Outils non invasifs de monitorage pulmonaire en réanimation

Echographie pulmonaire et tomographie d'impédance électrique

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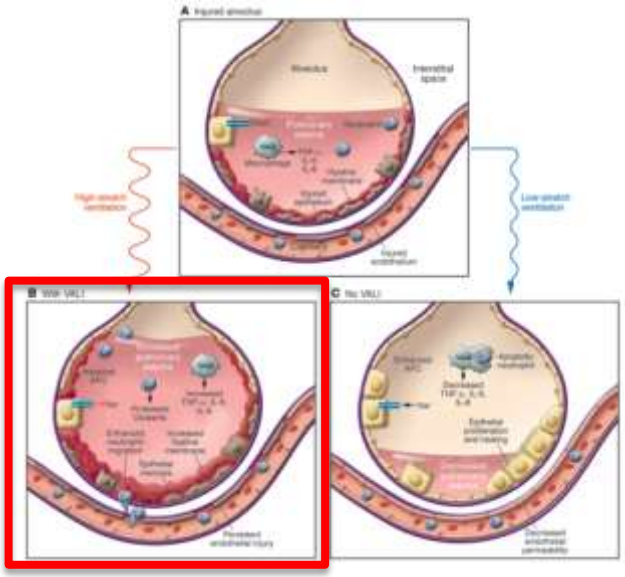
FRE3632

Inserm U959

réanimation 2017
PARIS 11-13 JANVIER

Pas de conflits d’intérêt

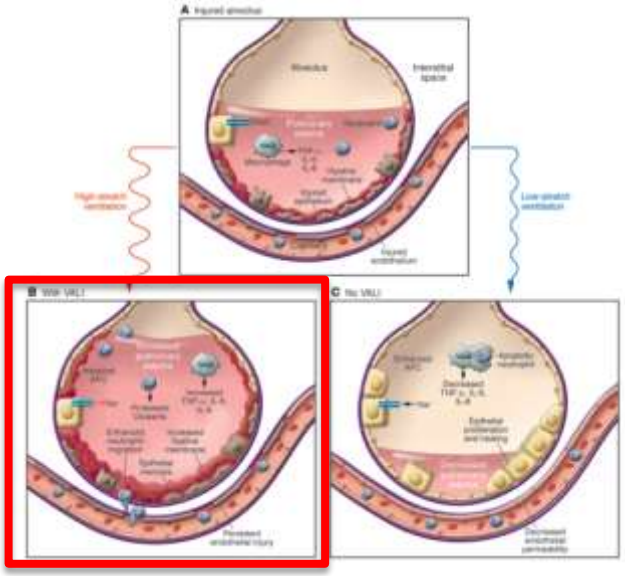
Entre collapsus et surdistension



Entre collapsus et surdistension

surdistension

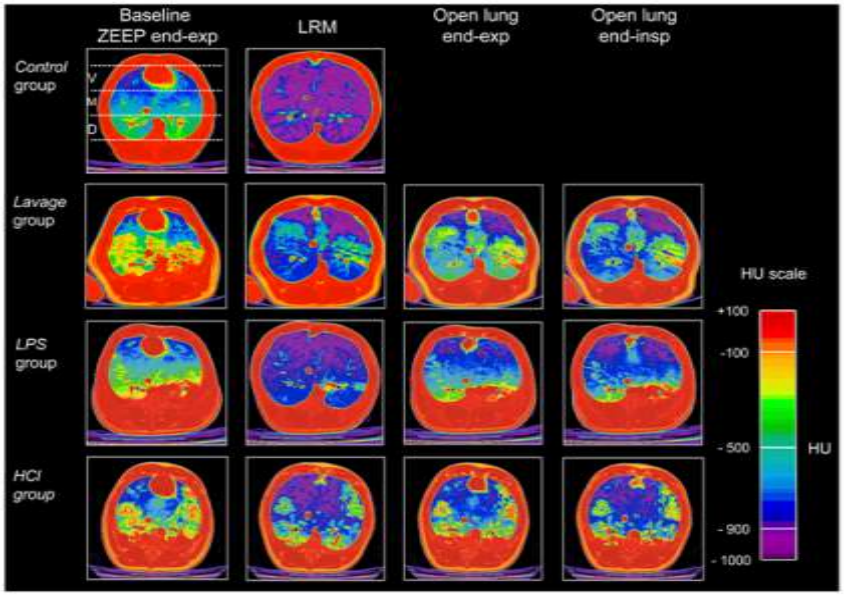
recrutement



Entre collapsus et surdistension

surdistension

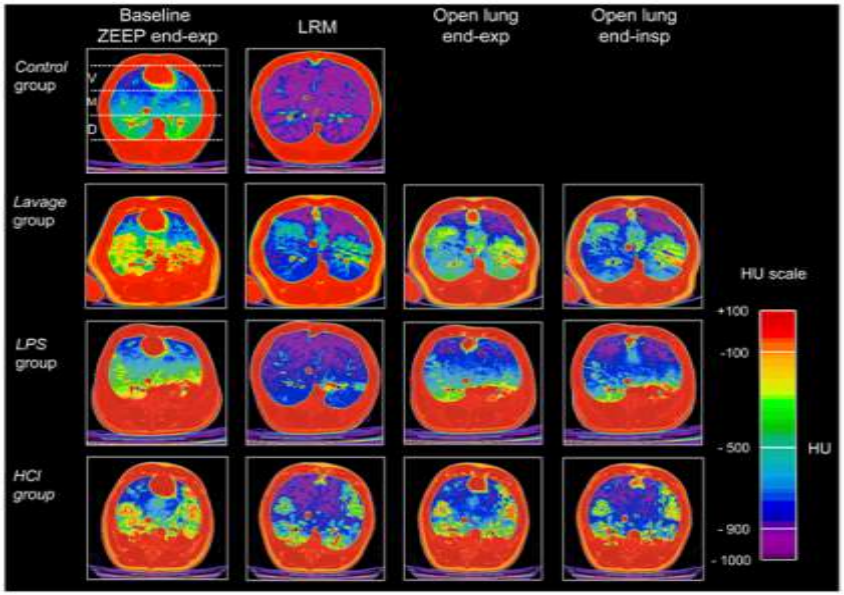
recrutement



- scanner

Rouby et al. *Crit Care Med*, 2003
Gattinoni et al. *Am J Resp Crit Care Med*, 1995

Entre collapsus et surdistension



- Transport du patient
- Rayons X
- Statique

Outils non-invasifs ?

- non invasif
- inocuité
- dynamique
- répétable
- au lit du patient

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Échographie pulmonaire

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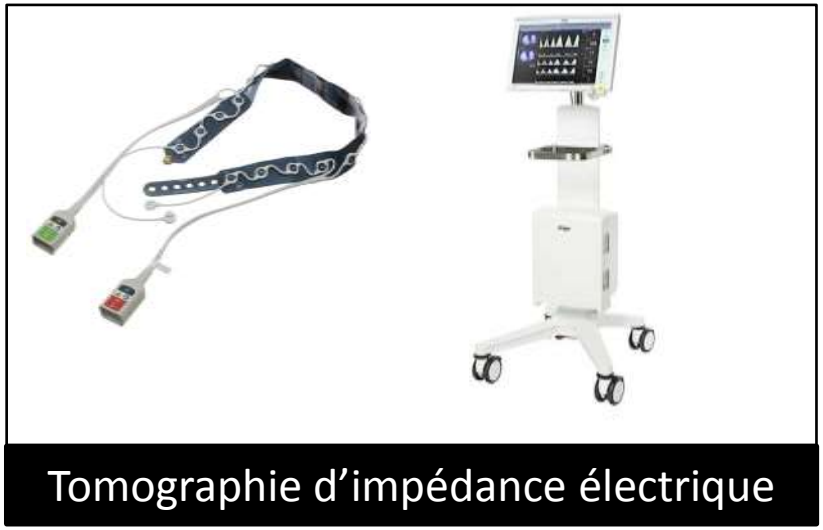
Échographie pulmonaire

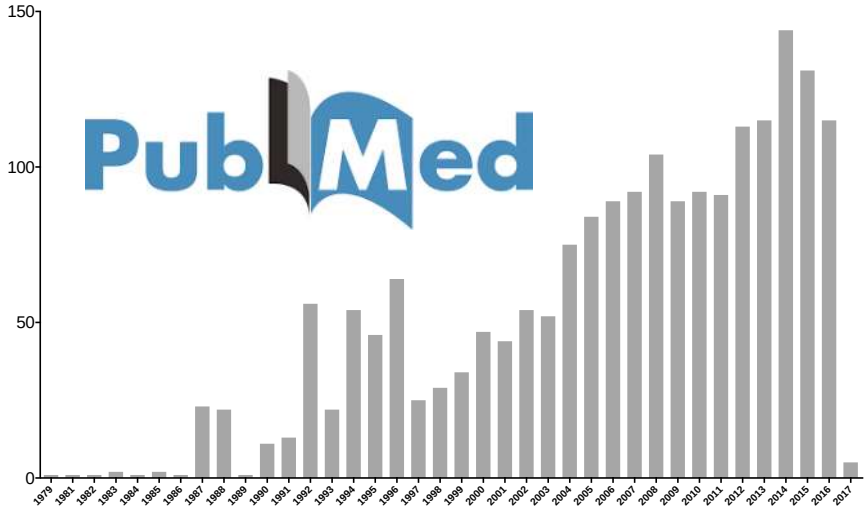
Tomographie d'impédance électrique

Outils non-invasifs ?

Échographie pulmonaire



Tomographie d'impédance électrique

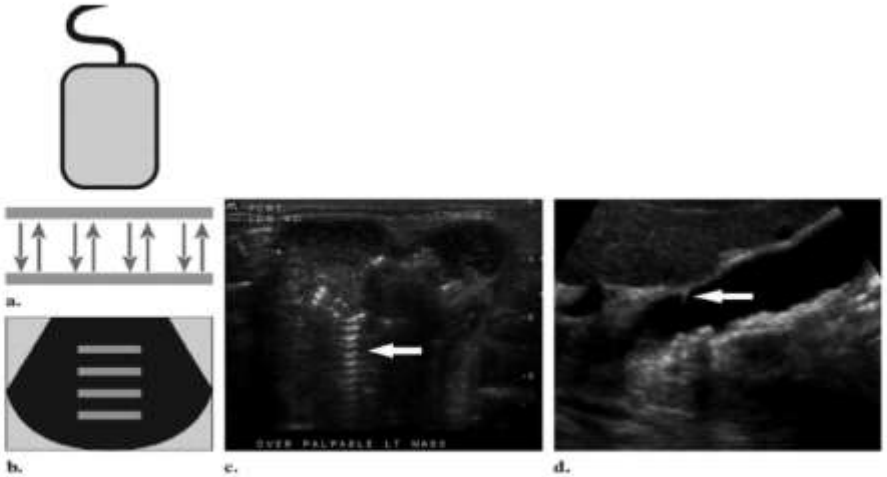


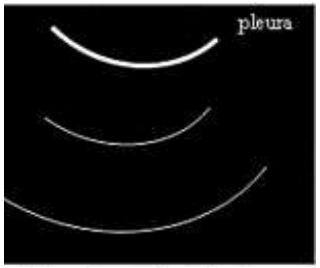
Echographie pulmonaire: principes

	Sonde convexe	Sonde « cardiaque »	Sonde micro convexe	Sonde linéaire (haute fréquence)
Applications	Abdomen	Cœur	Poumon	Peau, vaisseaux
Fréquence	2-6	2-4	5	5-10
Longueur d'onde	0,24-0,73 mm	0,36-0,73 mm	0,3 mm	0,15-0,3 mm

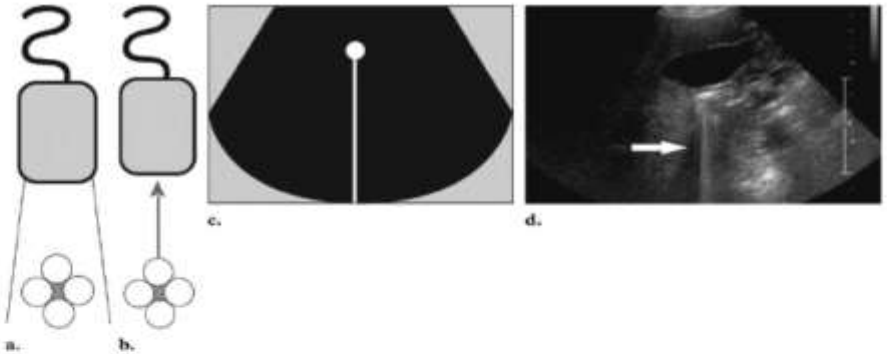
Echographie pulmonaire: principes

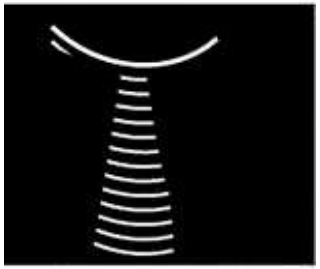
RadioGraphics



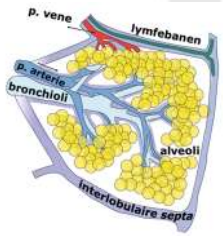


"ring-down" artifacts



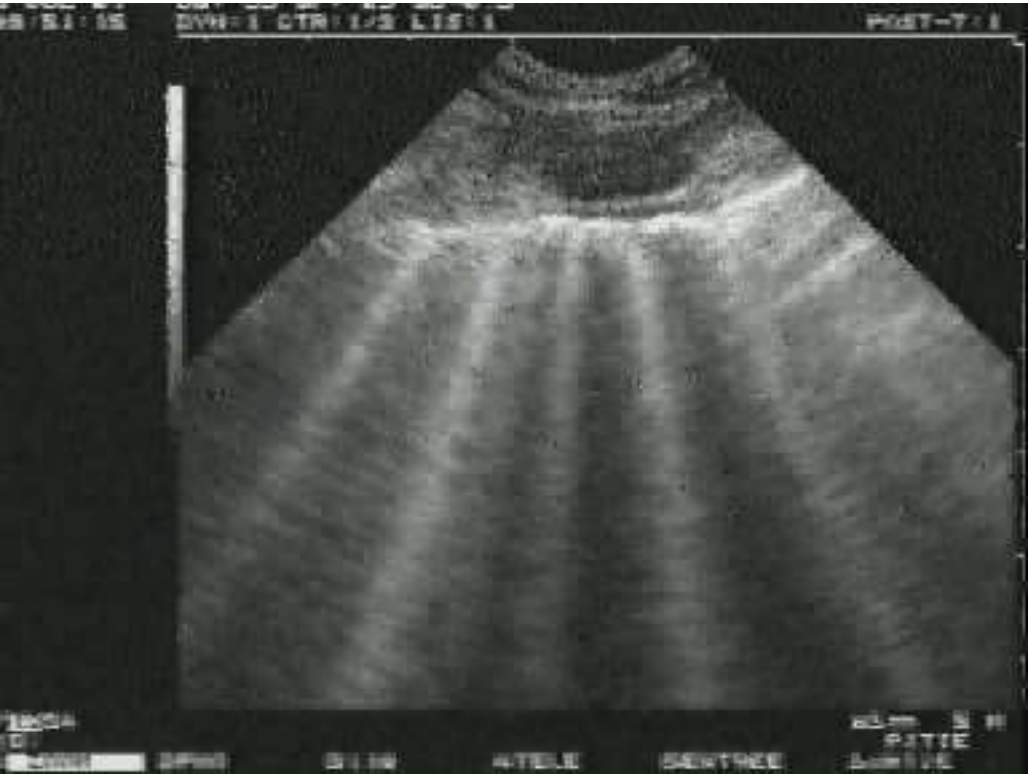


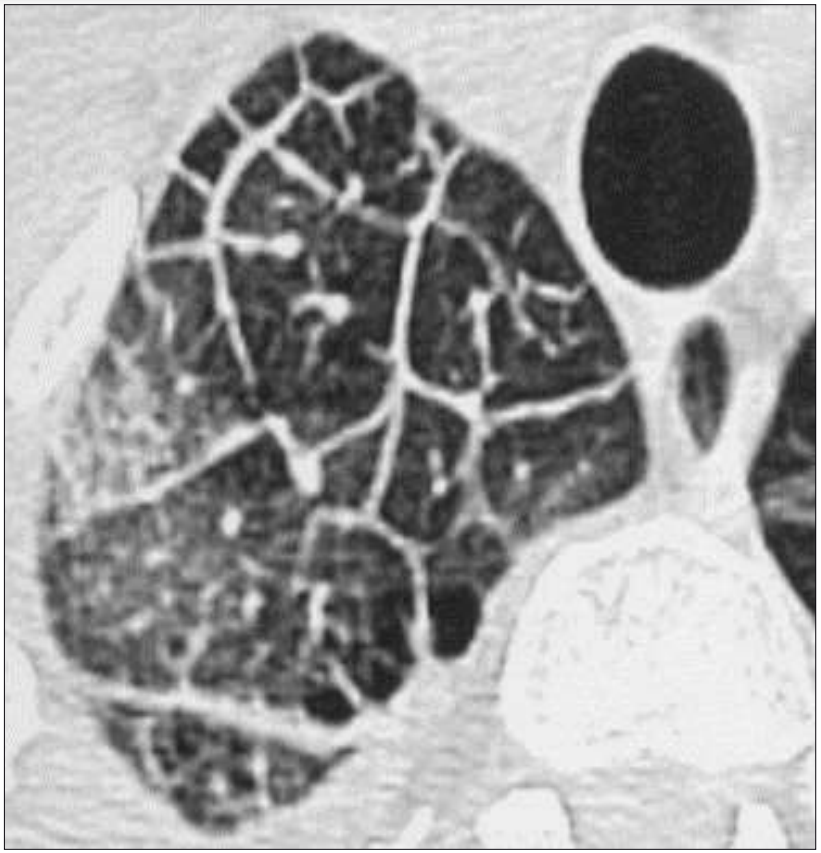
"comet-tail" artifact



B1 multiples régulières - « comet-tails » - = syndrome interstitiel

Lignes B espacées de 7 mm ➔ épaississement septa interlobulaires
B_1 régulières

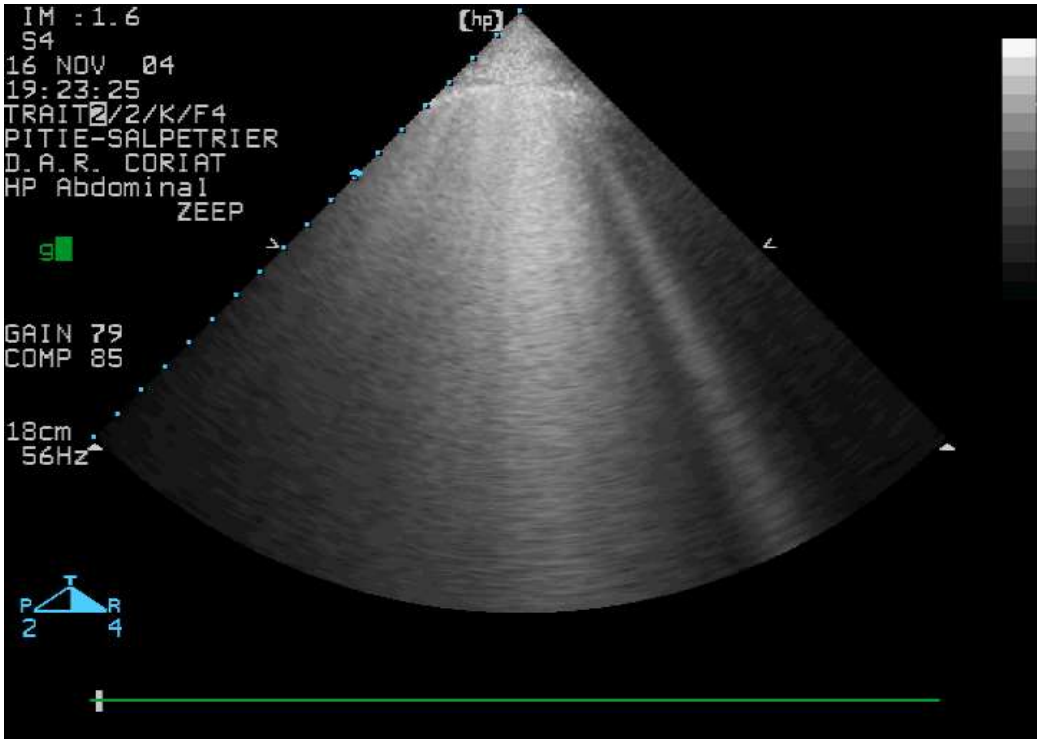


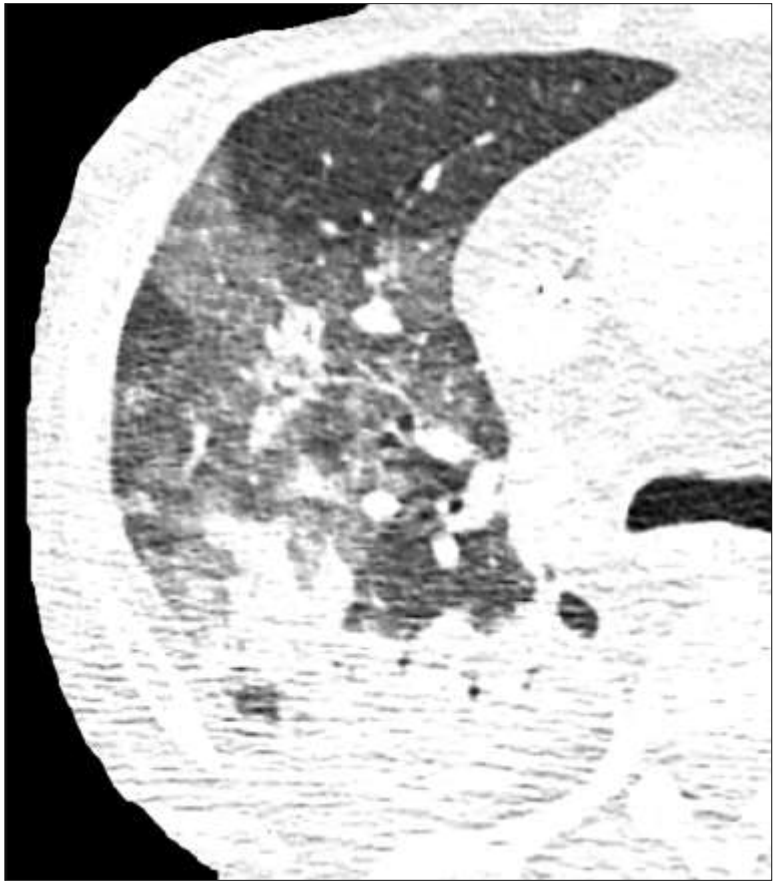


D Lichtenstein et al *AJRCCM* 156 : 1640-1646 , 1997

B2 coalescentes- « comet-tails » - = syndrome alvéolo-interstitiel

B_2 coalescentes ➔ verre dépoli





D Lichtenstein et al *AJRCCM* 156 : 1640-1646 , 1997

Perte d'aération et score échographique

0

Aération normale

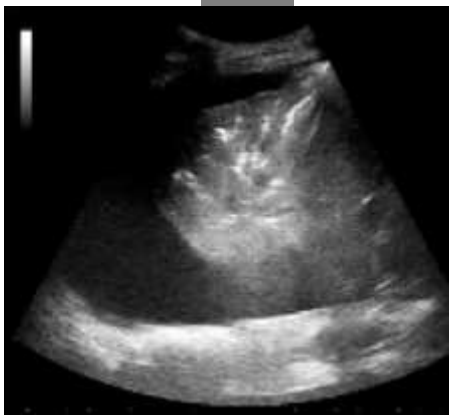
1

Perte d'aération modérée

2

Perte d'aération sévère

3



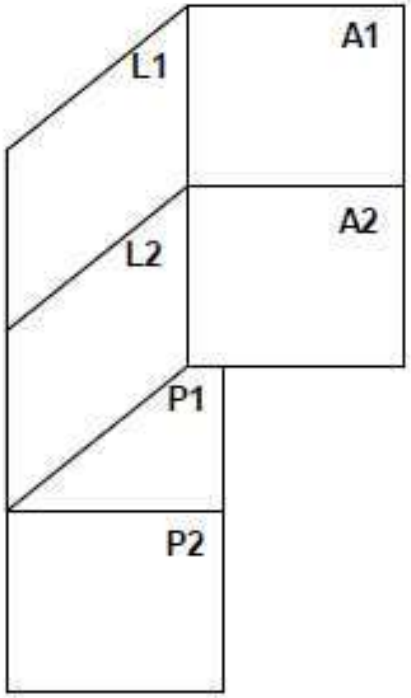
Perte d'aération complète

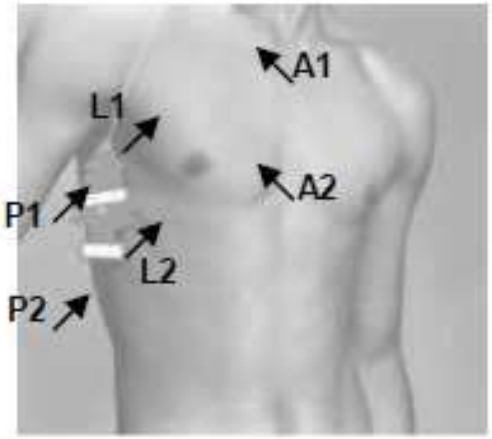
1r: régulier
1ir: irrégulière
1p: consolidation juxta-pleurale
1c: coalescent

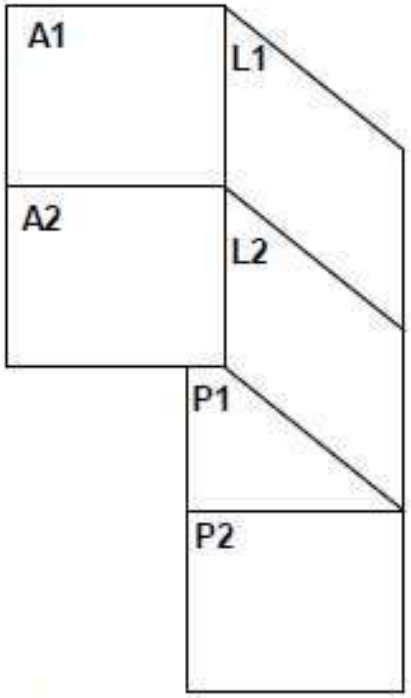
2
2p

Bronchogramme
Shunt

Perte d'aération et score échographique







Perte d'aération et score échographique

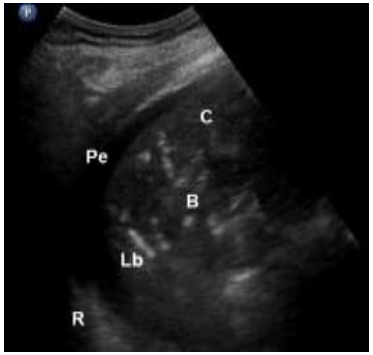
Ré-aération => Points positifs				**Perte d'aération => Points négatifs**		
+1 point	+3 points	+5 points		-5 points	-3 points	-1 point
1 -> 0 2 -> 1 3 -> 2	2 -> 0 3 -> 1	3 -> 0		0 -> 3	0 -> 2 1 -> 3	0 -> 1 1 -> 2 2 -> 3

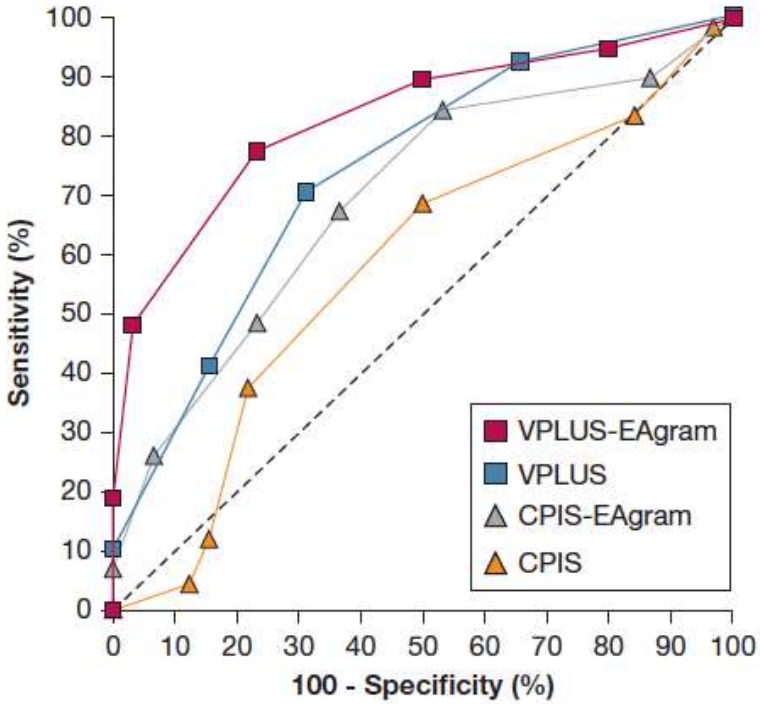
Diagnostic des PAVM: validation versus CPIS

Lung Ultrasound for Early Diagnosis of Ventilator-Associated Pneumonia

Silvia Mongodi, MD, PhD; Gabriele Via, MD; Martin Girard, MD; Isabelle Rouquette, MD; Benoit Misset, MD, PhD; Antonio Braschi, MD; Francesco Mojoli, MD; and Bélaïd Bouhemad, MD, PhD

Parameter	Points
VPLUS	
≥ 2 Areas with subpleural consolidations	1
≥ 1 Area with dynamic linear air bronchogram	2
Purulent secretions	1
Positive EAgram[a]/EAquant[b]	2



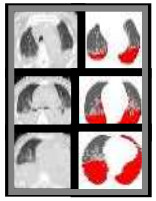


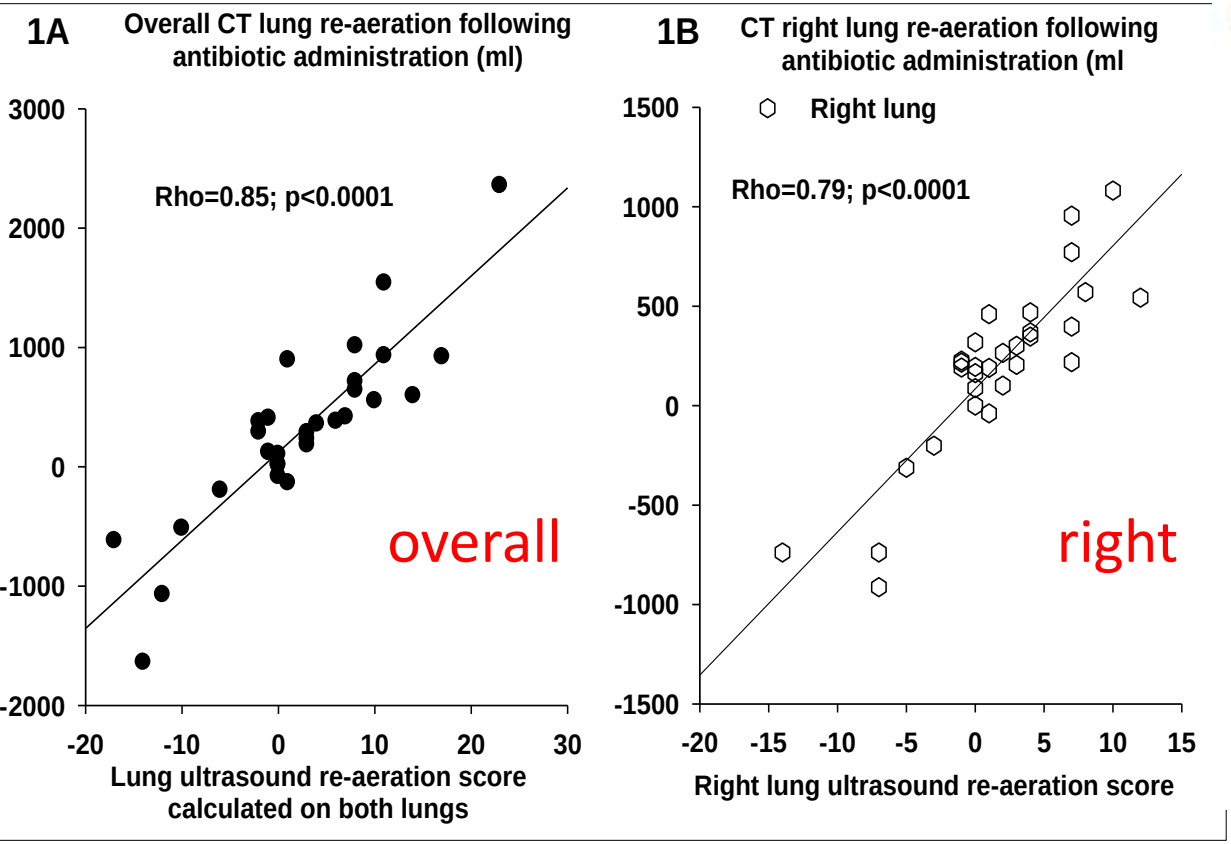
Mongodi et al. Chest, 2016

Réaération dans les PAVM: validation versus TDM

Ré-aération => Points positifs				Perte d'aération => Points négatifs		
+1 point	+3 points	+5 points		-5 points	-3 points	-1 point
1 -> 0 2 -> 1 3 -> 2	2 -> 0 3 -> 1	3 -> 0		0 -> 3	0 -> 2 1 -> 3	0 -> 1 1 -> 2 2 -> 3

versus





Bouhemad B, *Crit Care Med*, 2010

Réaération dans le SDRA: validation versus courbes P/V

ZEEP

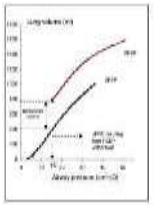
PEEP 10 cmH_2O

Bouhemad B, *AJRCCM*, 2011

Réaération dans le SDRA: validation versus courbes P/V

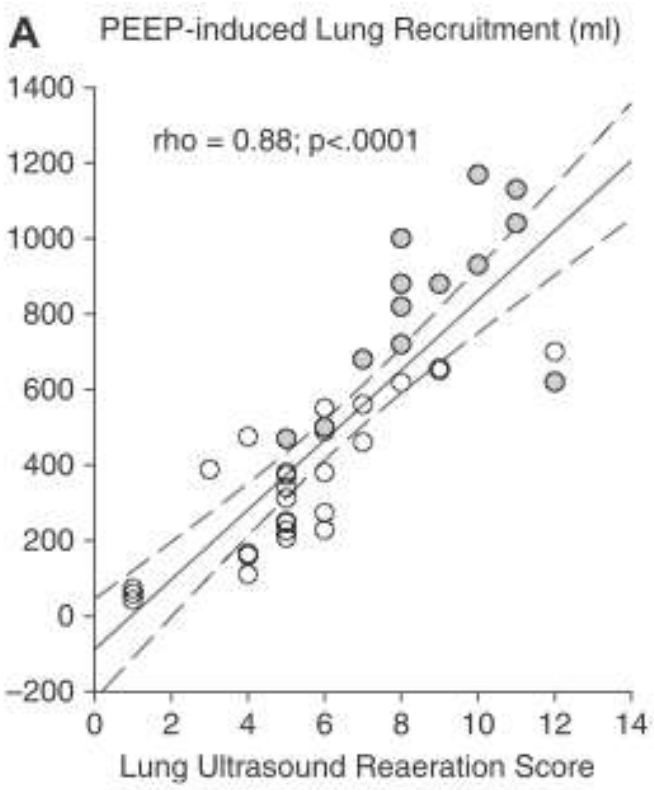
Ré-aération => Points positifs				Perte d'aération => Points négatifs		
+1 point	+3 points	+5 points		-5 points	-3 points	-1 point
1 -> 0 2 -> 1 3 -> 2	2 -> 0 3 -> 1	3 -> 0		0 -> 3	0 -> 2 1 -> 3	0 -> 1 1 -> 2 2 -> 3

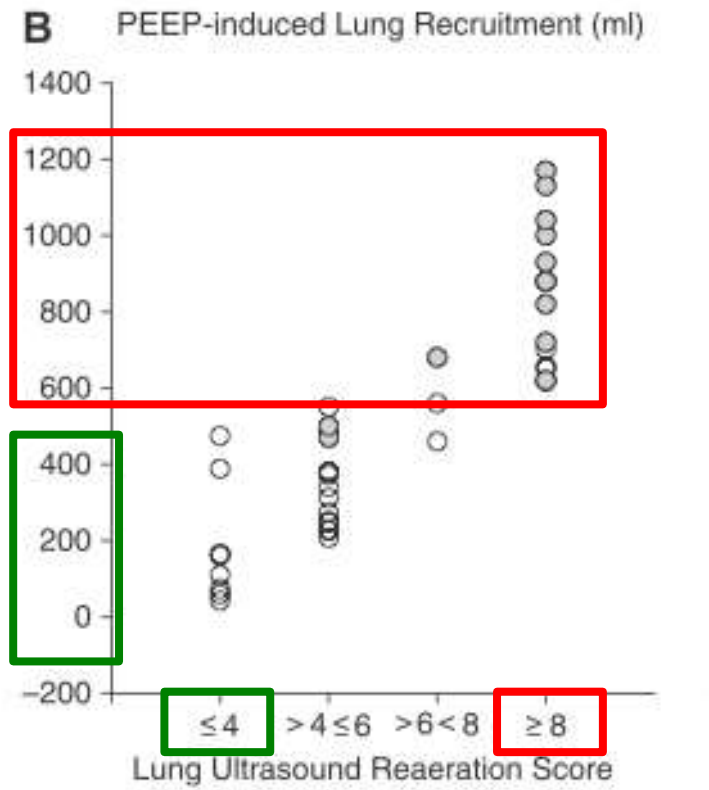
versus



20 patients
Peep 15 cm H2O
15 min

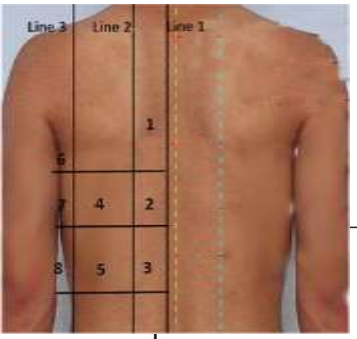
Score de ré-aération 8 ou plus
=> Volume recruté > 600ml



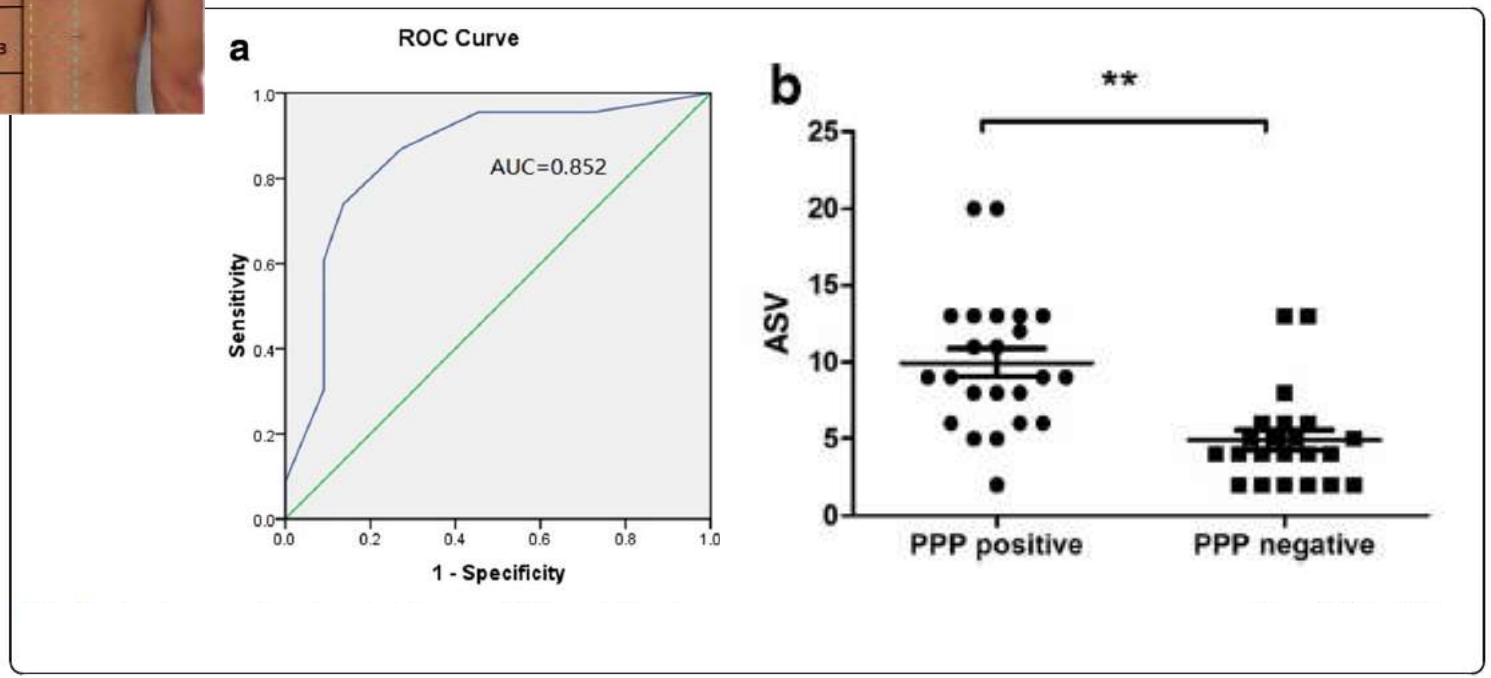


Bouhemad B, *AJRCCM*, 2011

Réaération dans le SDRA: validation lors de décubitus ventral

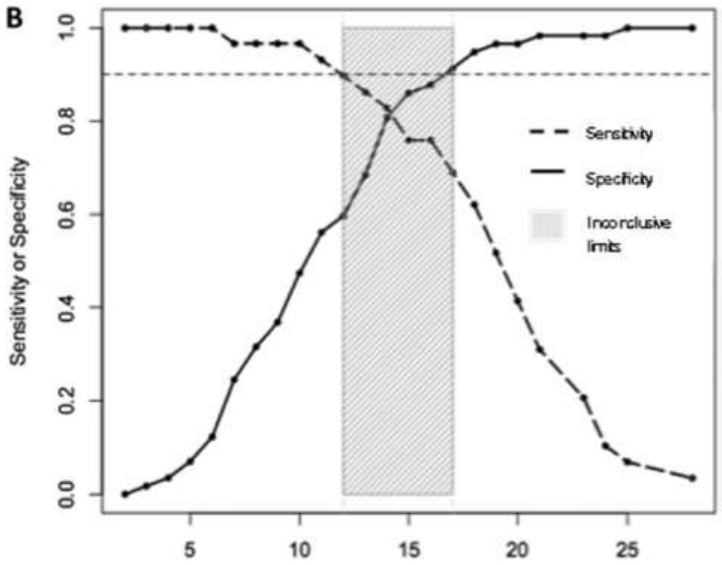


- n = 60



Wang et al. Crit Care, 2016

Dérecrutement lors du sevrage: prédiction de l'échec de sevrage



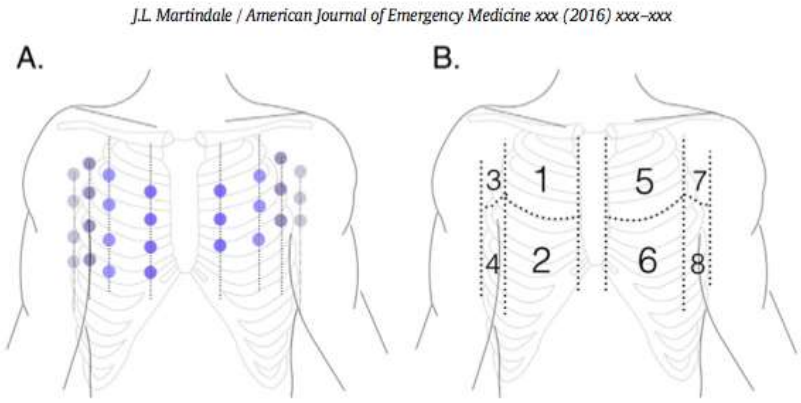
Fin d'épreuve de VS

Sevrage respiratoire > 48h

<13 => sevrage réussi
>17 => échec de sevrage

Soumer et al. Crit Care Med, 2012

Perte d'aération dans l'OAP: Eau pulmonaire extra-vasculaire



Score	Nombre de Lignes B	Eau pulmonaire extravasculaire
0	≤ 6	Non pathologique
1	6 – 15	Peu sévère
2	15 – 30	Modérément sévère
3	> 30	Très sévère

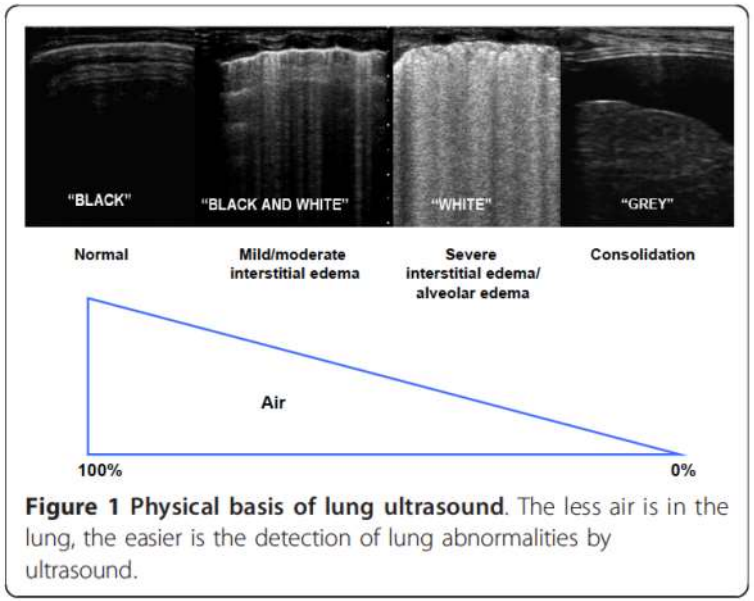
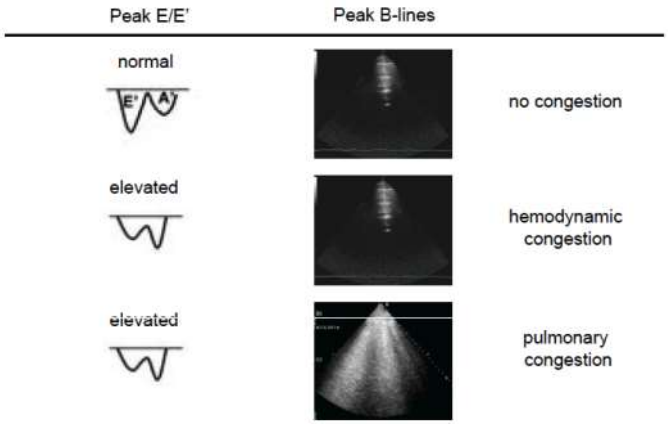


Figure 1 Physical basis of lung ultrasound. The less air is in the lung, the easier is the detection of lung abnormalities by ultrasound.

Martindale et al. *Am J Em Med*, 2016

Perte d'aération dans l'OAP: Eau pulmonaire extra-vasculaire

- Echographie pulmonaire et « congestion pulmonaire »
  - Validé *versus* NYHA
  - Validé *versus* lignes de Kerley
  - Validé *versus* Thermodilution
  - Validé versus PAPO
  - Validé *versus* dysfonction diastolique ETT
  - Validé *versus* BNP
  - Validé *versus* « stress-echo »
  - Validé versus TTT
    - Diurétiques
    - Dialyse
    - Traitement de l'insuffisance cardiaque
  - Pronostic



Martindale et al. *Am J of Em Med,* 2016
Gargani et al. *Cardiovasc Ultras*, 2011

conclusion

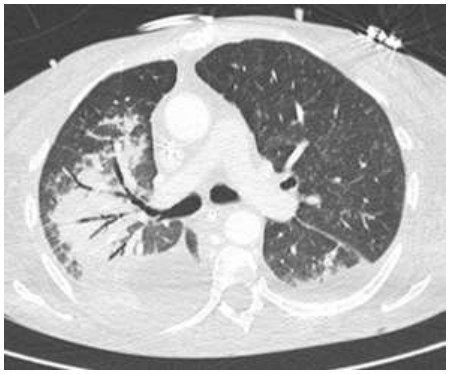
- Non invasif
- Réalisable au lit
- Apprentissage rapide
- Diagnostic → validé
  - Pneumopathie
  - SDRA (PEEP, DV)
  - Échec de VS/tube (sevrage VM)
  - Œdème
- Monitorage → validé
  - Recrutement
  - Dérecrutement
  - Distribution régionale

Mongodi et al. Chest, 2016
Bouhemad B, AJRCCM, 2011
Wang et al. Crit Care, 2016
Martindale et al. *Am J of Em Med,* 2016
Gargani et al. *Cardiovasc Ultras*, 2011
Soumer et al. Crit Care Med, 2012

Limites

- Parenchyme sain
- Emphysème sous cutanée
- Echogénicité
- Opérateur-dépendant
- Aveugle de la surdistension

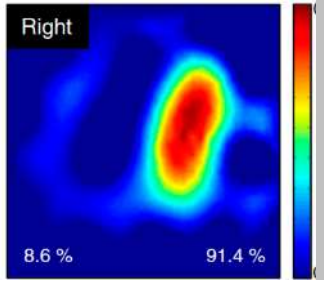
?



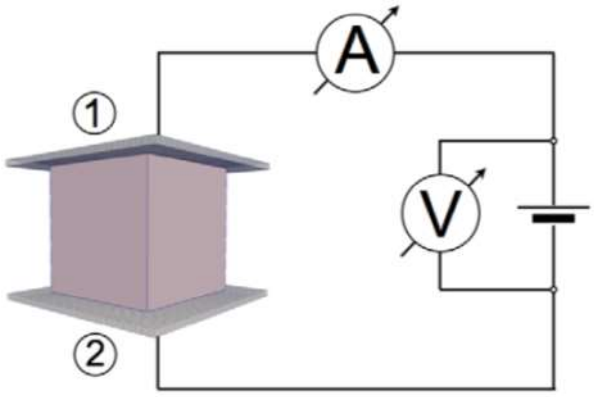
Outils non-invasifs ?

Échographie pulmonaire

Tomographie d’impédance électrique

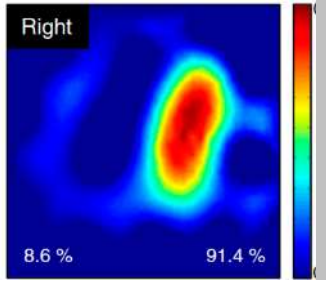


Tomographie d'impédance: principes

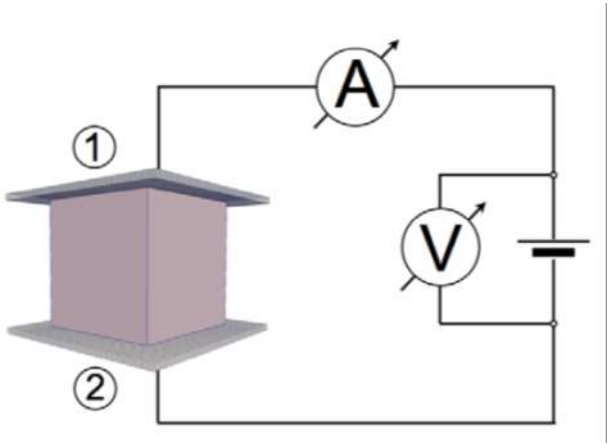


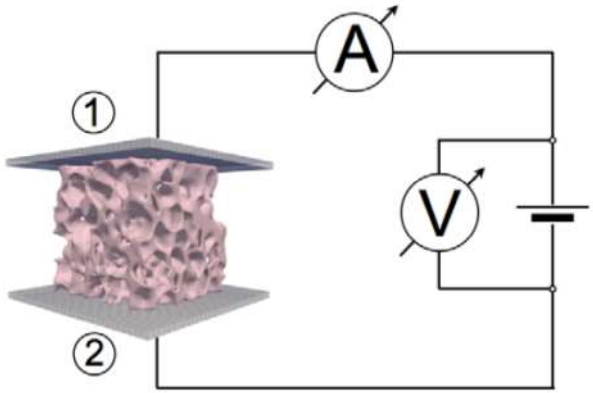
Z_1

- Impédance (résistance) varie en fonction de l'état d'aération d'une particule élémentaire



Tomographie d'impédance: principes

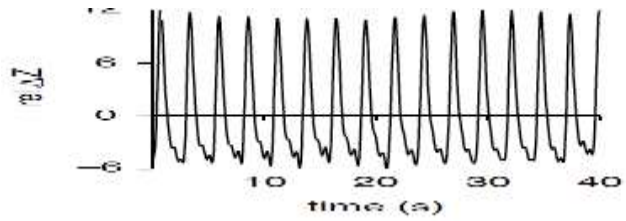




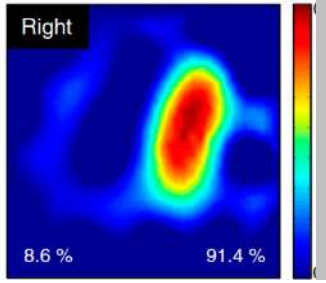
Z_1 ⟷ Z_2

Δ_Z

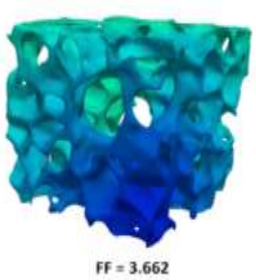
T_1 → T_2

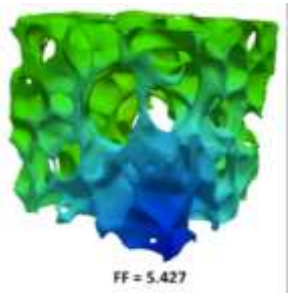


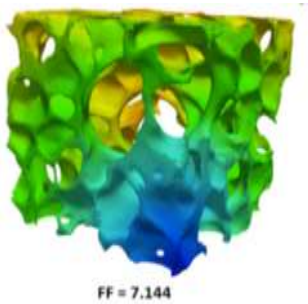
= une couleur
= aération
= ventilation
= stretching
= Vt / voxel



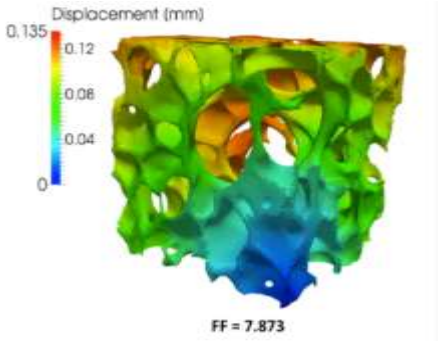
Tomographie d'impédance: principes







Δ_z

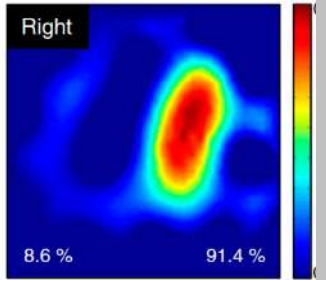


Contrainte 1

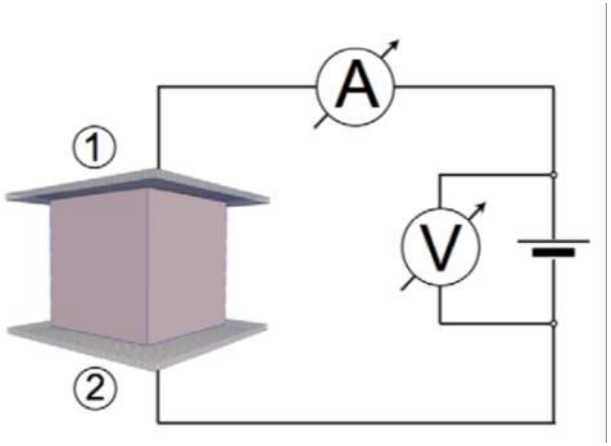
Contrainte 2

Contrainte 3

Contrainte 4



Tomographie d'impédance: principes



Z_1

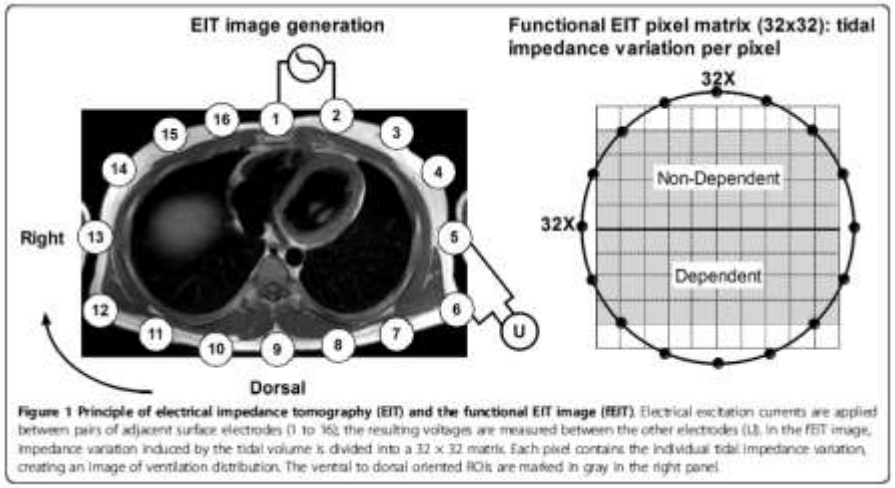
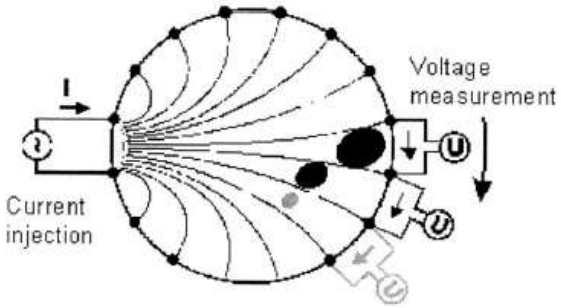
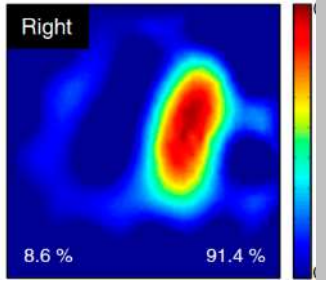


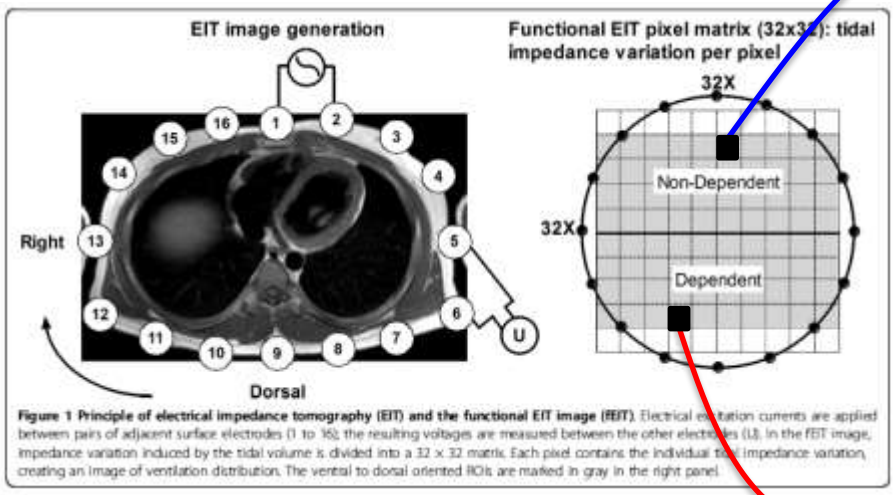
Figure 1 Principle of electrical impedance tomography (EIT) and the functional EIT image (fEIT). Electrical excitation currents are applied between pairs of adjacent surface electrodes (1 to 16); the resulting voltages are measured between the other electrodes (U). In the fEIT image, impedance variation induced by the tidal volume is divided into a 32 × 32 matrix. Each pixel contains the individual tidal impedance variation, creating an image of ventilation distribution. The ventral to dorsal oriented ROIs are marked in gray in the right panel.

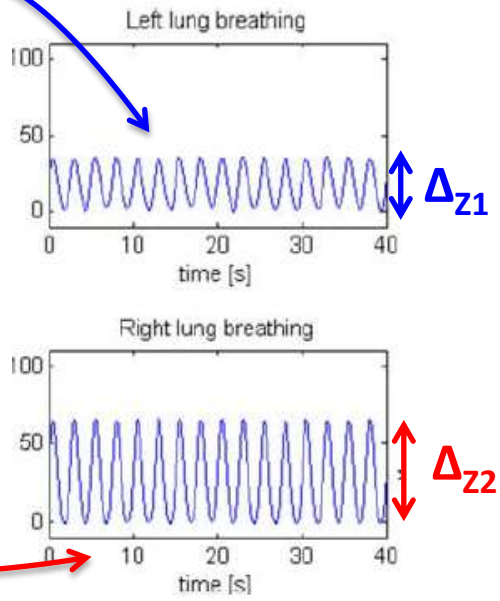


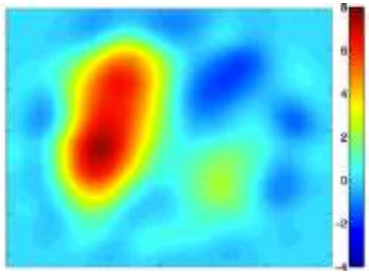
50 rotations par seconde

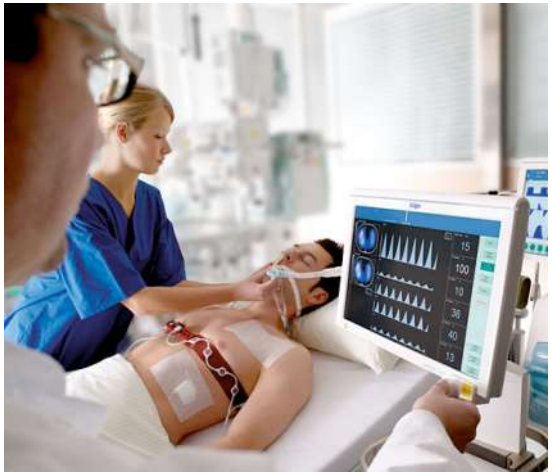


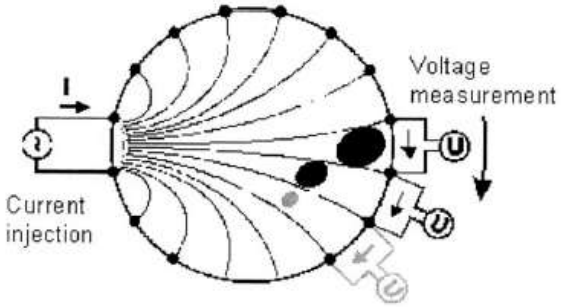
Tomographie d'impédance: principes



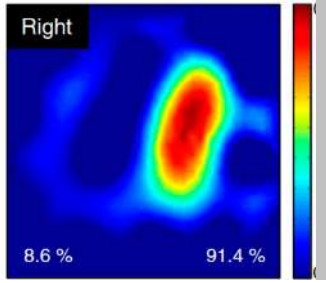




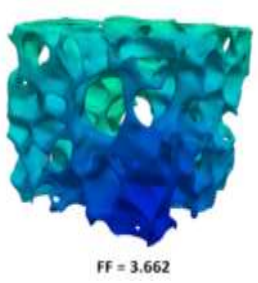




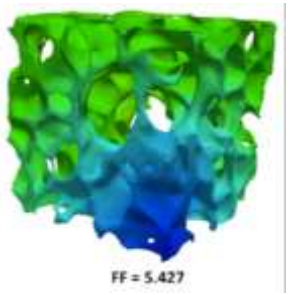
50 rotations par seconde



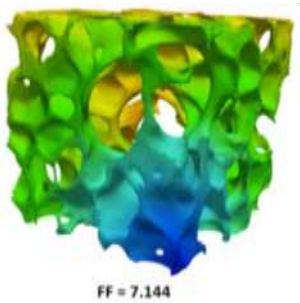
Tomographie d'impédance: principes



Contrainte 1

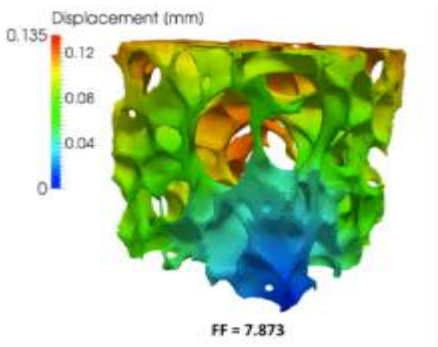


Contrainte 2



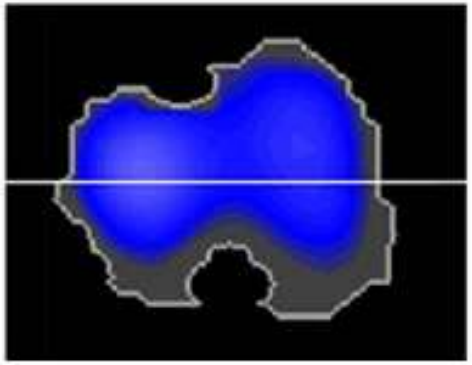
Contrainte 3

Δ_z

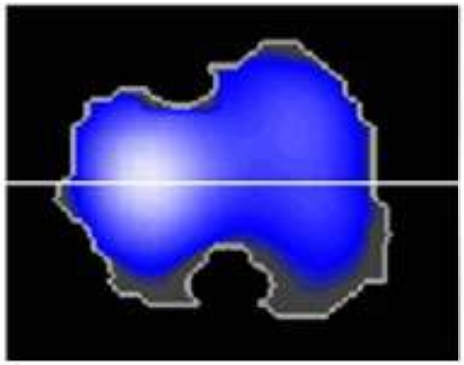


Contrainte 4

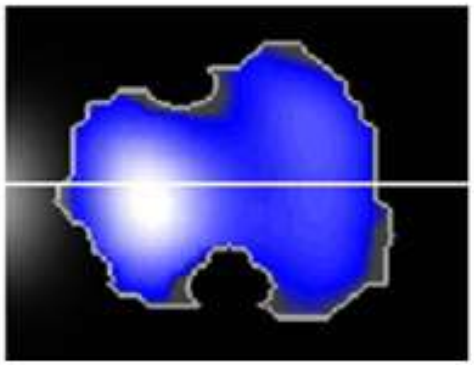
PEEP 0 cm H2O



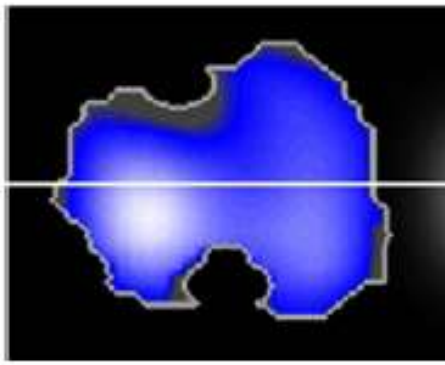
PEEP 5 cm H2O

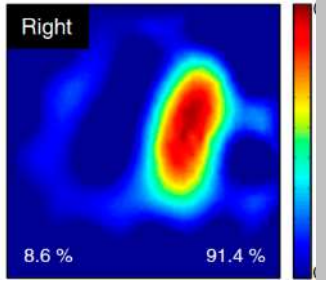


PEEP 10 cm H2O



PEEP 15 cm H2O



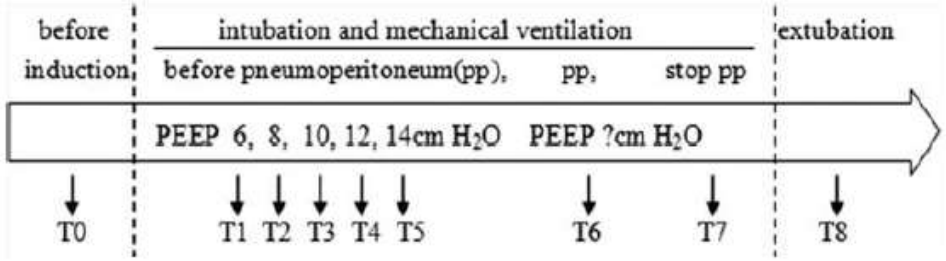


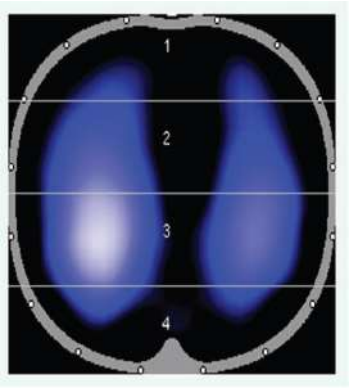
PEEP en peropératoire

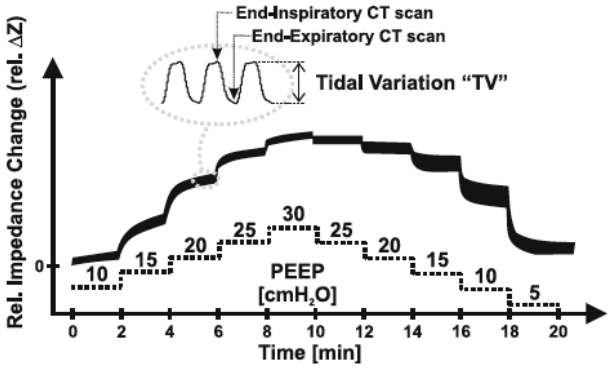
Medicine
CLINICAL TRIAL/EXPERIMENTAL STUDY
OPEN

Electrical Impedance Tomography-guided PEEP Titration in Patients Undergoing Laparoscopic Abdominal Surgery

Xingying He, MD, PhD, Jingjing Jiang, MD, Yuli Liu, MD, Haitao Xu, MD, Shuangqiong Zhou, MD, Shibo Yang, MD, Xueyin Shi, MD, PhD, and Hongbin Yuan, MD, PhD

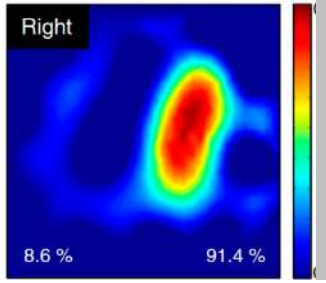






- Groupe expérimental (n=25)
  - Best-PEEP
    - deltaZ max zones 3-4
    - deltaZ min zones 1-2
- Groupe contrôle (n=25)
  - Best-PEEP: compliance dynamique

He et al. *Medicine,* 2016



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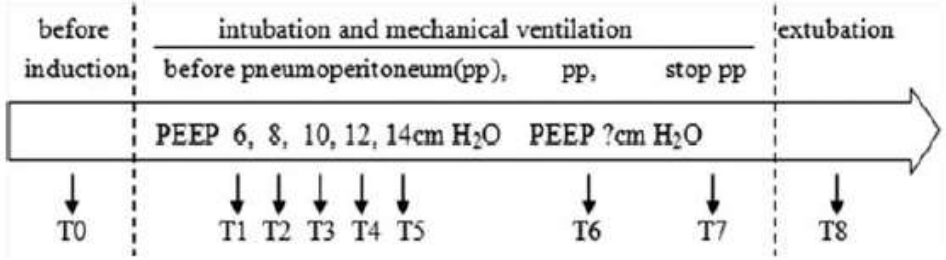
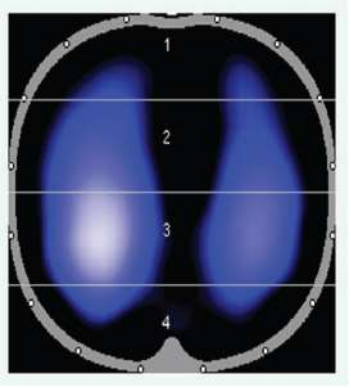
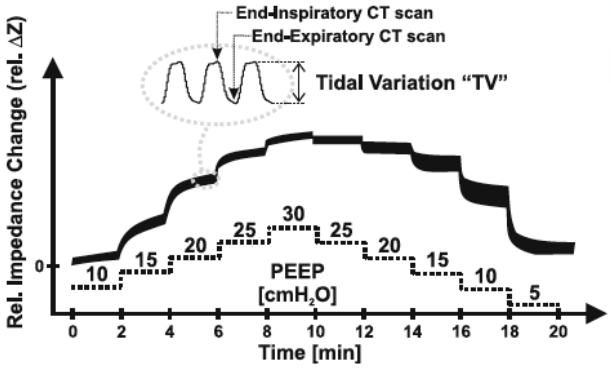
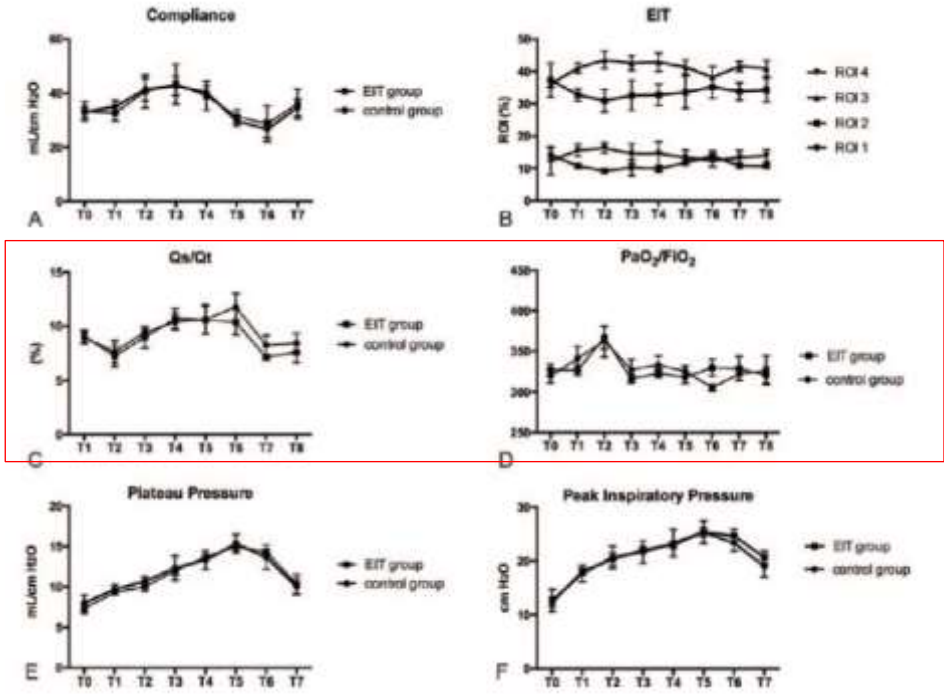
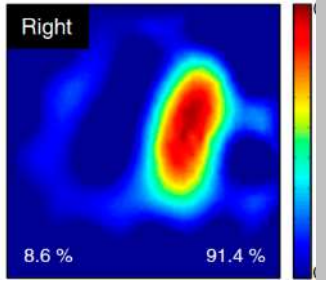








He et al. *Medicine,* 2016



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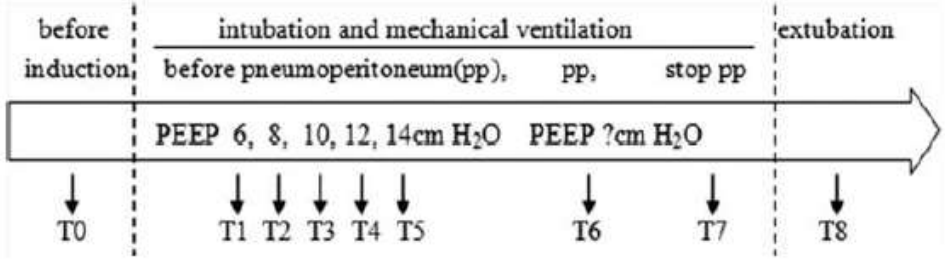
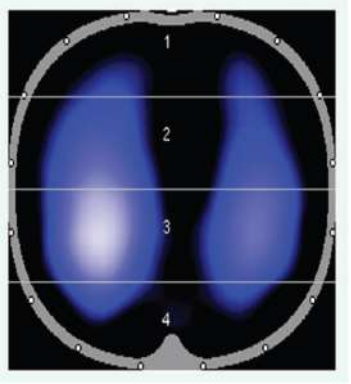
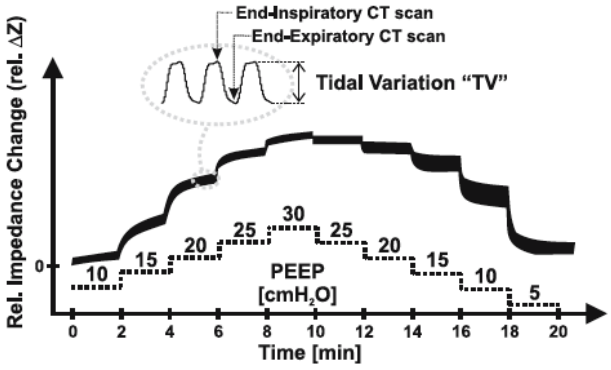
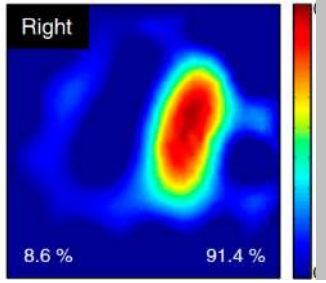


	Control Group (n = 23)	EIT Group (n = 19)
Hypoxia ($SpO_2 < 90\%$)	2	1
Atelectasis	2	1
Pneumonia	0	0
Suspected pulmonary Infection	0	0
Development of ARDS	0	0





He et al. *Medicine,* 2016

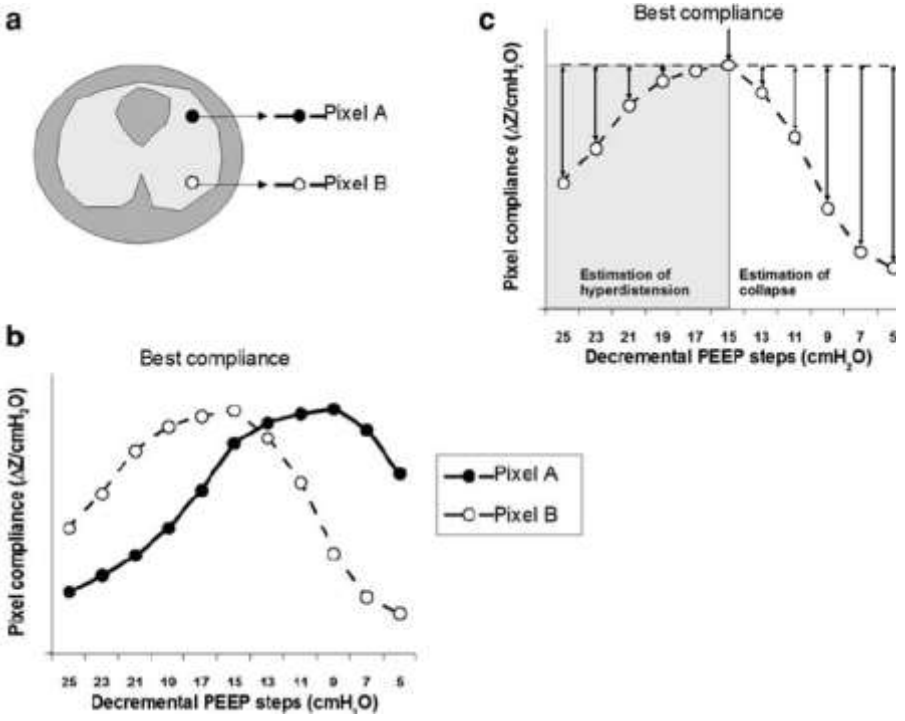


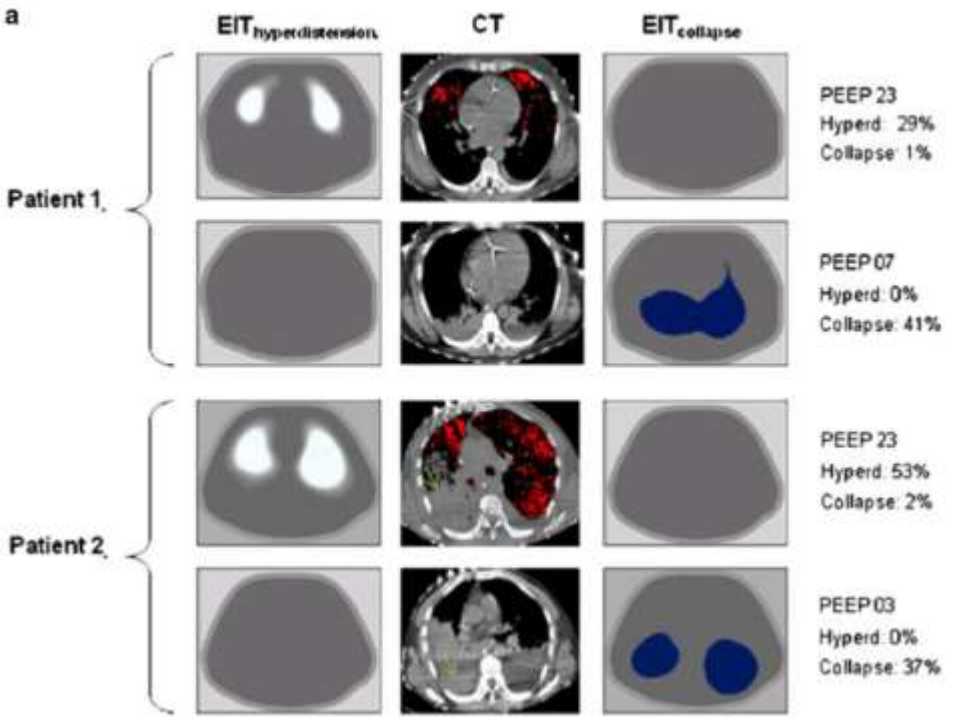
PEEP dans le SDRA

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

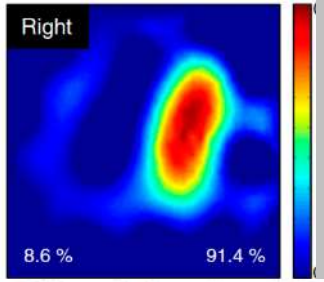
Bedside estimation of recruitable alveolar collapse and hyperdistension by electrical impedance tomography

- n = 2
  - PEEP décroissante





Costa et al. *Int Care Med,* 2009

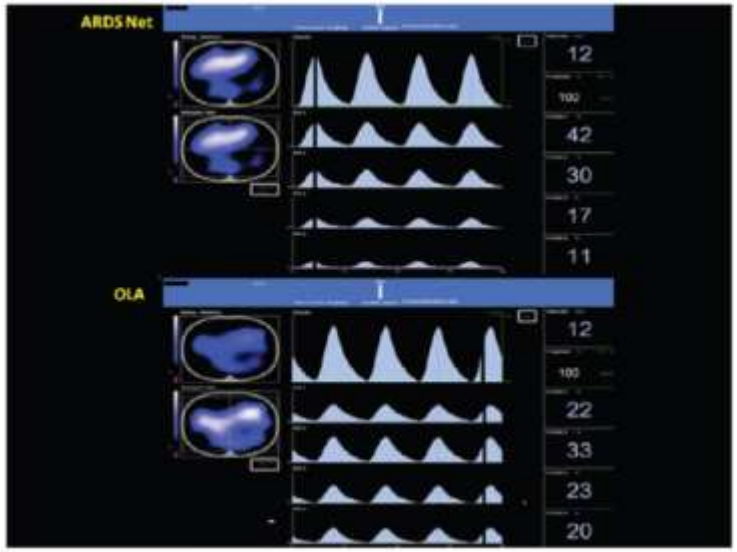


« open lung strategy » dans le SDRA

Physiological Effects of the Open Lung Approach in Patients with Early, Mild, Diffuse Acute Respiratory Distress Syndrome

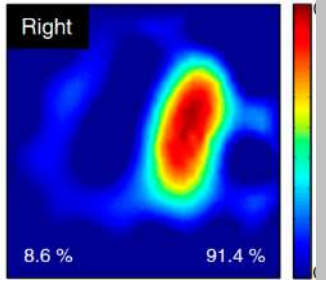
An Electrical Impedance Tomography Study

Gilda Cinnella, M.D., Salvatore Grasso, M.D., Ph.D., Pasquale Raimondo, M.D., Davide D'Antini, M.D., Lucia Mirabella, M.D., Ph.D., Michela Rauseo, M.D., Michele Dambrosio, M.D., Ph.D.



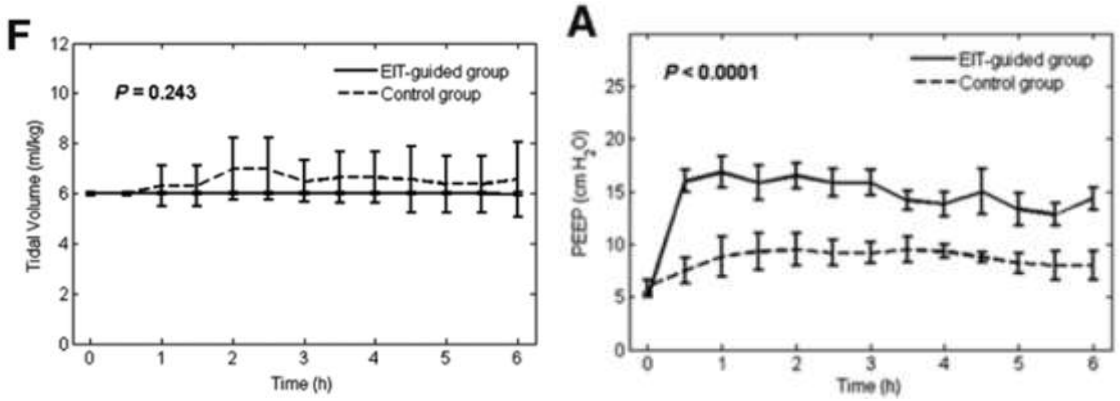
	Pre-OLA	Post-OLA	Wilcoxon, *P* Value
$ROI_{Ventral}$ (%)	66 ± 4.3	54 ± 2	<0.00001
ROI_{Dorsal} (%)	33 ± 4.3	45 ± 2	<0.00001
$ROI_{Ventral/Dorsal}$	2.01 ± 0.36	1.19 ± 0.1	<0.00003
$V_{T_{Ventral}}$/kg (ml/kg)	4.22 ± 0.64	4.26 ± 0.43	NS
$V_{T_{Dorsal}}$/kg (ml/kg)	2.11 ± 0.3	3.55 ± 0.41	<0.00001

Cinella et al. *Anesthesiology*, 2015

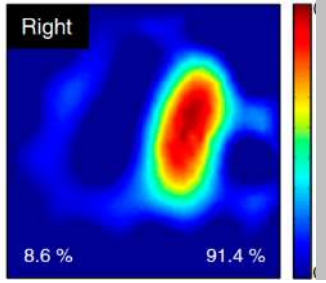


Ventilation guidée par impédance

- n = 6 (contrôle) *versus* 6 (groupe « EIT »)
  - Contrôle: ARDSnet
    - PEEP/FiO2 abaques
    - 6 mL/kg
    - Pplat < 30 cmH_2O
  - Expérimental: EIT-guided
    - 6 mL/kg
    - PEEP qsp meilleur compliance zone dépendante sans surdistension des zones non-dépendantes



Wolf et al. *Crit Care Med,* 2013



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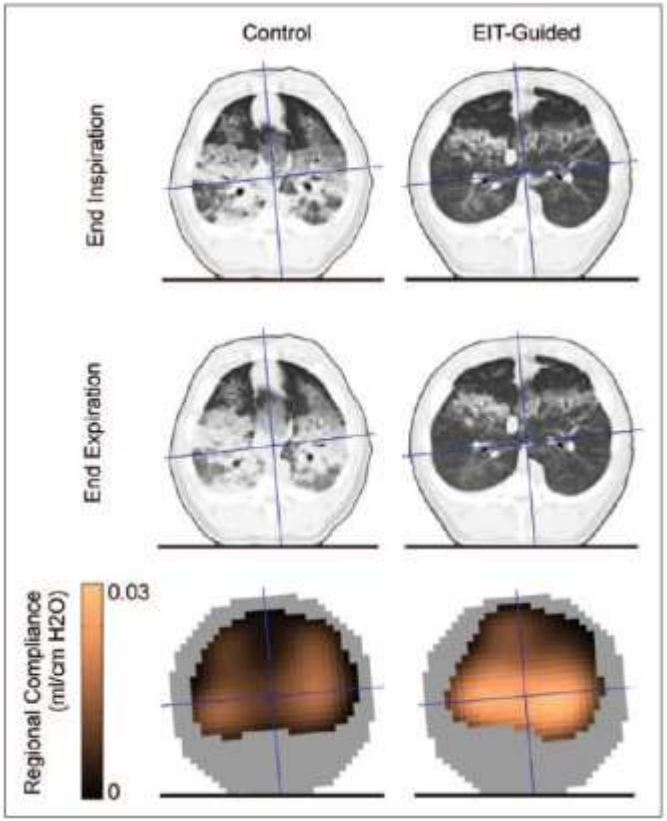
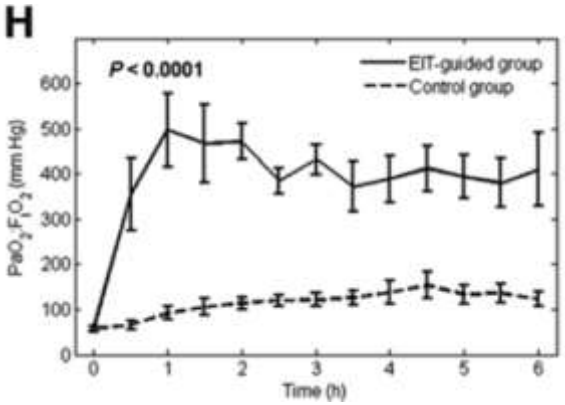
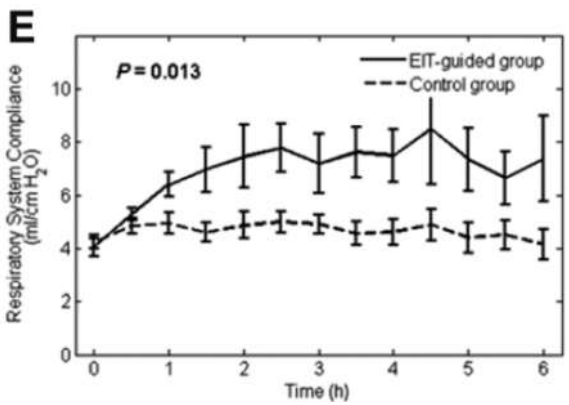
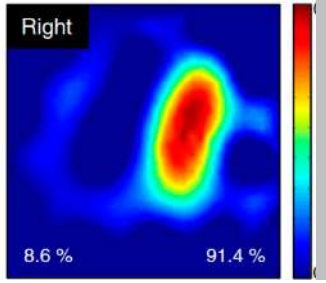






Wolf et al. *Crit Care Med,* 2013



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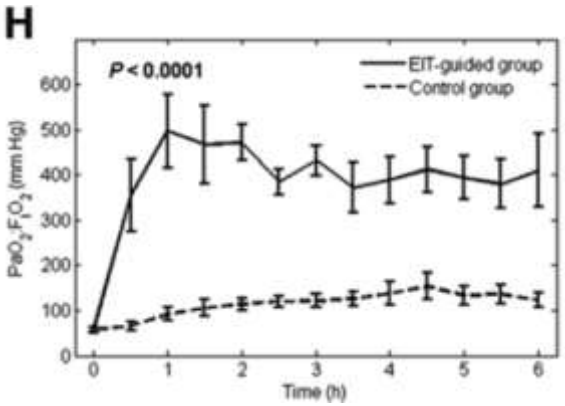
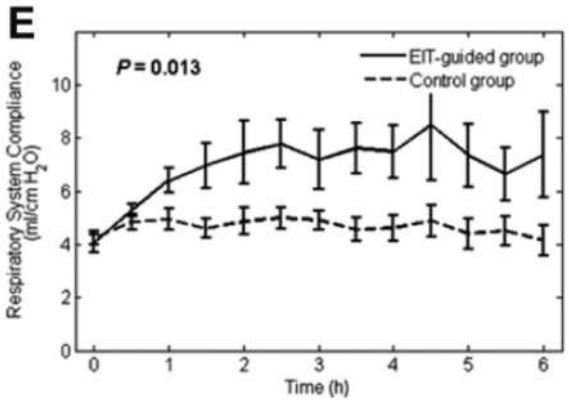
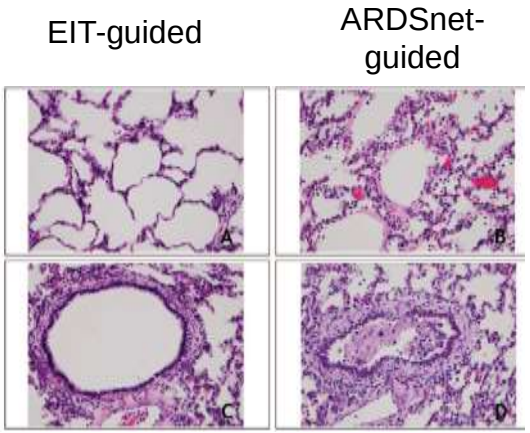
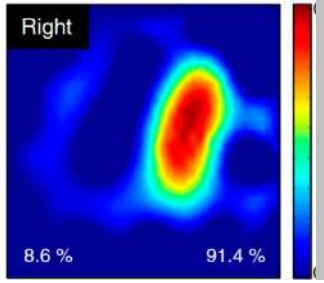






Wolf et al. *Crit Care Med,* 2013



Tomographie d'impédance: validation

- SDRA expérimental (cochons)
  - Recrutabilité - dérecrutement
  - Eau pulmonaire extravasculaire
  - « best PEEP »
  - Ventilation guidée sur l'EIT

Meier et al. *Int Care Med,* 2008
Trepte et al. *Crit Care*, 2016
Wolf et al. *Min Anesth*, 2013

- Per-opératoire (célioscopie)
  - « Best-PEEP » per-opératoire (1 étude négative)
  - Recrutement induit par la PEEP

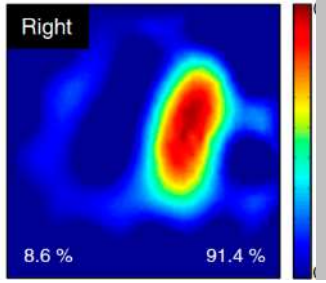
He et al. *Medicine,* 2016
Karsten et al. *Minerva*, 2014
Karsten et al. *Acta Anesth*, 2011
Erlandsson et al. *Acta Anesth*, 2006

- Réanimation
  - Recrutement induit par la PEEP en réanimation – **surdistension** (n = 14)

Bikker et al. *Crit Care*, 2010

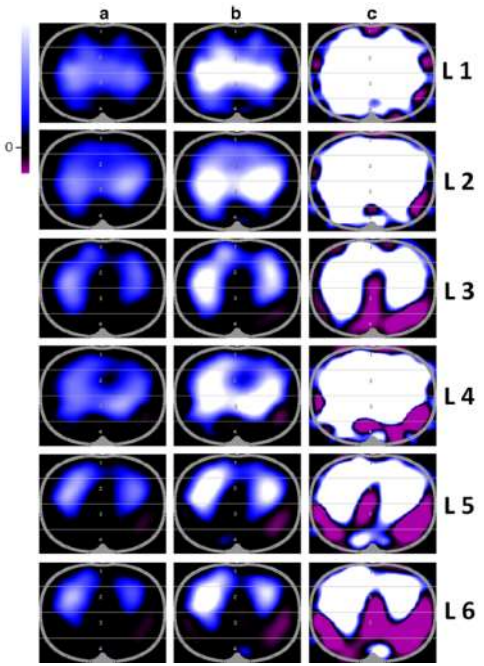
- Recrutement dans le SDRA
  - Induit par la PEEP (n = 8)
  - « Best-PEEP » -- **surdistension** (n = 12)
  - « Open lung strategy » (n = 15)
  - *versus* TDM : recrutabilité – **surdistension** (n = 2)
  - Homogénéisation des rapports V/Q (n = 10)

Costa et al. *Int Care Med,* 2009
Mauri et al. *Crit Care Med*, 2013
Cinella et al. *Anesthesiology*, 2015
Hinz et al. Eur J Anesth, 2005
Blankman et al. *Crit Care*, 2014

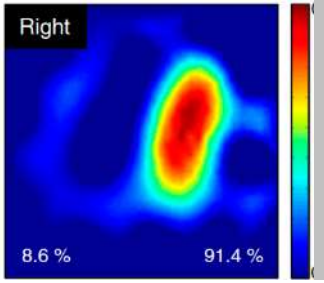


Tomographie d'impédance: limites

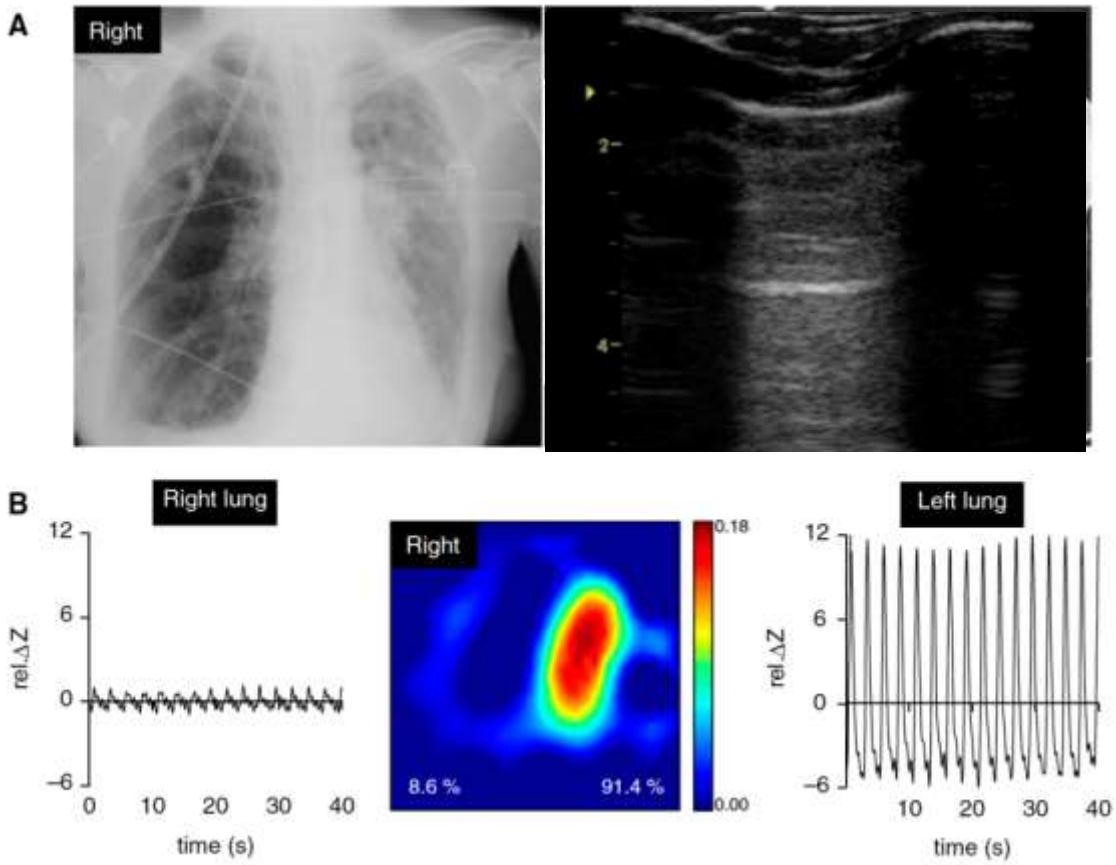
- Expérimental: peu de patients
  - Effectifs faibles
  - Peu d'études contrôlées
  - Peu d'évaluation de l'impact sur la morbi-mortalité
- Limites techniques:
  - Un seul niveau de coupe
  - Position des électrodes: niveau de coupe
  - Réglages
  - Déphasages
- Ambiguïté du $\Delta z = 0$
  - Complémentaire avec échographie ?



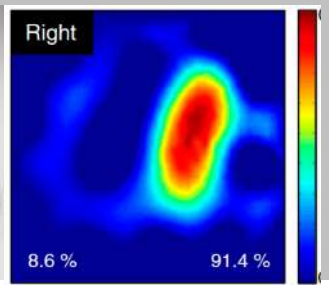
Karsten et al. *Crit Care*, 2016
Ericsson et al. *PlosOne,* 2016



Tomographie d’impédance: limites



Guérin et al. *Am J Respir Crit Care Med,* 2014



conclusions

- 2 techniques qui ne s’opposent pas
  - Complémentaires
  - Pas au même stade de développement
- Espoir sur le monitorage de la surdistension
  - Seule technique morphologique permettant de monitorer la surdistension
  - Au lit du patient
- Perspectives
  - Développer les études contrôlées sur l’impact de l’outil échographique
  - Continuer d’évaluer l’EIT
  - Augmenter les effectifs, faire du contrôlé, morbi-mortalité
  - Tester l’approche mixte: écho + EIT