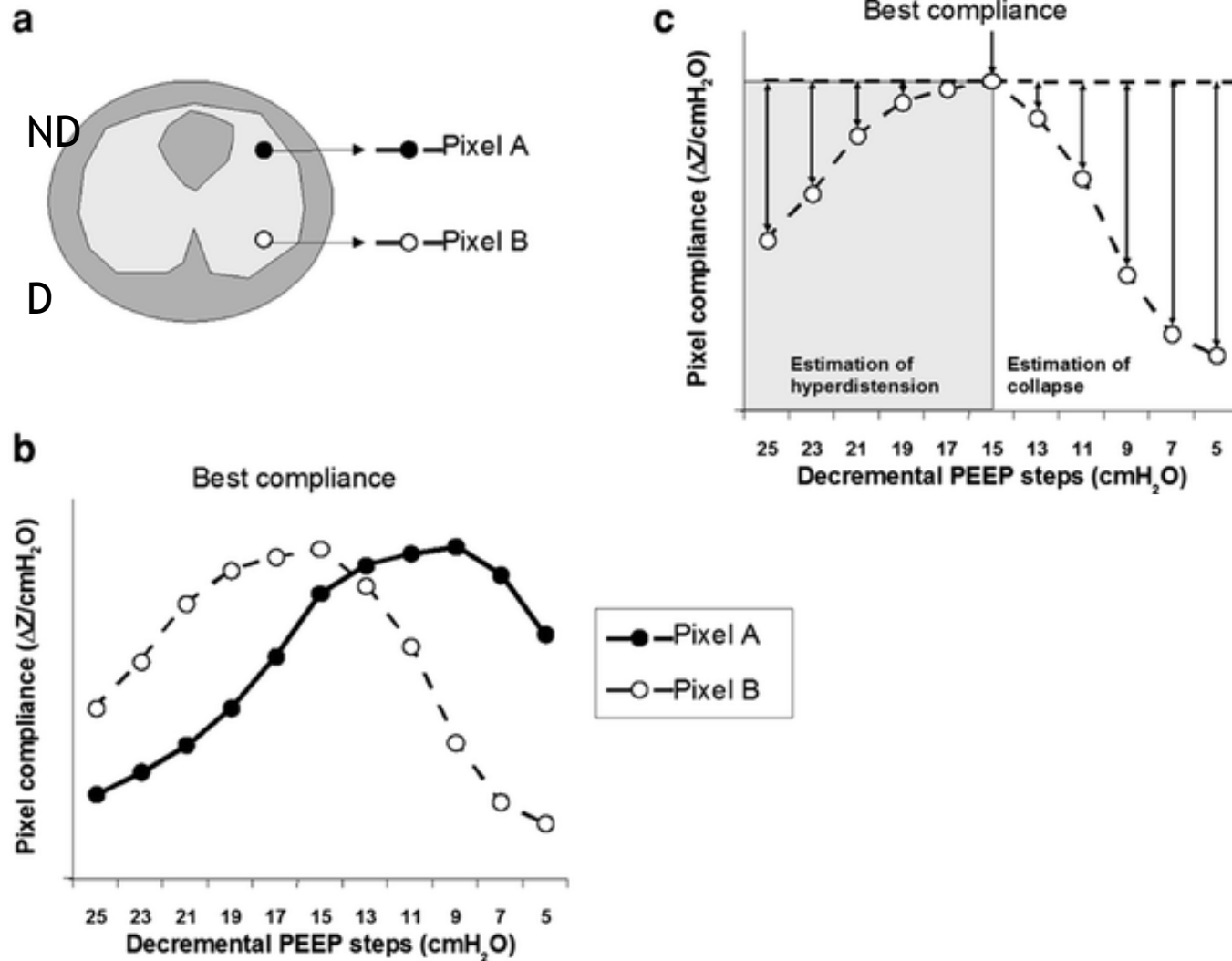


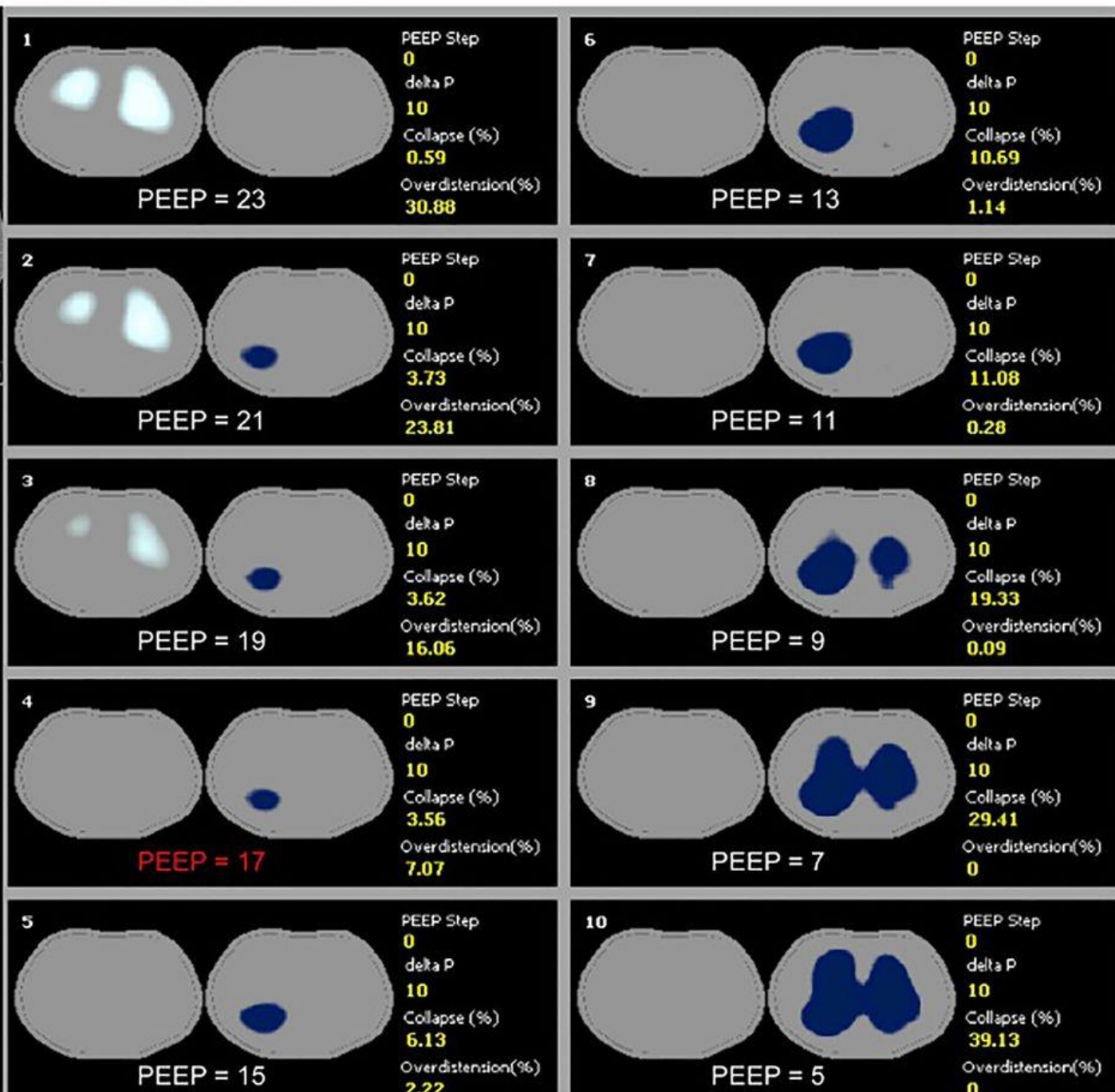
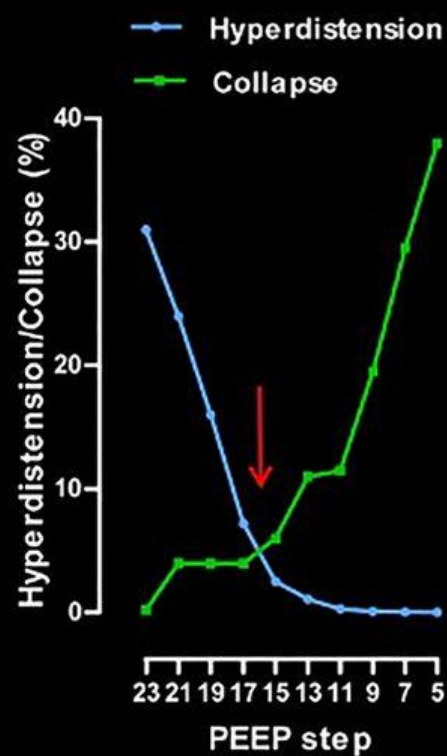
Physiologic Effects of High-Flow Nasal Cannula in Acute Hypoxemic Respiratory Failure

Tommaso Mauri^{1,2}, Cecilia Turrini^{1,3}, Nilde Eronia⁴, Giacomo Grasselli¹, Carlo Alberto Volta³, Giacomo Bellani^{4,5}, and Antonio Pesenti^{1,2}

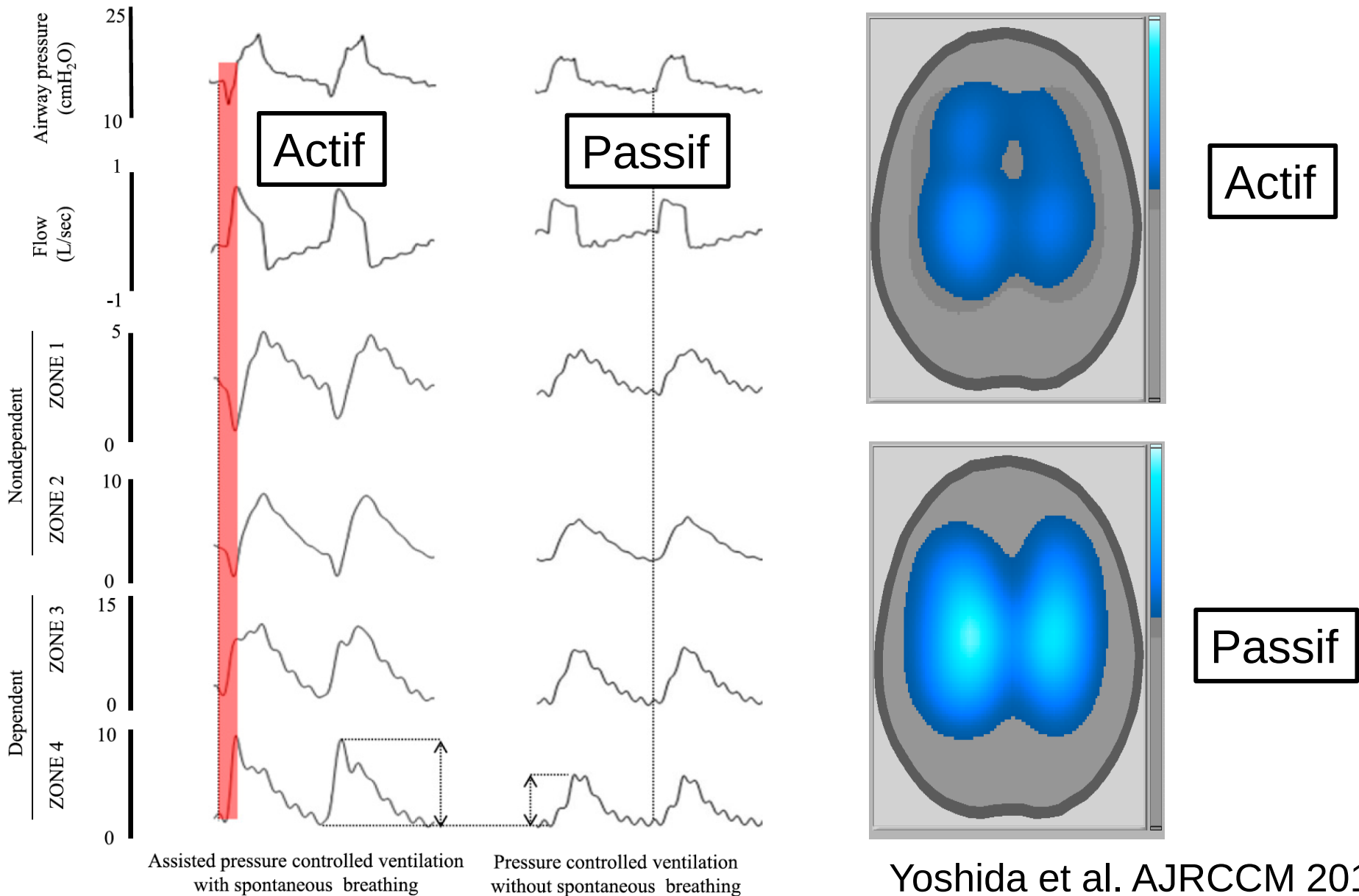
Variable	Oxygen Facial Mask	High-Flow Nasal Cannula	P Value*
$\Delta EELI_{glob}$ (change from facial mask), % of baseline V_T	—	51 ± 57	<0.001
$\Delta EELI_{non-dep}$ (change from facial mask), % of baseline V_T	—	29 ± 36	≤ 0.001
$\Delta EELI_{dep}$ (change from facial mask), % of baseline V_T	—	26 ± 33	≤ 0.01
GI index	0.50 (0.49 to 0.57)	0.47 (0.43 to 0.60)	<0.01
PIF_{glob} (change from facial mask), %	—	-15 ± 23	0.07
PEF_{glob} (change from facial mask), %	—	-27 ± 22	≤ 0.001
$PIF_{non-dep}$ (change from facial mask), %	—	-11 ± 29	0.29
PIF_{dep} (change from facial mask), %	—	-20 ± 19	<0.01
$PEF_{non-dep}$ (change from facial mask), %	—	-19 ± 32	0.07
PEF_{dep} (change from facial mask), %	—	-34 ± 18	<0.001
Ti , s	1.2 ± 0.2	1.2 ± 0.3	0.84
Te , s	1.3 ± 0.2	1.5 ± 0.6	<0.05
Ti/T_{tot}	0.5 ± 0.0	0.4 ± 0.0	<0.05

Compliances régionales et PEEP



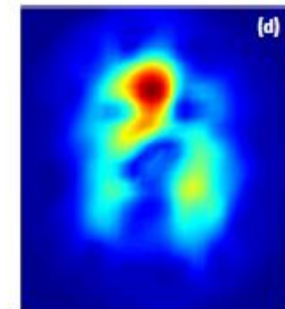
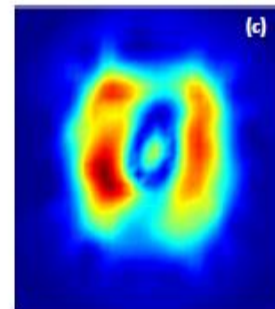
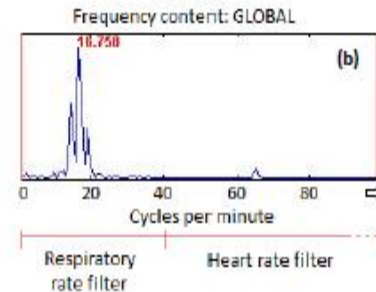
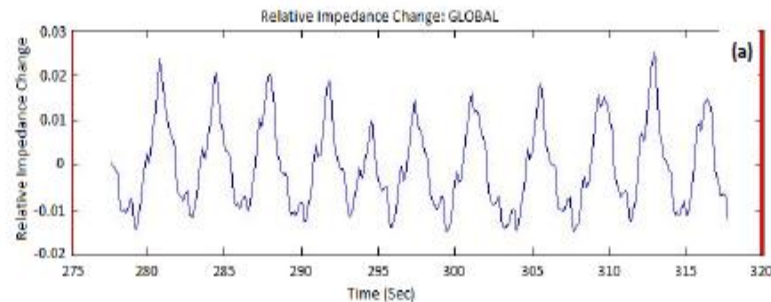


Spontaneous Effort Causes Occult Pendelluft during Mechanical Ventilation



EIT et perfusion pulmonaire

- 97% de la variation d'impédance est aérienne, 3% d'origine cardiaque
- 2 solutions pour extraire le signal de perfusion :
 - Produit de contraste = SSH (non validé chez l'homme) → variation importante de l'impédance, mais mesure discontinue
 - Utilisation de filtres, idéalement sensibilisés par une pause sur le ventilateur





OPEN ACCESS

Chest electrical impedance tomography examination, data analysis, terminology, clinical use and recommendations: consensus statement of the TRanslational EIT developmeNt stuDy group

Inéz Frerichs,¹ Marcelo B P Amato,² Anton H van Kaam,³ David G Tingay,⁴ Zhanqi Zhao,⁵ Bartłomiej Grychtol,⁶ Marc Bodenstein,⁷ Hervé Gagnon,⁸ Stephan H Böhm,⁹ Eckhard Teschner,¹⁰ Ola Stenqvist,¹¹ Tommaso Mauri,¹² Vinicius Torsani,² Luigi Camporota,¹³ Andreas Schibler,¹⁴ Gerhard K Wolf,¹⁵ Diederik Gommers,¹⁶ Steffen Leonhardt,¹⁷ Andy Adler,⁸ TREND study group

réanimation 2018

Paris 24-26 janvier 2018

Paris Expo - Porte de Versailles

