CEC EN CHIRURGIE THORACIQUE

PR HADRIEN ROZÉ

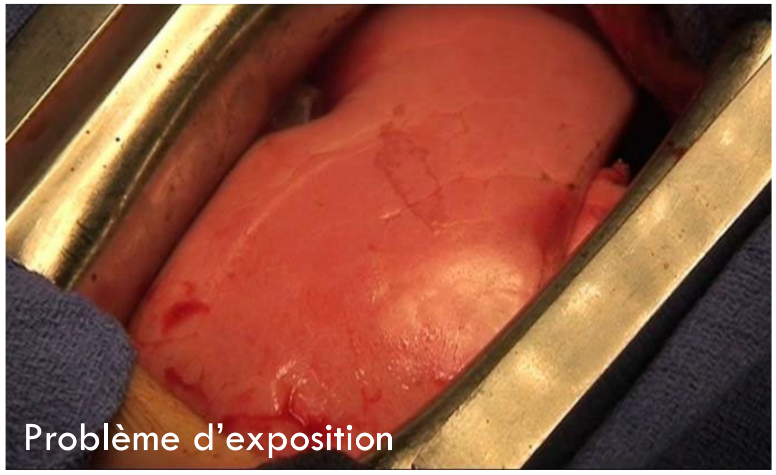
DU CEC JUIN 2024

EXPOSITION CHIRURGICALE

MAINTIENT DE L'HÉMATOSE
MAINTIENT DU DÉBIT CARDIAQUE

PROTECTION VENTILATION

PROTECTION PERFUSION



Problème d'exposition

Problème d'hématose

CARDIAQUE ET/OU PULMONAIRE

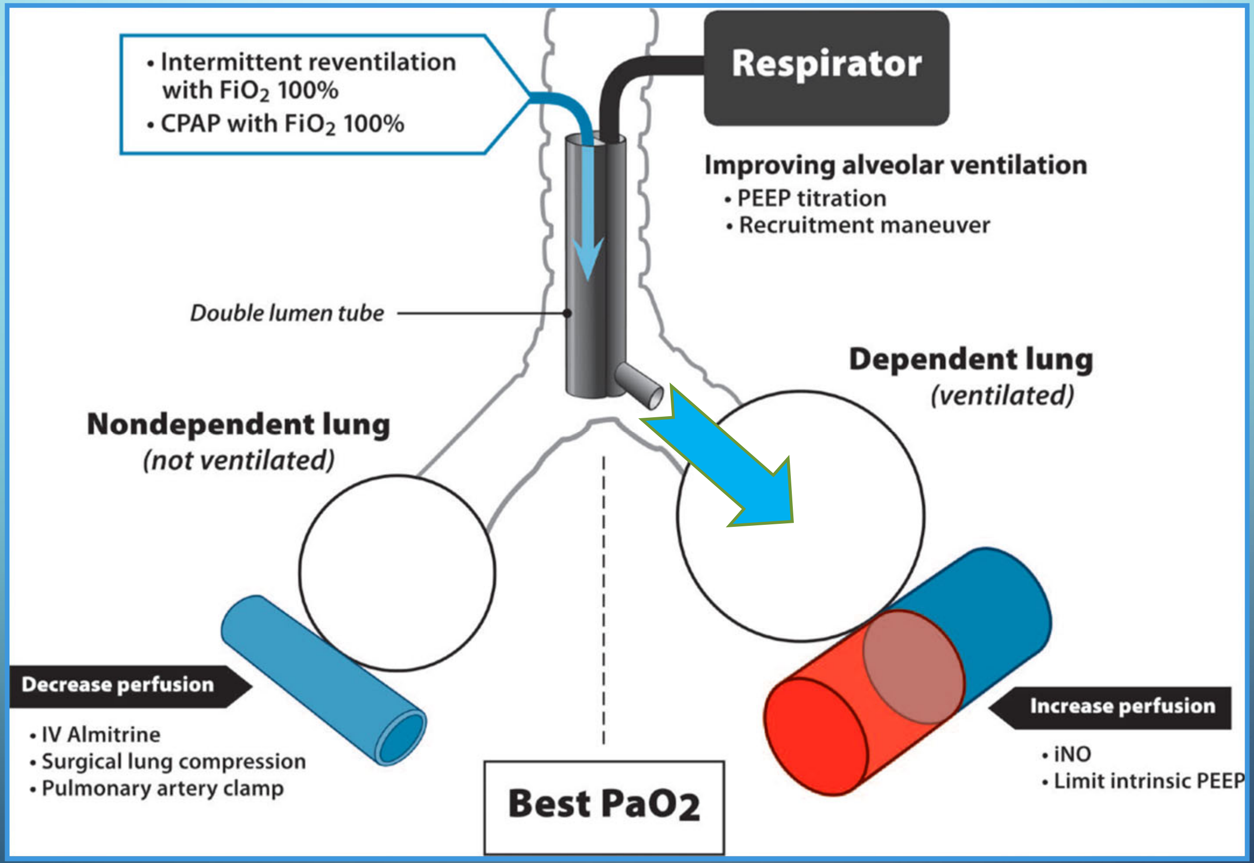
- **Assistance cardiaque**
- Hématose 100% CEC
  - Oxygénation
  - Décarboxylation
- +/-Ventilation alvéolaire
  - De 0 à 100%

Poumons sains

- **Assistance respiratoire**
- Hématose mixte
- CEC ou ECMO
- Mécanique respiratoire
  - Volume aéré, volume courant
  - Pressions : Pplat, Pmo et PEEP
  - Fréquence respiratoire

Poumons lésés

LA VENTILATION UNIPULMONAIRE



- Intermittent reventilation with FiO_2 100%
- CPAP with FiO_2 100%

Respirator

Improving alveolar ventilation
- PEEP titration
- Recruitment maneuver

Double lumen tube

Dependent lung
(ventilated)

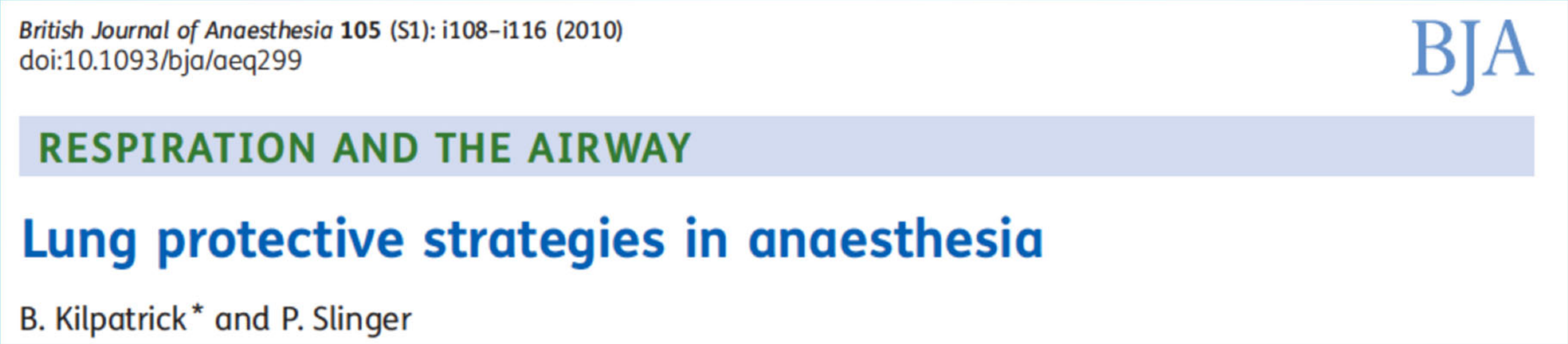
Nondependent lung
(not ventilated)

Decrease perfusion
- IV Almitrine
- Surgical lung compression
- Pulmonary artery clamp

Increase perfusion
- iNO
- Limit intrinsic PEEP

Best PaO2

Roze et al. Anesthesiology 2011



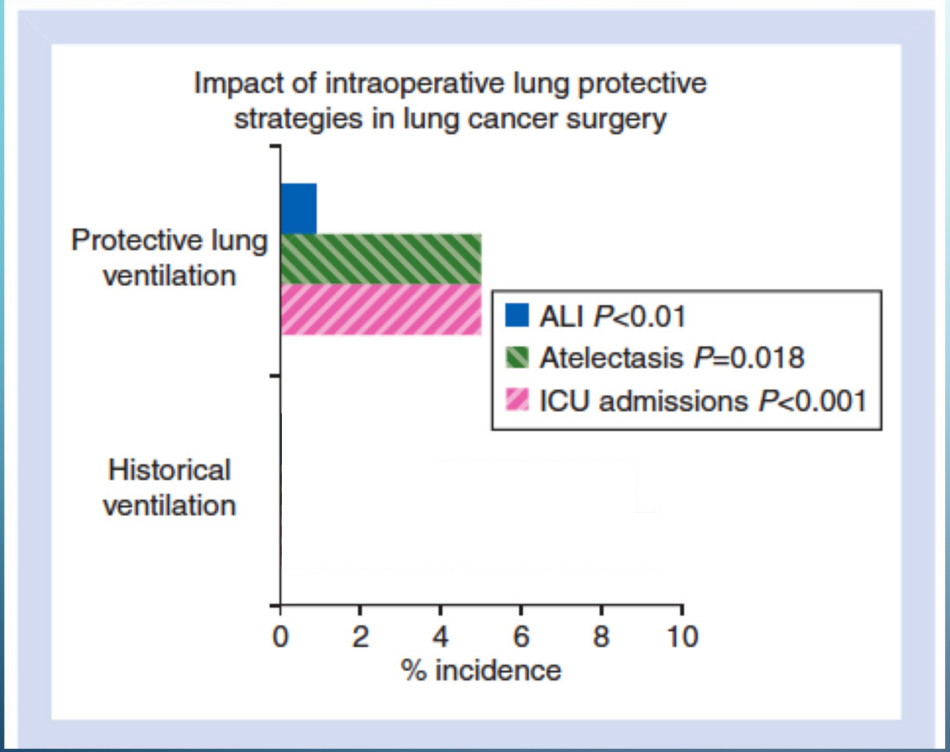
British Journal of Anaesthesia **105** (S1): i108–i116 (2010)
doi:10.1093/bja/aeq299

BJA

RESPIRATION AND THE AIRWAY

Lung protective strategies in anaesthesia

B. Kilpatrick* and P. Slinger



Protective
Moins de Volume = Moins de complications

VS

Historique
Gros Volume = Meilleure PaO2

ASSISTANCE VEINO VEINEUSE

- Objectif garantir l’hématose (sécurité): CaO_2, pas d’assistance du débit TaO_2 et extraction du CO_2
- Possibilité de diminuer la ventilation minute: Volume et fréquence
- Possibilité d’être protecteur avec une pression motrice contrôlée

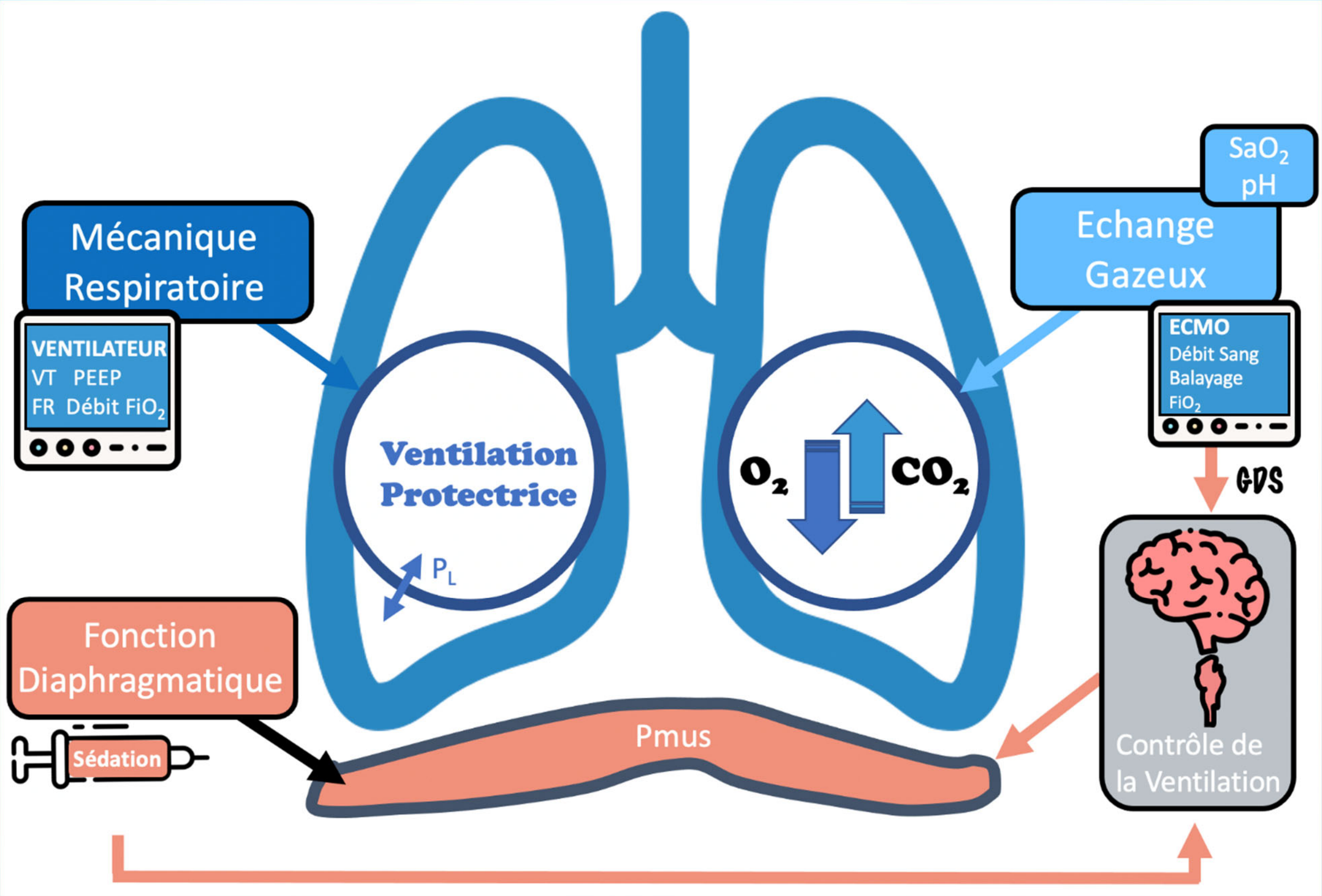
VENTILATION SOUS ECMO VV

Poumons lésés

- Hématose
  - Oxygénation
  - Décarboxylation

- Mécanique respiratoire
  - Volume aéré et volume courant
  - Pressions : Pplat Pmo et PEEP
  - Pression motrice
  - Fréquence respiratoire

Dissociation



Mécanique Respiratoire

VENTILATEUR
VT PEEP
FR Débit FiO_2

Ventilation Protectrice

P_L

Echange Gazeux

SaO_2
pH

ECMO
Débit Sang
Balayage
FiO_2

O_2 CO_2

GDS

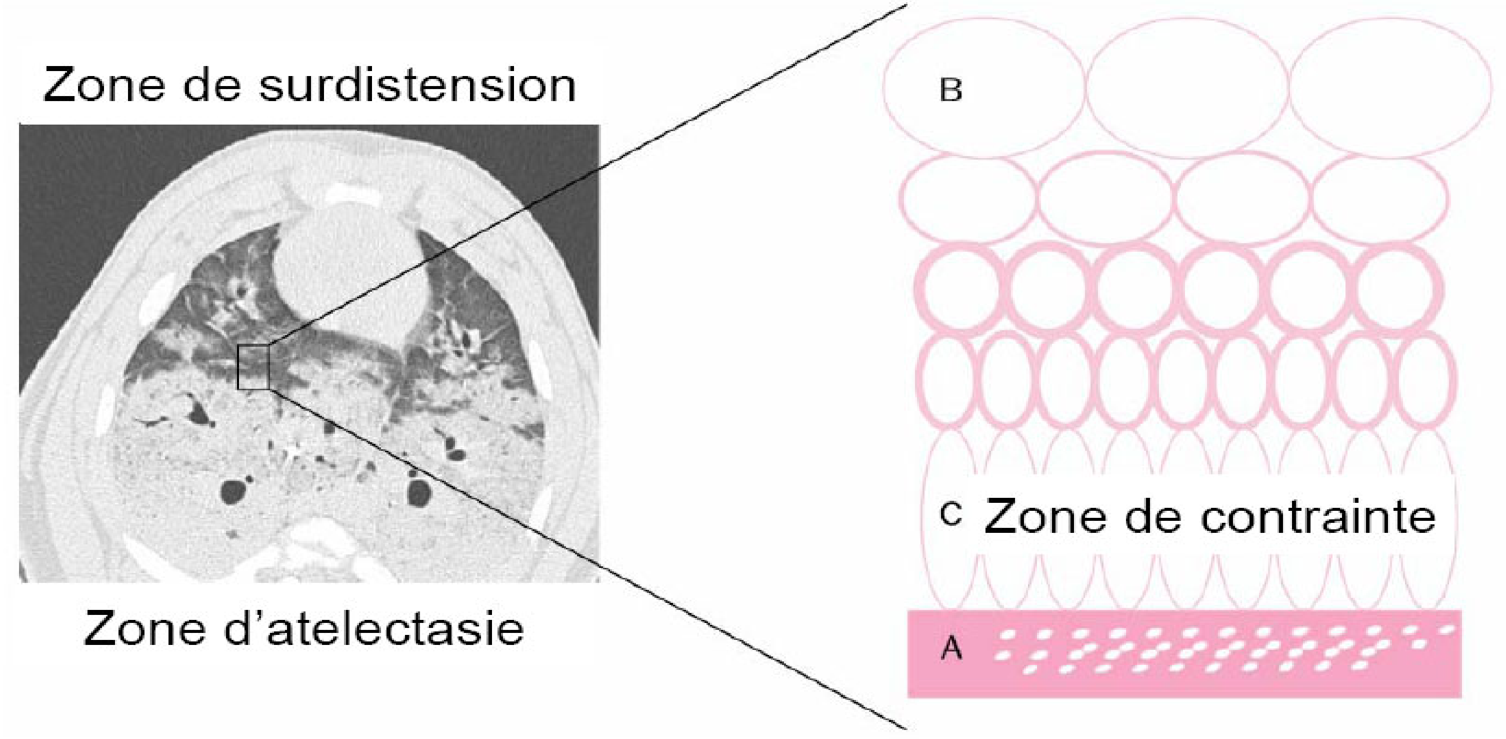
Fonction Diaphragmatique

Sédation

Pmus

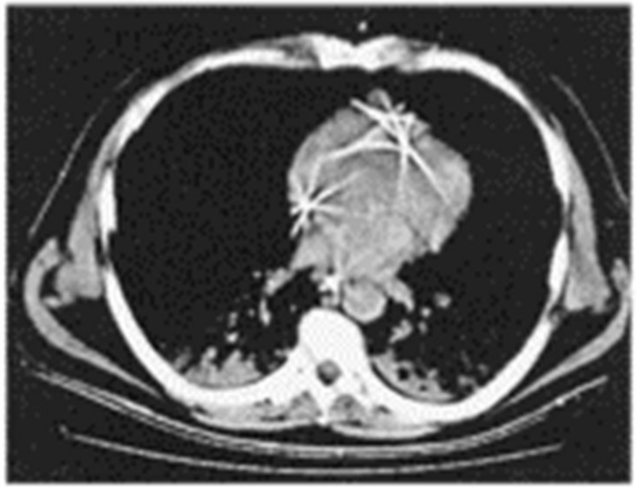
Contrôle de la Ventilation

LÉSIONS ALVEOLAIRES DE LA VENTILATION

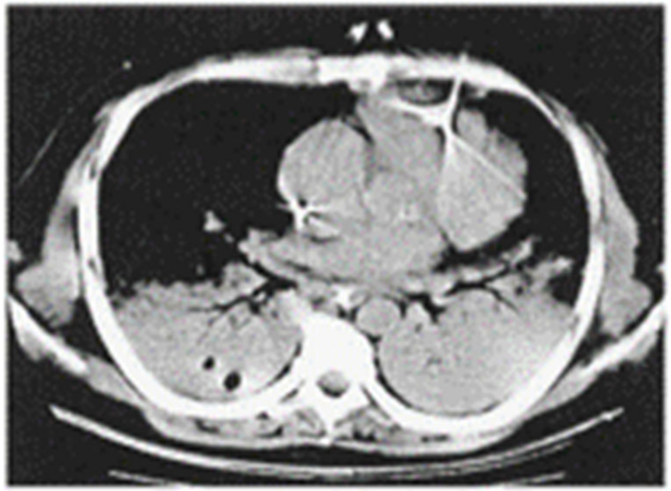

Zone de surdistension
Zone d'atelectasie
B
C Zone de contrainte
A

Etirement Alvéolaire

VOLUME PULMONAIRE AÉRÉ N'EST PAS LA CPT SI LÉSIONS



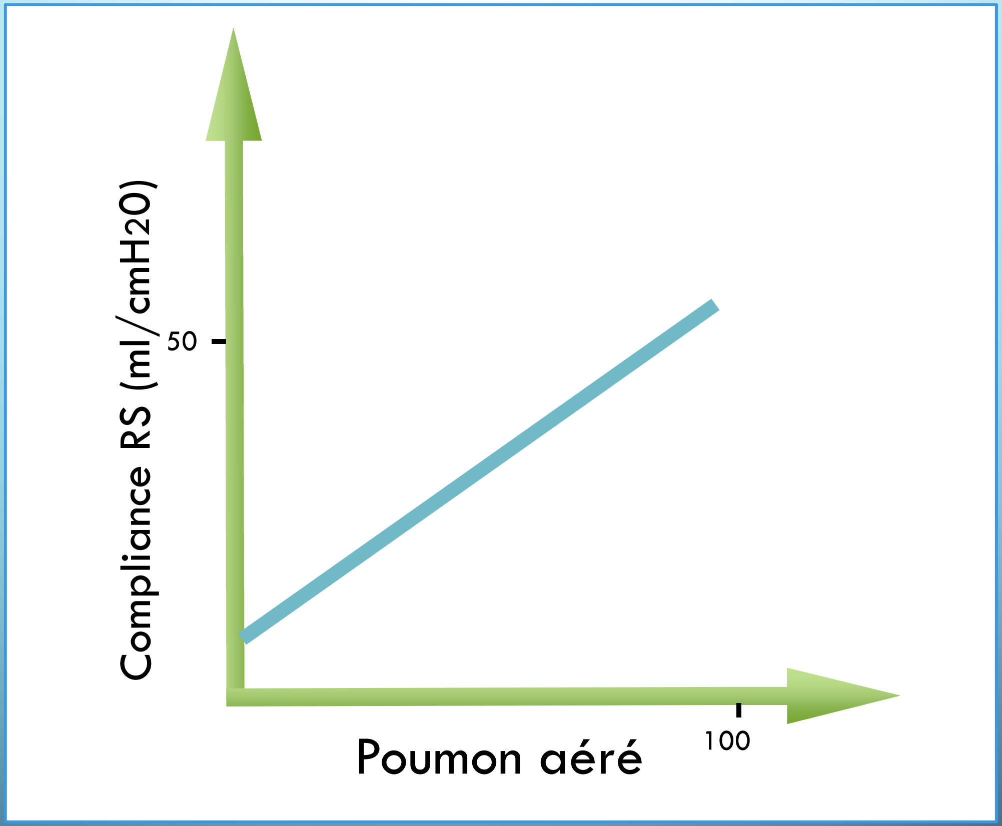
Tissu non aéré = 11,7%
PaO2/FiO2 =350



Tissu non aéré = 55,6%
PaO2/FiO2 =100

Faut il donner le même V_T ?

DANS LE SDRA LE POUMON AÉRÉ EST CORRÉLÉ À LA COMPLIANCE C_{RS}

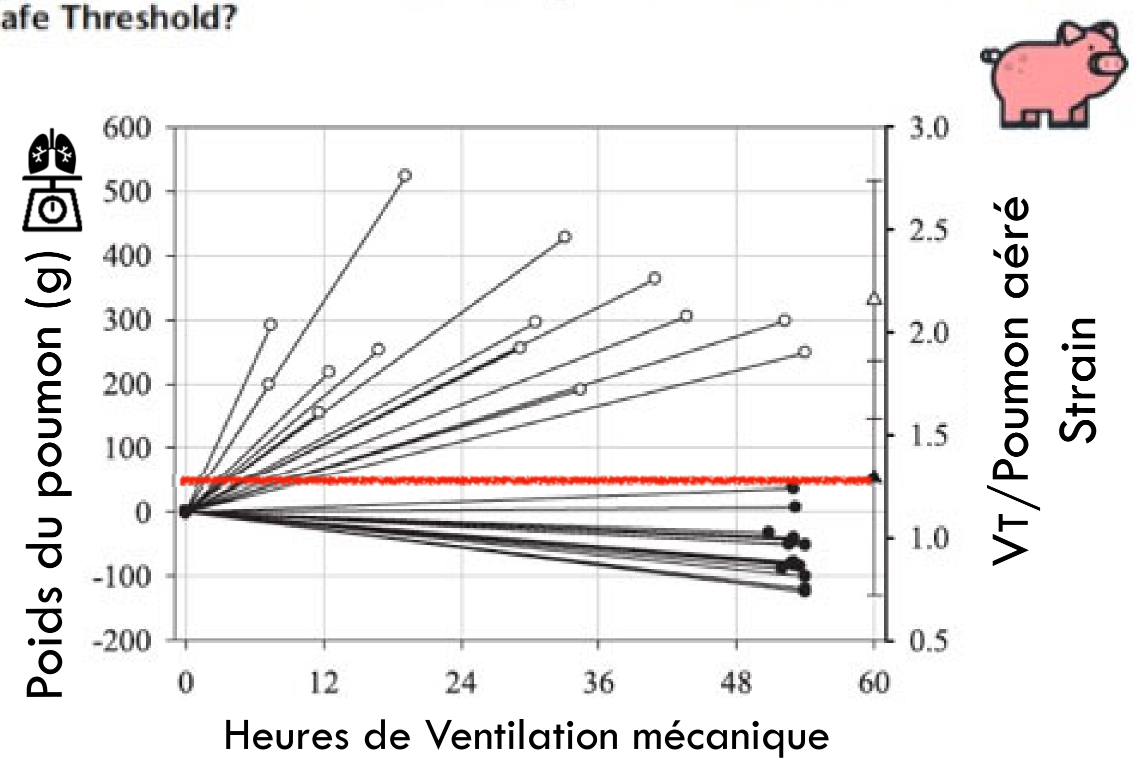


Gattinoni et al. Am rev Respir Dis 1987;136:730-736

EFFETS DU RATIO VT/POUMON AÉRÉ SUR L'OEDEME

Lung Stress and Strain during Mechanical Ventilation

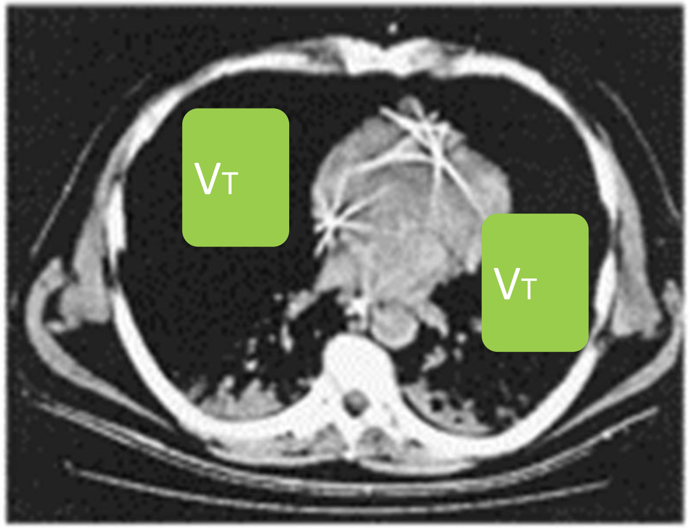
Any Safe Threshold?



Am J respir Crit Care Med 2011;183:1354-1362

ON DOIT ADAPTÉ LE VT AU POUMON AÉRÉ (BABYLUNG)

Espace mort VD/VT



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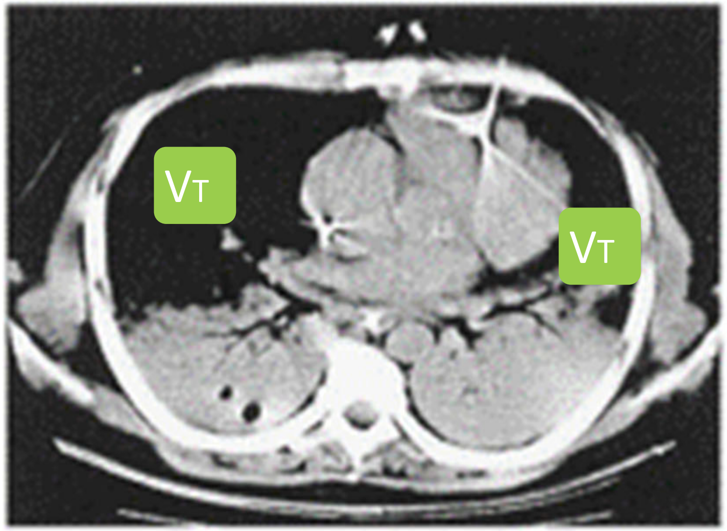


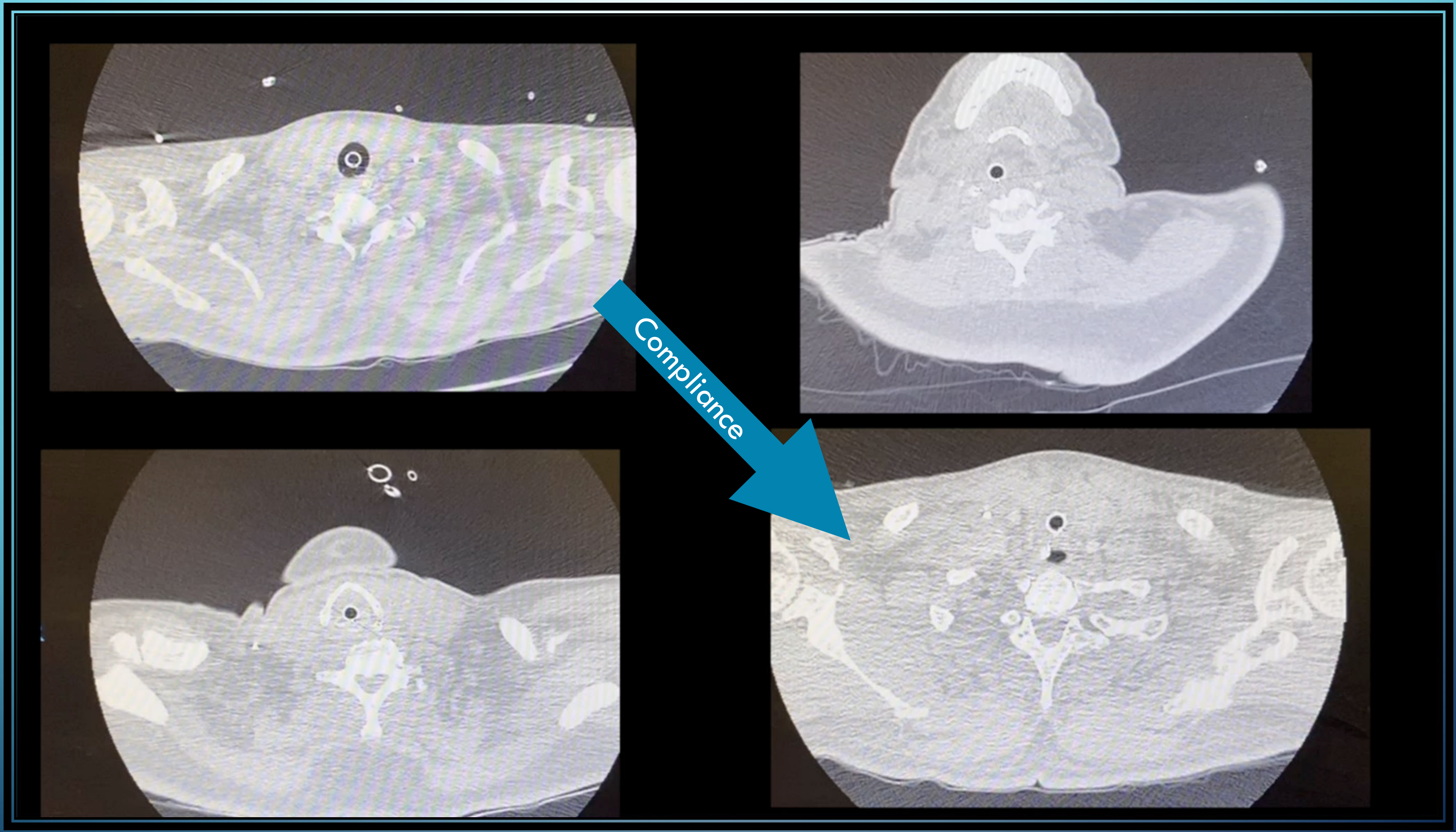
Tissu non aéré = 55,6%
PaO2/FiO2 =100

Hypercapnie permissive dans une certaine limite : pH <7,15

- Il faut adapter le V_T au volume pulmonaire aéré
- Le volume pulmonaire aéré est corrélé à la Compliance du système respiratoire (Crs)
- VT normalisé à la Crs = VT/Crs = $\cancel{VT} / (\cancel{VT}/\text{Pplat-PEEPtot})$

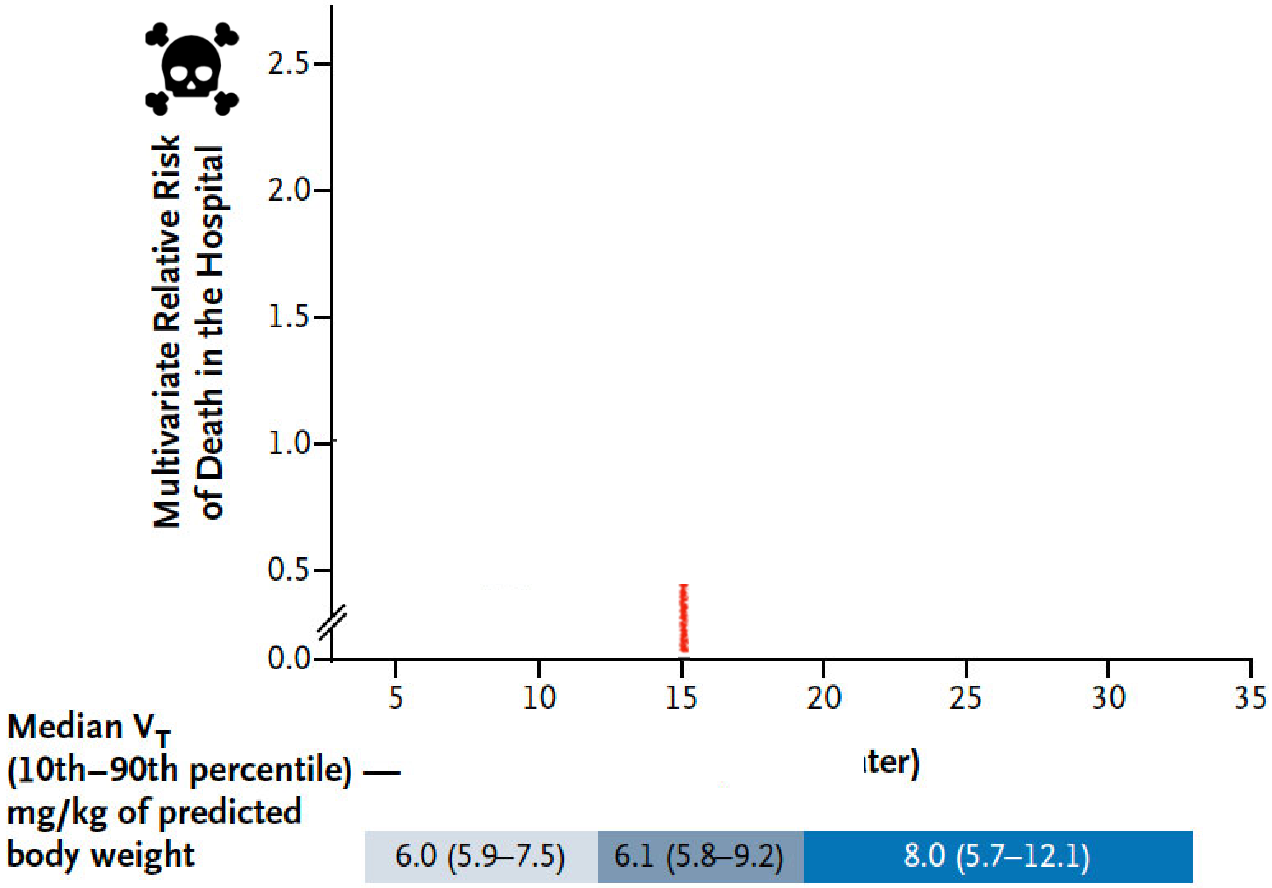
Donc

V_T/Crs= Plat-PEEPtot = Pression Motrice


Compliance

SDRA COVID-19

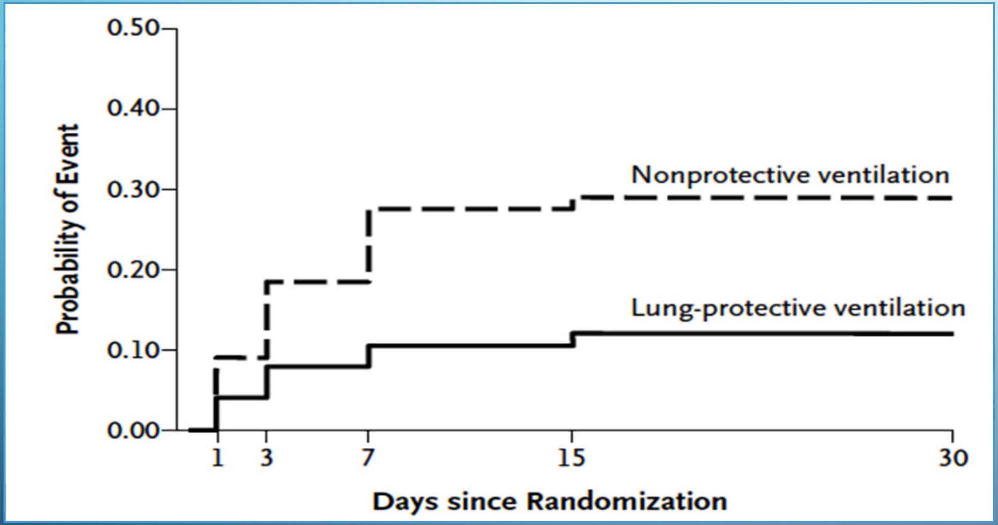
DIMINUER LA PRESSION MOTRICE DIMINUE LE RISQUE DE ☠



Amato et al. NEJM 2015

VT PER OPÉRATOIRE EN EN CHIRURGIE ABDOMINALE

Protocole de ventilation protectrice:
V_T 6 à 8 ml/kg de poids idéal, PEEP 6 à 8 cmH20
et MRA: PEEP 30 cmH2O pendant 30 sec toutes les 30 minutes



MRA augmente poumon aéré
Vt diminué à 6-8 ml/kg PP

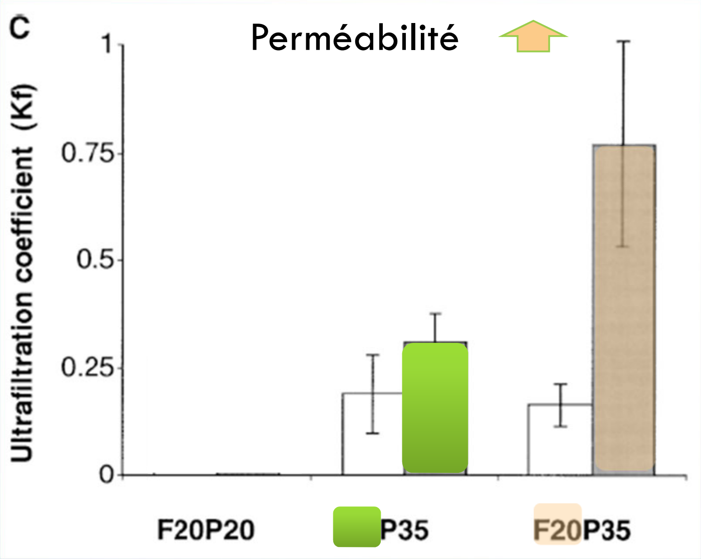
Ventilation protectrice améliore le pronostic post opératoire respiratoire

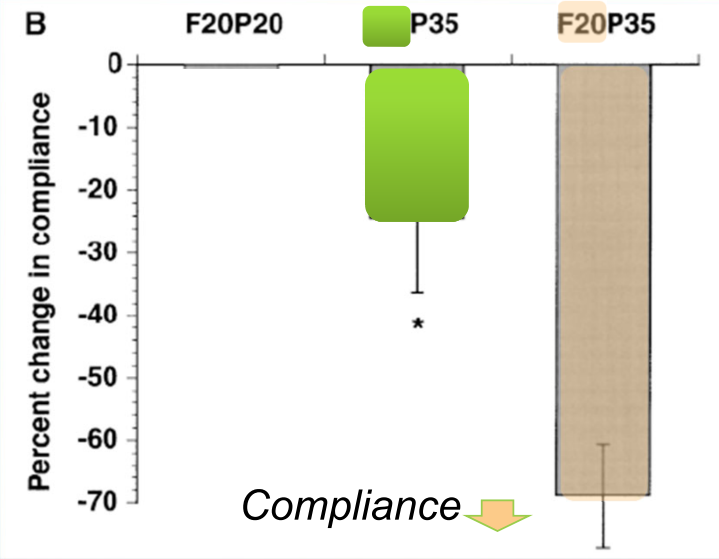
Futier et al. NEJM 203;369:428-37

Effects of Decreased Respiratory Frequency on Ventilator-induced Lung Injury

JOHN R. HOTCHKISS, Jr., LLUIS BLANCH, GASTON MURIAS, ALEXANDER B. ADAMS, DOUG A. OLSON, O. D. WANGENSTEEN, PERRY H. LEO, and JOHN J. MARINI

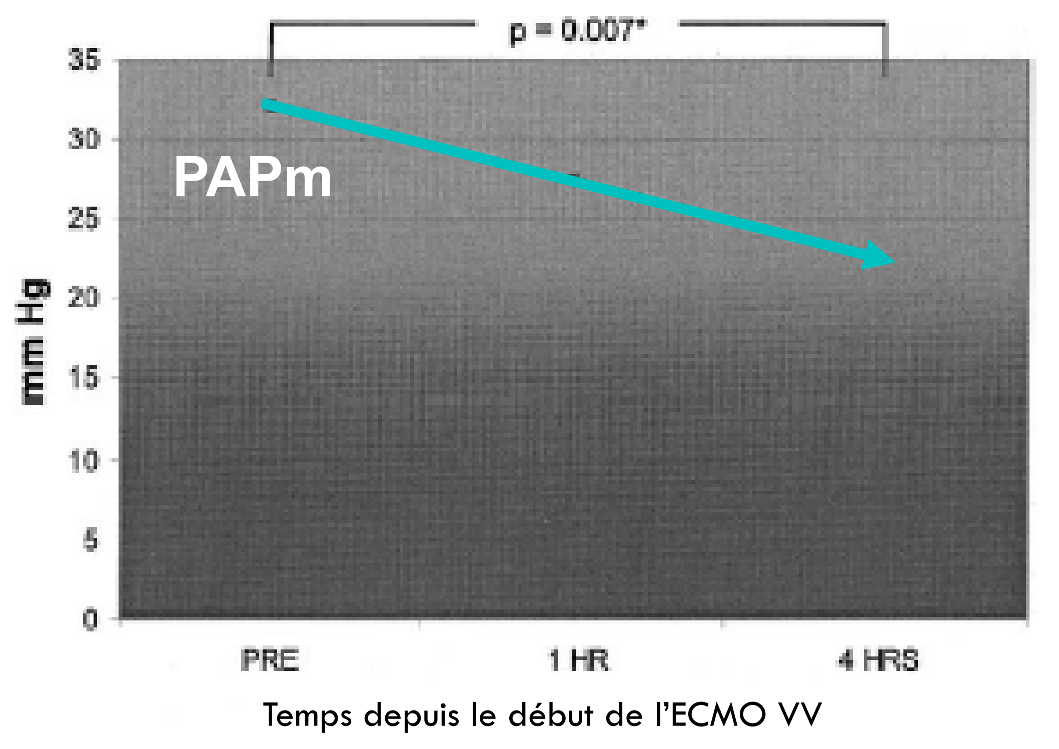
FRÉQUENCE RESPIRATOIRE





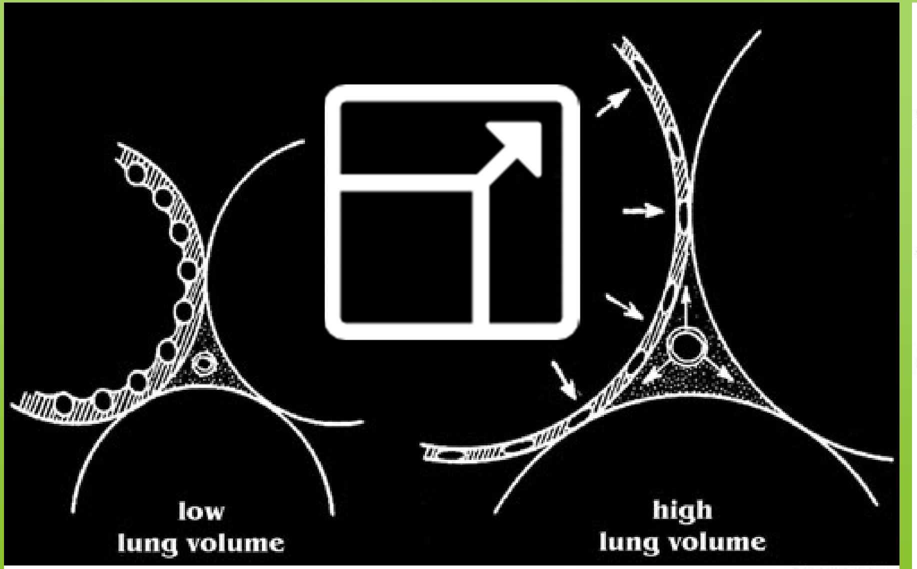
AM J RESPIR CRIT CARE MED 2000;161:463–468.

PVO$_2$ ELEVÉE SOUS ECMO-VV INHIBE LA VPH

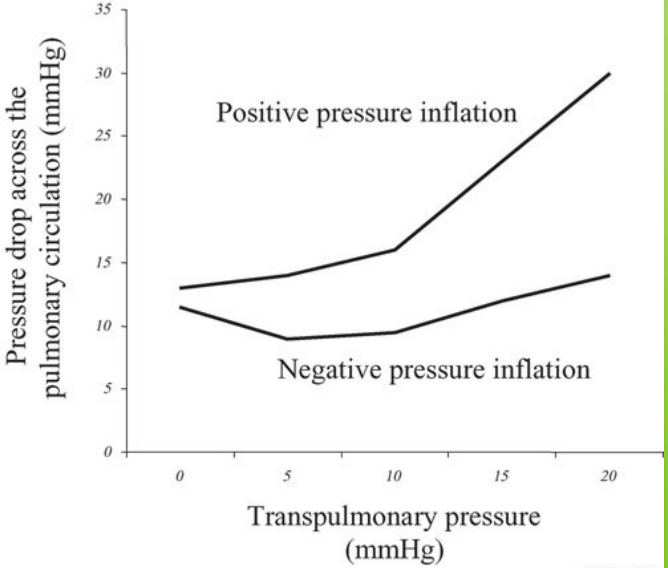


Dans cette étude la ventilation n'a pas été modifié sous ECMO !!

Ann Thorac Surg 2005;80:1872–80


low
lung volume
high
lung volume

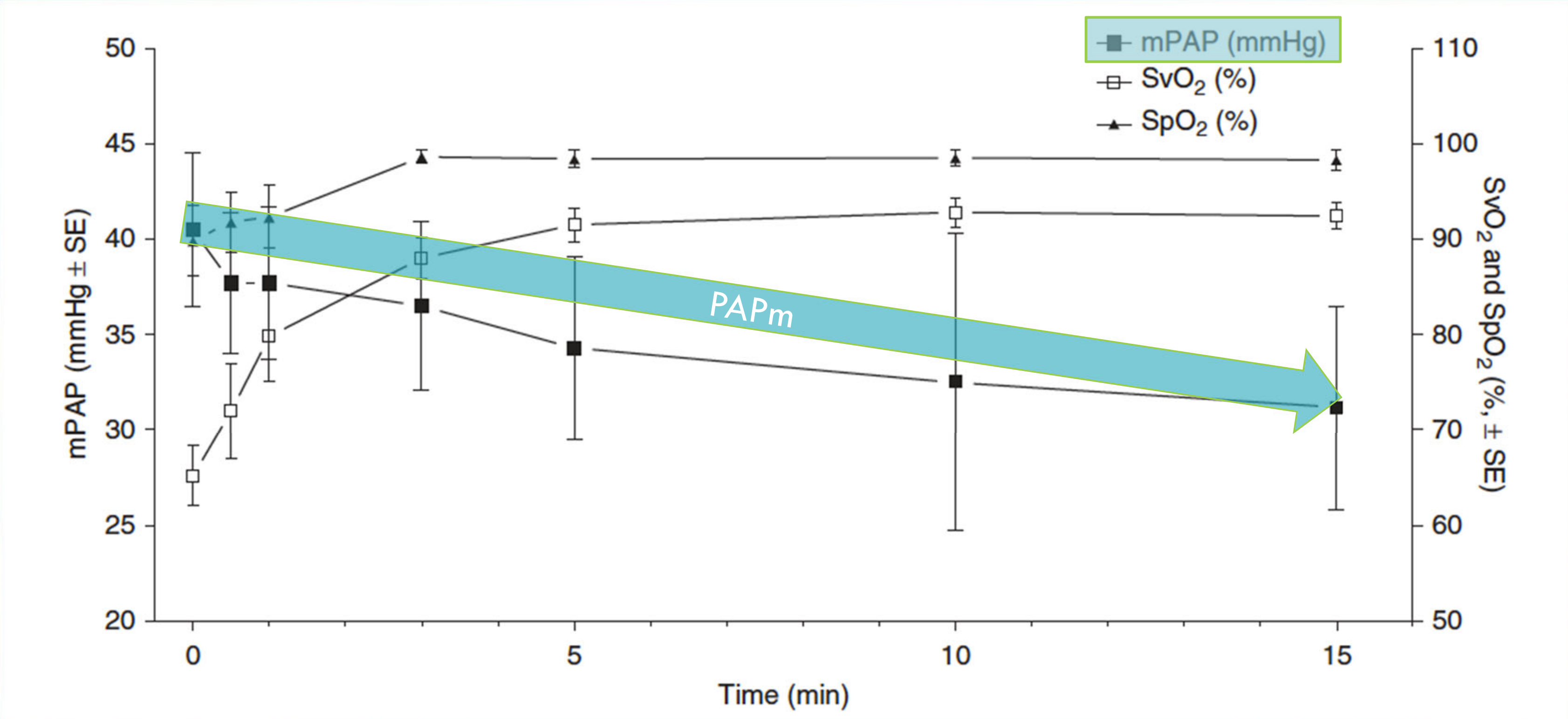
Critical Care



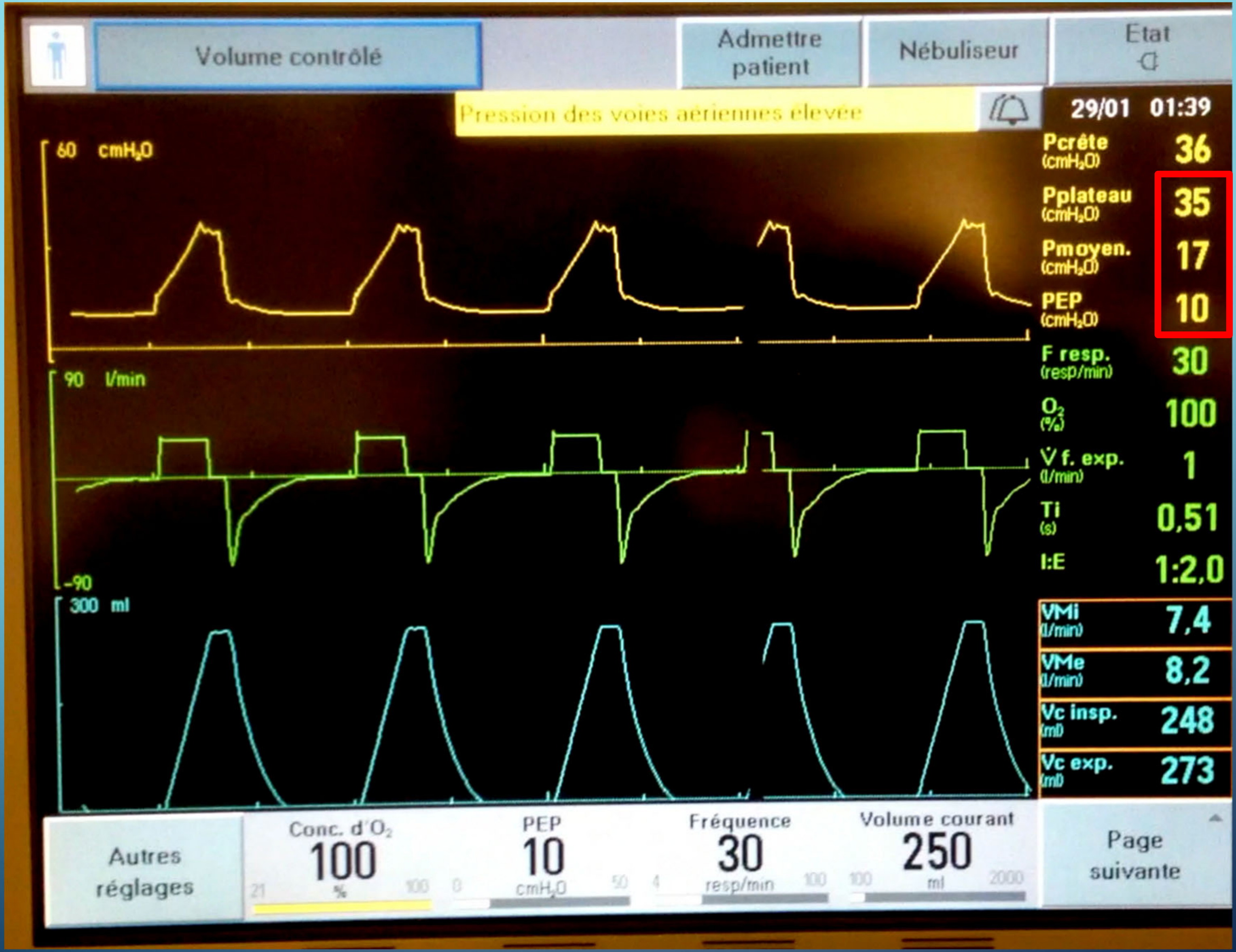
Critical Care

Right Ventricular Unloading after Initiation of Venovenous Extracorporeal Membrane Oxygenation

AMERICAN JOURNAL OF
Respiratory and Critical Care Medicine



Miranda et al. AJRCCM 2015


Volume contrôlé
Admettre patient
Nébuliseur
Etat
60 cmH$_2$O
90 l/min
-90
300 ml
Autres réglages
Page suivante
21
100
0
50
4
100
100
2000

Pression des voies aériennes élevée

29/01 01:39

Pcrête (cmH$_2$O) 36

Pplateau (cmH$_2$O) 35

Pmoyen. (cmH$_2$O) 17

PEP (cmH$_2$O) 10

F resp. (resp/min) 30

O_2 (%) 100

$\dot{V}$ f. exp. (l/min) 1

Ti (s) 0,51

I:E 1:2,0

VMi (l/min) 7,4

VMe (l/min) 8,2

Vc insp. (ml) 248

Vc exp. (ml) 273

Conc. d'O_2 100 %

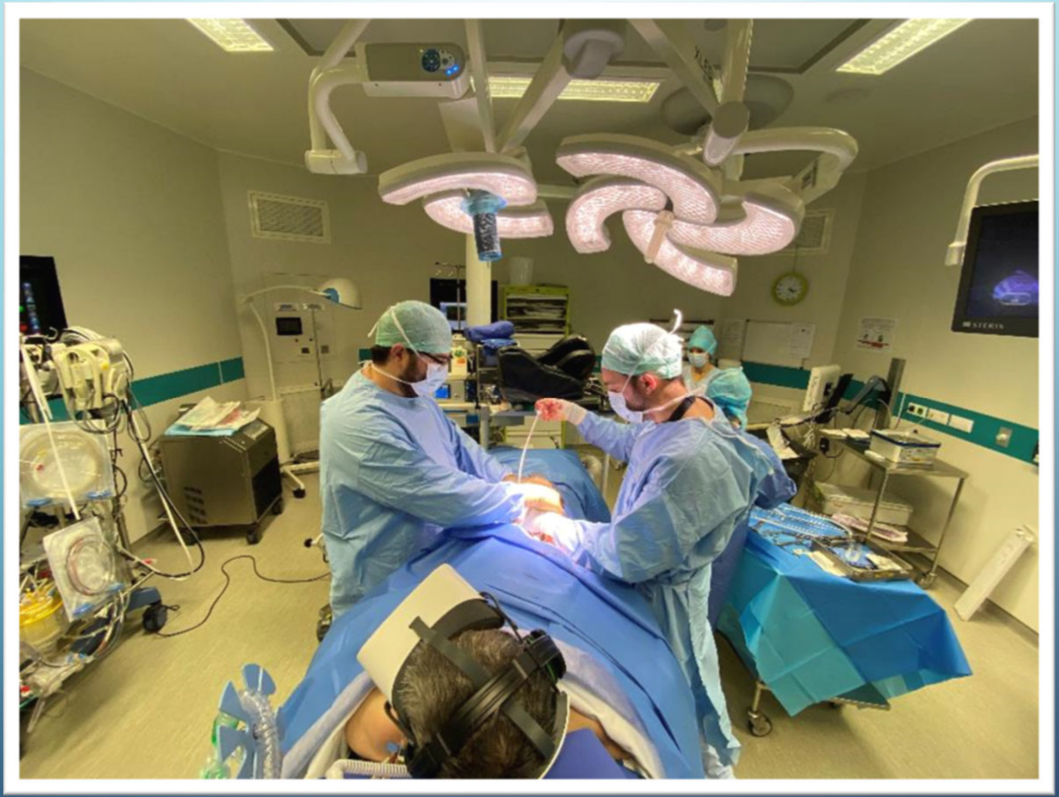
PEP 10 cmH$_2$O

Fréquence 30 resp/min

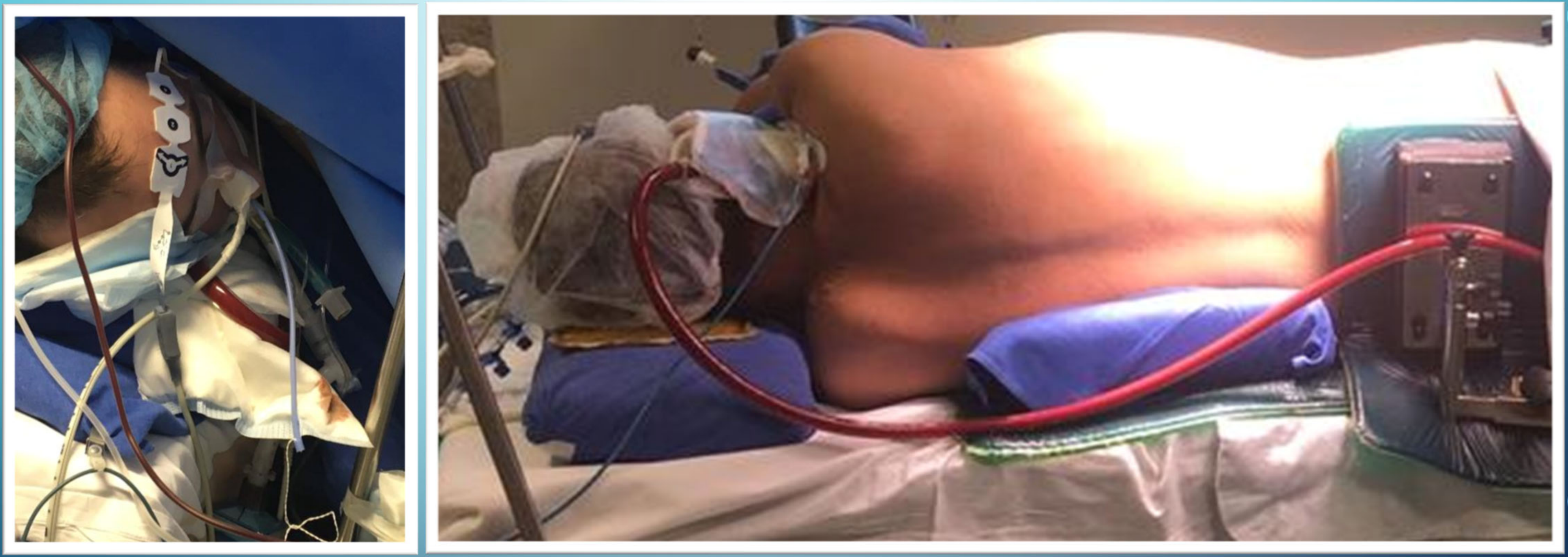
Volume courant 250 ml

Pression motrice
25 cmH$_2$O

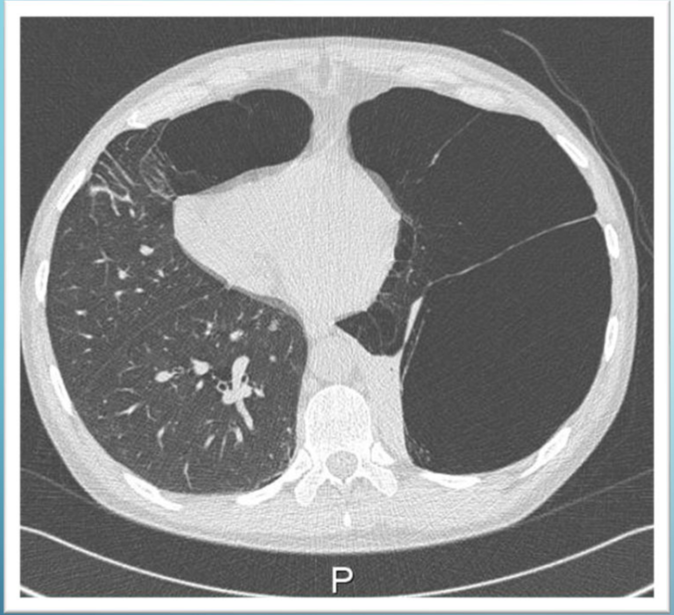
POSE SOUS HYPNOSE : HTAP & EMPHYSEME

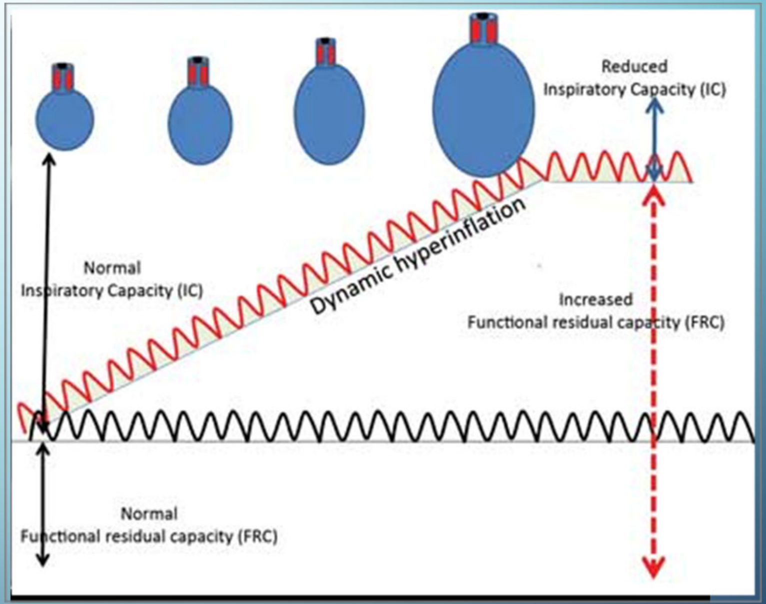


DLD



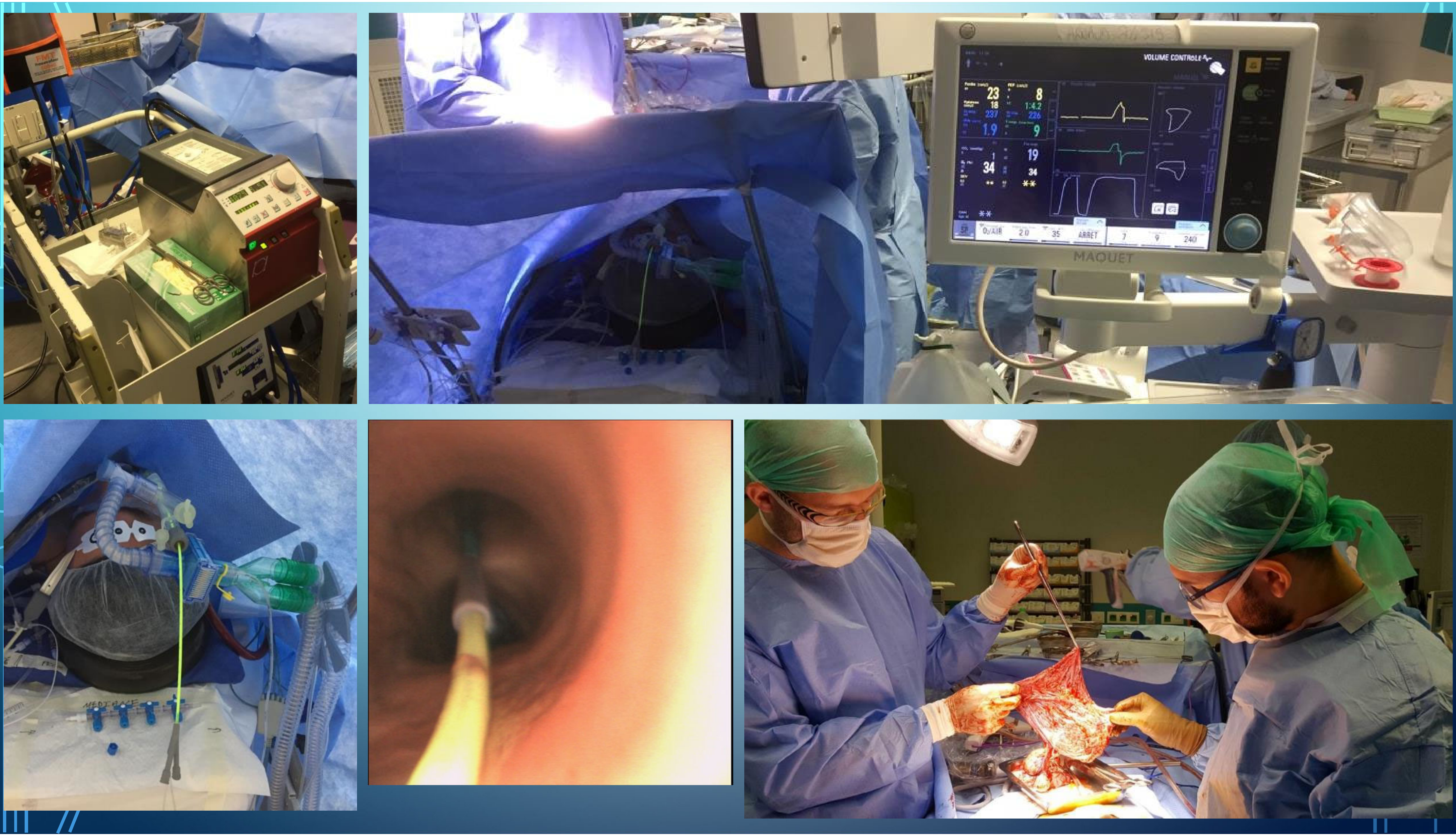
CHIRURGIE DE L'EMPHYSÈME



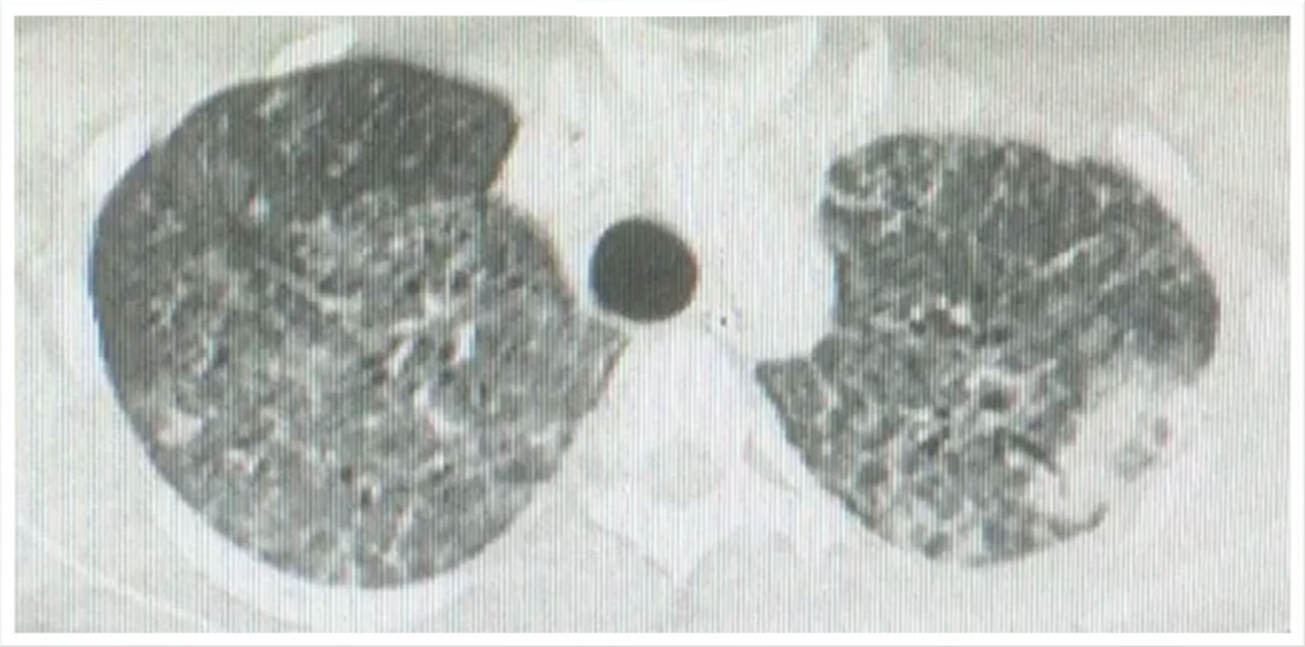

Reduced
Inspiratory Capacity (IC)
Normal
Inspiratory Capacity (IC)
Dynamic hyperinflation
Increased
Functional residual capacity (FRC)
Normal
Functional residual capacity (FRC)

Hypoxémie, Hypercapnie, O_2 à domicile, VEMS<50%Théo, TLCO >30%, Cœur Pulmonaire Chronique?

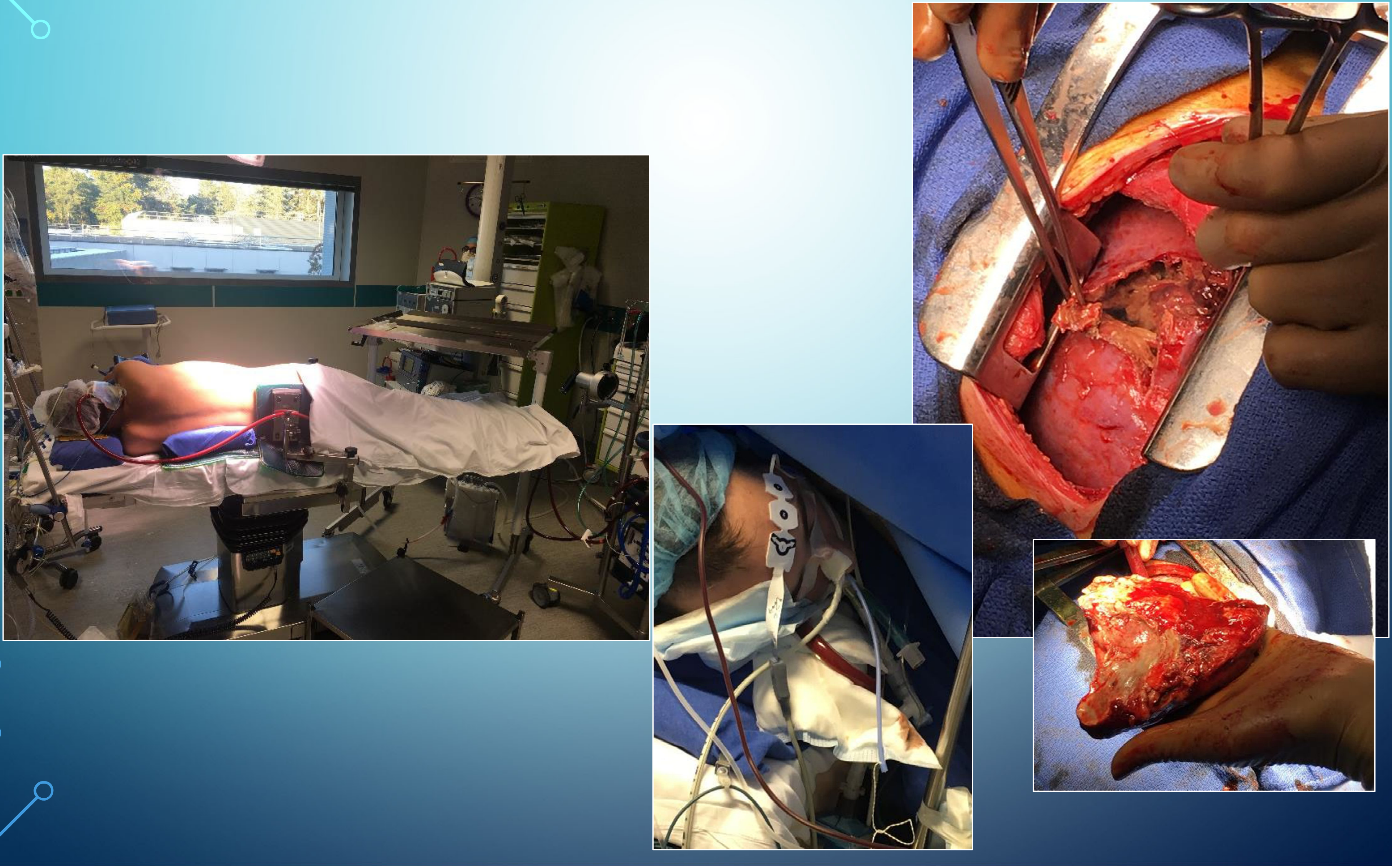
Sécurité pour l'hématose et le risque de tamponnade gazeuse


VOLUME CONTROLE
23
18
237
1.9
8
1:4.2
226
9
19
34
34
O2/AIR
20
35
ARRET
7
9
240
MAQUET

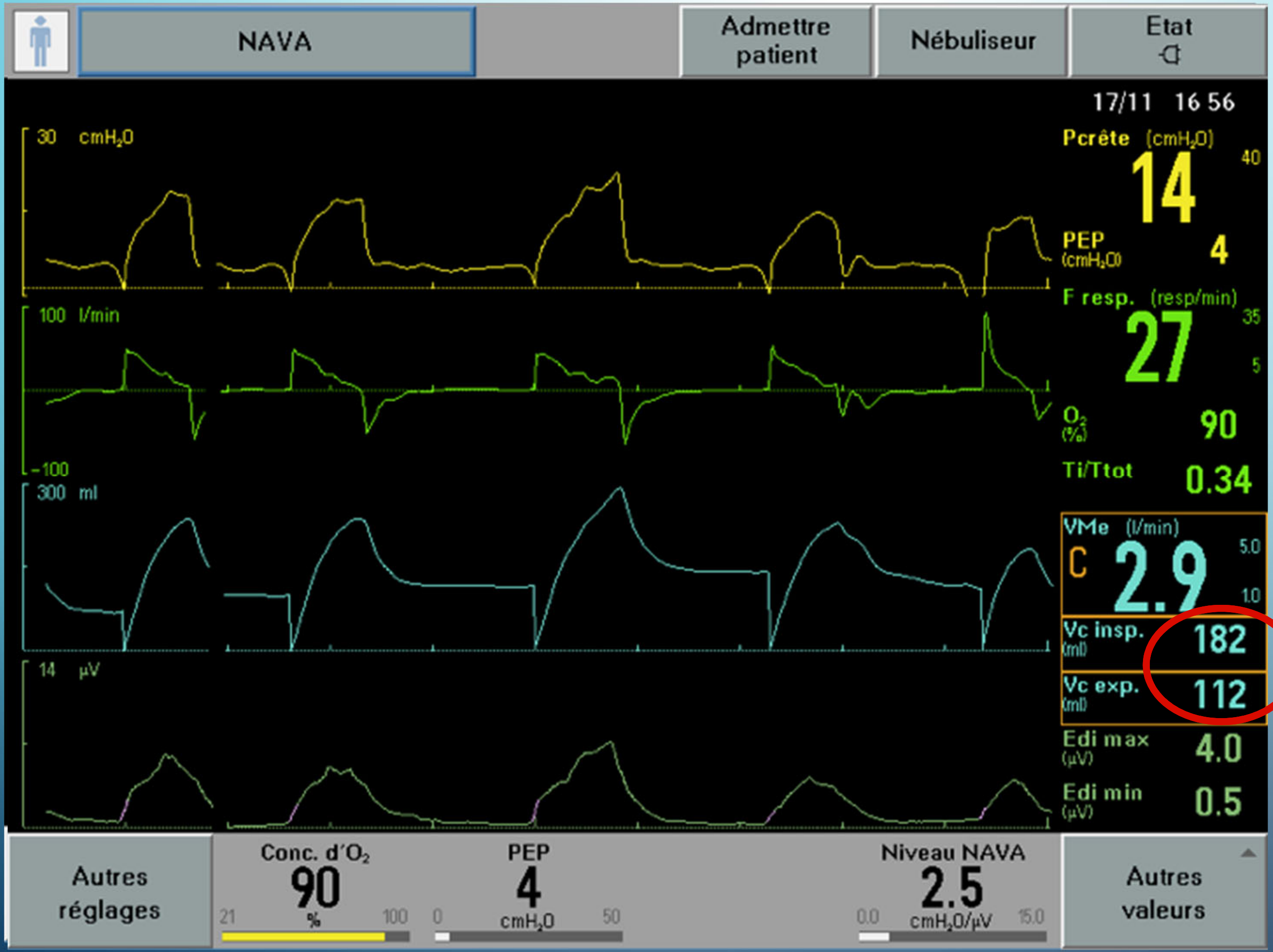
CHIRURGIE DE PROPRETÉ



Contusion / abcès fistule / bronchopleurale



FISTULES BRONCHO PLEURALES


30 cmH₂O
100 l/min
-100
300 ml
14 µV
40
35
5
5.0
1.0
21
100
0
50
0.0
15.0

NAVA

Admettre patient

Nébuliseur

Etat

17/11 16 56

Pcrête (cmH₂O) 14

PEP (cmH₂O) 4

F resp. (resp/min) 27

O₂ (%) 90

Ti/Ttot 0.34

VMe (l/min) C 2.9

Vc insp. (ml) 182

Vc exp. (ml) 112

Edi max (µV) 4.0

Edi min (µV) 0.5

Autres réglages

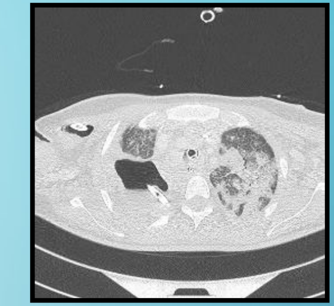
Conc. d'O₂ 90 %

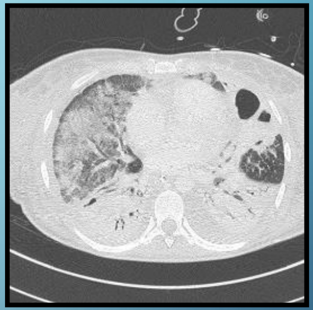
PEP 4 cmH₂O

Niveau NAVA 2.5 cmH₂O/µV

Autres valeurs

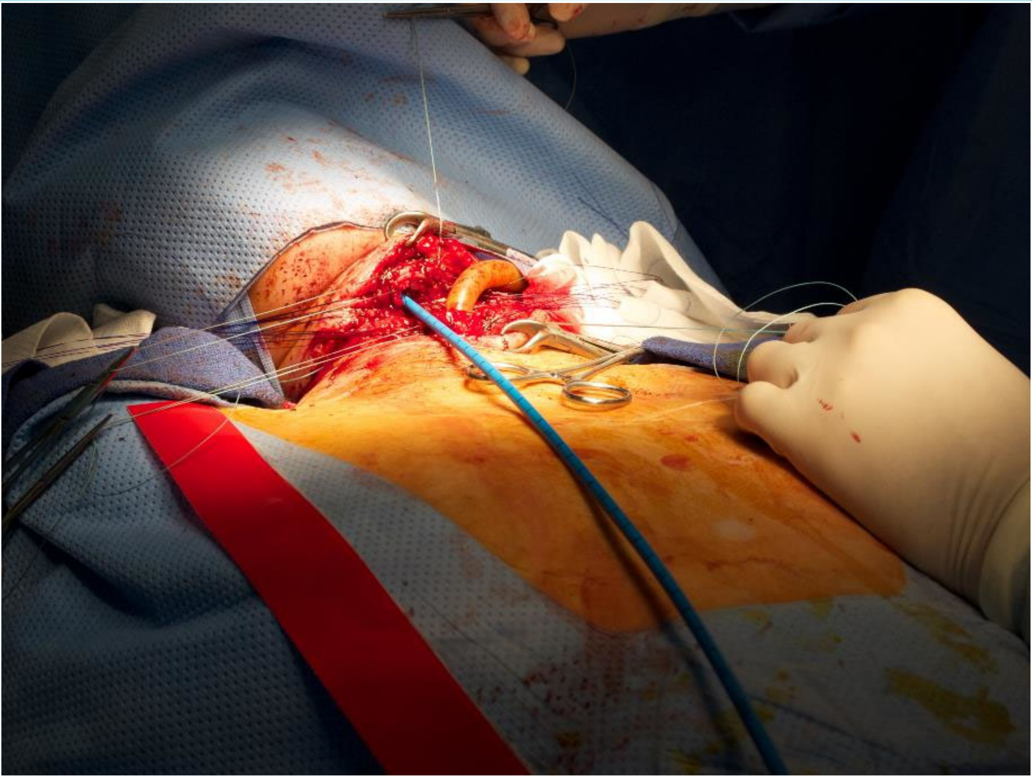
V_D/V_T

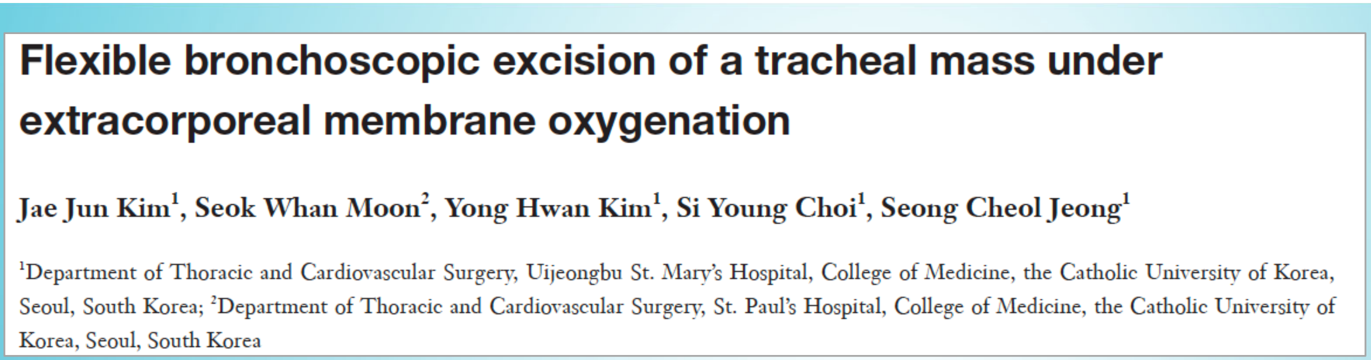




Rozé et al. Intensive Care Med. 2012;38:922-3

CHIRURGIE DE LA TRACHÉE

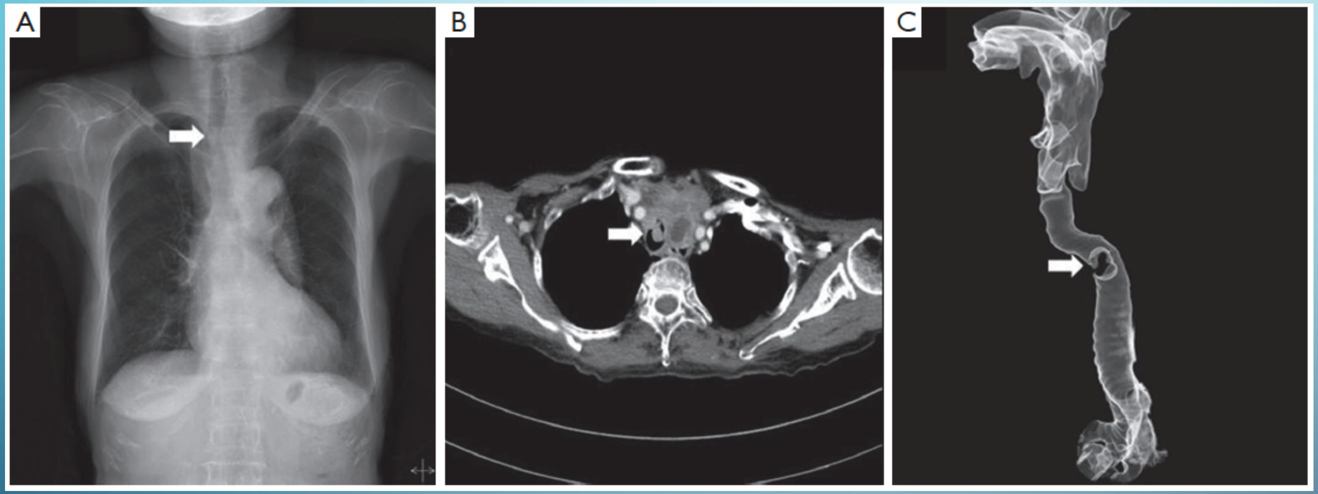


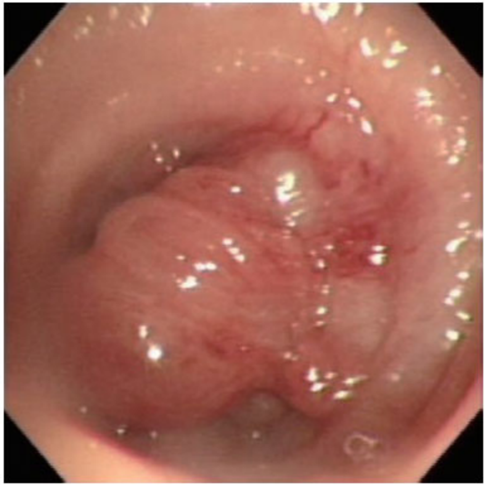


Flexible bronchoscopic excision of a tracheal mass under extracorporeal membrane oxygenation

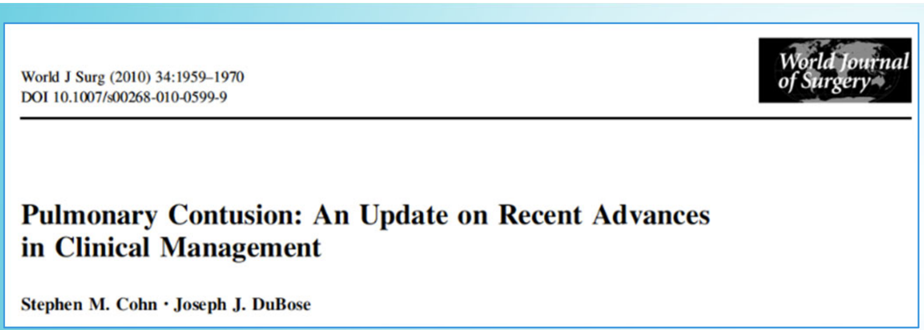
Jae Jun Kim[1], Seok Whan Moon[2], Yong Hwan Kim[1], Si Young Choi[1], Seong Cheol Jeong[1]

[1]Department of Thoracic and Cardiovascular Surgery, Uijeongbu St. Mary's Hospital, College of Medicine, the Catholic University of Korea, Seoul, South Korea; [2]Department of Thoracic and Cardiovascular Surgery, St. Paul's Hospital, College of Medicine, the Catholic University of Korea, Seoul, South Korea





J Thorac Dis 2015;7(3):E54-E57

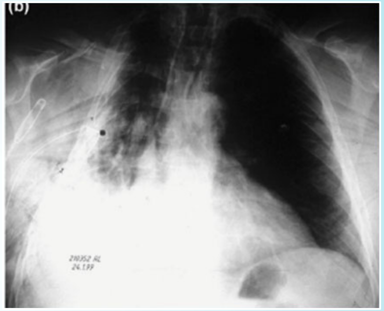


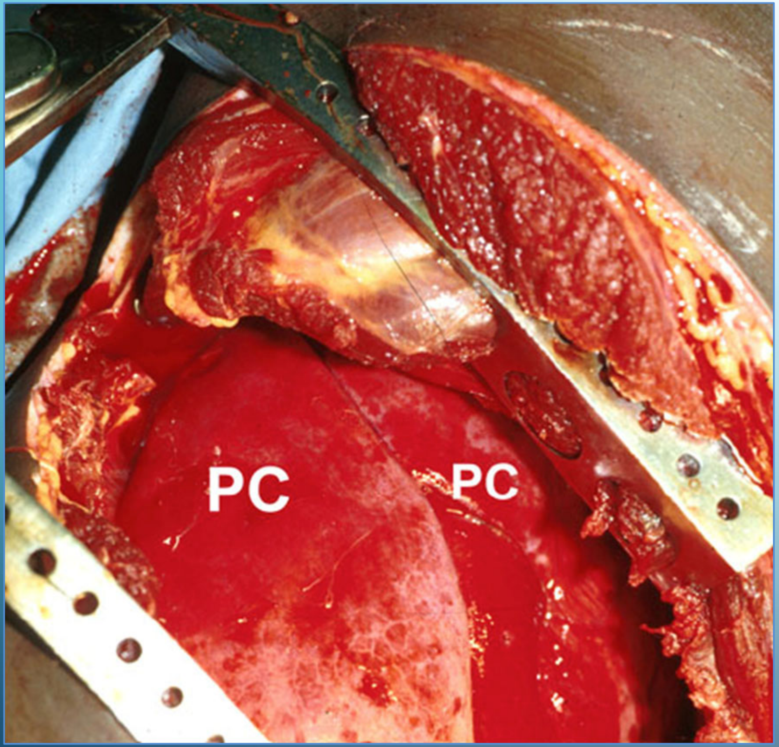
World J Surg (2010) 34:1959–1970
DOI 10.1007/s00268-010-0599-9

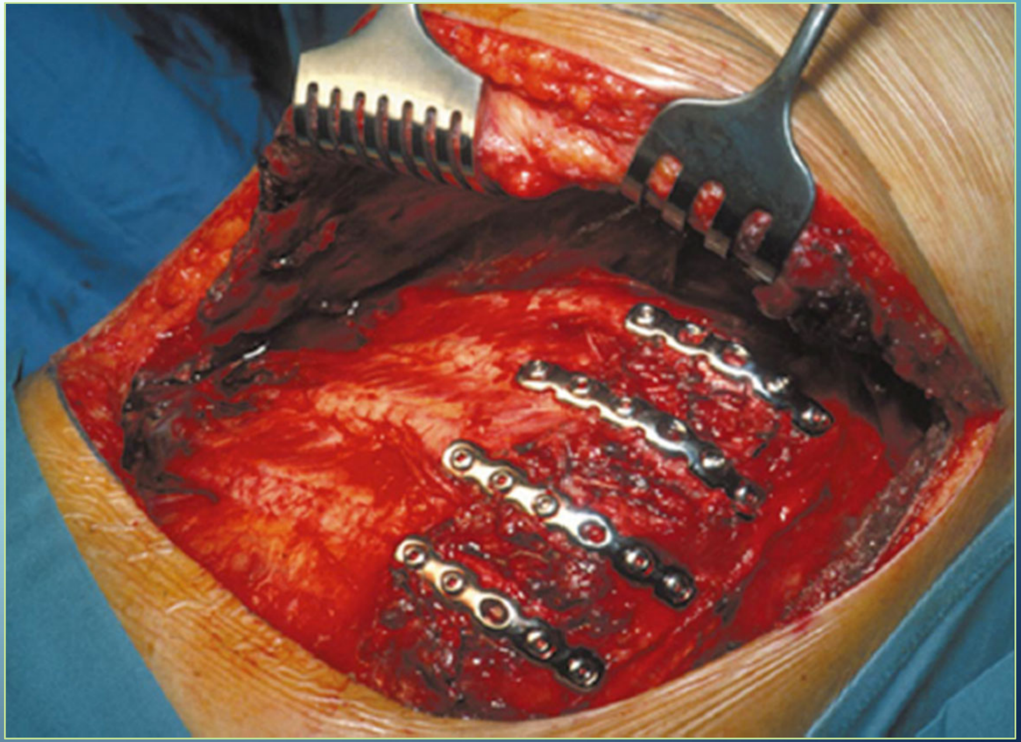
World Journal of Surgery

Pulmonary Contusion: An Update on Recent Advances in Clinical Management

Stephen M. Cohn · Joseph J. DuBose



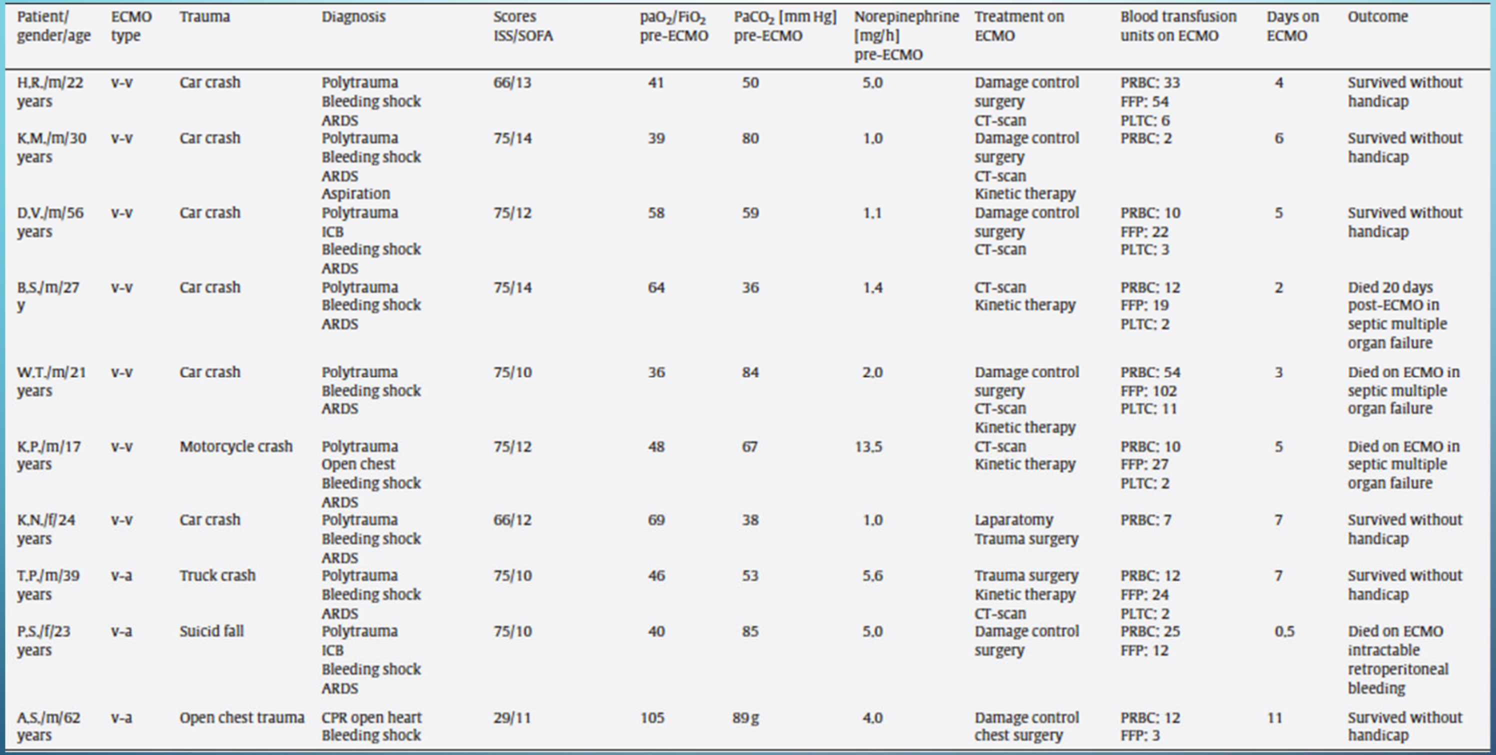




Risque hémorragique parfois TC associé donc pas trop d'héparine donc circuit ECMO bolus puis stop

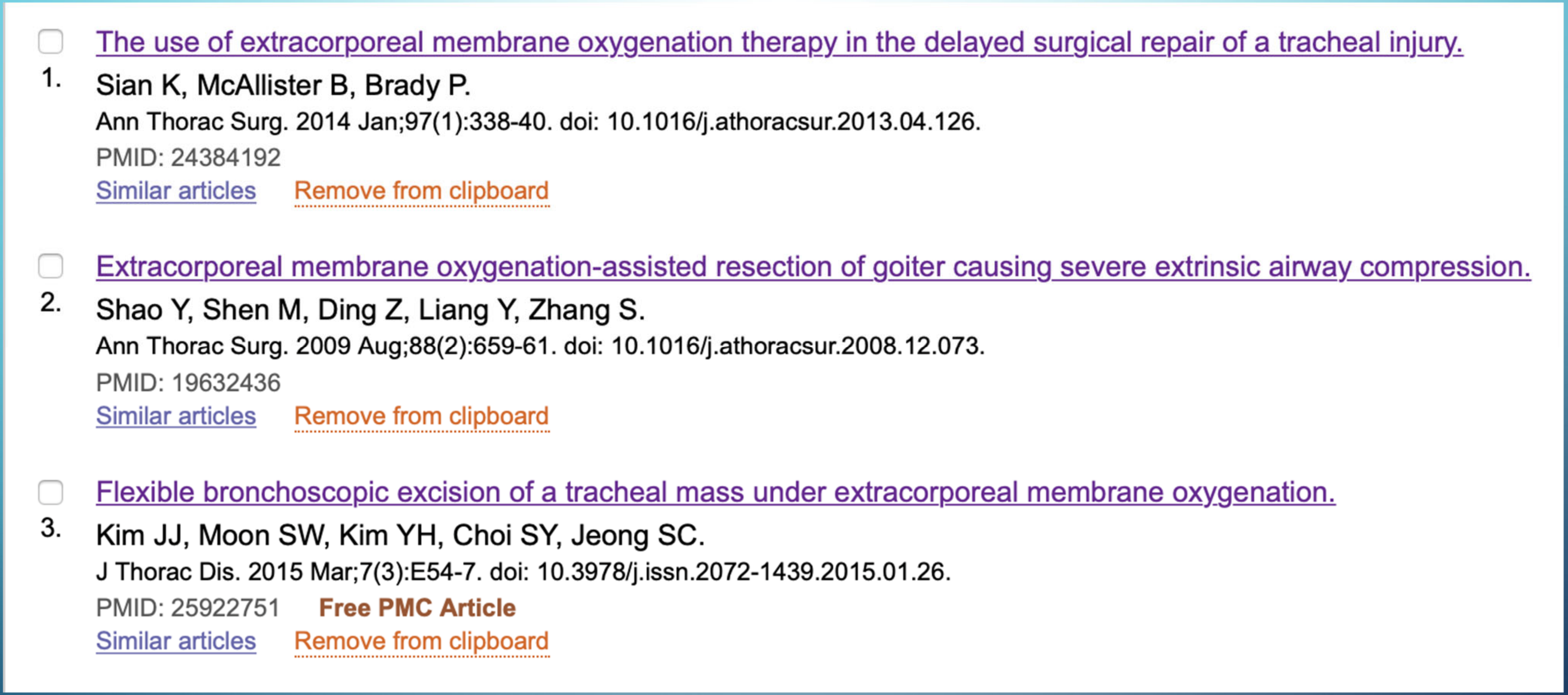
Extracorporeal membrane oxygenation in severe trauma patients with bleeding shock☆

Matthias Arlt*, Alois Philipp, Sabine Voelkel, Leopold Rupprecht, Thomas Mueller, Michael Hilker, Bernhard M. Graf, Christof Schmid



Patient/ gender/age	ECMO type	Trauma	Diagnosis	Scores ISS/SOFA	paO_2/FiO_2 pre-ECMO	$PaCO_2$ [mm Hg] pre-ECMO	Norepinephrine [mg/h] pre-ECMO	Treatment on ECMO	Blood transfusion units on ECMO	Days on ECMO	Outcome
H.R./m/22 years	v-v	Car crash	Polytrauma Bleeding shock ARDS	66/13	41	50	5.0	Damage control surgery CT-scan	PRBC: 33 FFP: 54 PLTC: 6	4	Survived without handicap
K.M./m/30 years	v-v	Car crash	Polytrauma Bleeding shock ARDS Aspiration	75/14	39	80	1.0	Damage control surgery CT-scan Kinetic therapy	PRBC: 2	6	Survived without handicap
D.V./m/56 years	v-v	Car crash	Polytrauma ICB Bleeding shock ARDS	75/12	58	59	1.1	Damage control surgery CT-scan	PRBC: 10 FFP: 22 PLTC: 3	5	Survived without handicap
B.S./m/27 y	v-v	Car crash	Polytrauma Bleeding shock ARDS	75/14	64	36	1.4	CT-scan Kinetic therapy	PRBC: 12 FFP: 19 PLTC: 2	2	Died 20 days post-ECMO in septic multiple organ failure
W.T./m/21 years	v-v	Car crash	Polytrauma Bleeding shock ARDS	75/10	36	84	2.0	Damage control surgery CT-scan Kinetic therapy	PRBC: 54 FFP: 102 PLTC: 11	3	Died on ECMO in septic multiple organ failure
K.P./m/17 years	v-v	Motorcycle crash	Polytrauma Open chest Bleeding shock ARDS	75/12	48	67	13.5	CT-scan Kinetic therapy	PRBC: 10 FFP: 27 PLTC: 2	5	Died on ECMO in septic multiple organ failure
K.N./f/24 years	v-v	Car crash	Polytrauma Bleeding shock ARDS	66/12	69	38	1.0	Laparatomy Trauma surgery	PRBC: 7	7	Survived without handicap
T.P./m/39 years	v-a	Truck crash	Polytrauma Bleeding shock ARDS	75/10	46	53	5.6	Trauma surgery Kinetic therapy CT-scan	PRBC: 12 FFP: 24 PLTC: 2	7	Survived without handicap
P.S./f/23 years	v-a	Suicid fall	Polytrauma ICB Bleeding shock ARDS	75/10	40	85	5.0	Damage control surgery	PRBC: 25 FFP: 12	0.5	Died on ECMO intractable retroperitoneal bleeding
A.S./m/62 years	v-a	Open chest trauma	CPR open heart Bleeding shock	29/11	105	89g	4.0	Damage control chest surgery	PRBC: 12 FFP: 3	11	Survived without handicap

M. Arlt et al. / Resuscitation 81 (2010) 804–809



☐ [The use of extracorporeal membrane oxygenation therapy in the delayed surgical repair of a tracheal injury.]

1. Sian K, McAllister B, Brady P.
   Ann Thorac Surg. 2014 Jan;97(1):338-40. doi: 10.1016/j.athoracsur.2013.04.126.
   PMID: 24384192
   Similar articles
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☐ [Extracorporeal membrane oxygenation-assisted resection of goiter causing severe extrinsic airway compression.]

2. Shao Y, Shen M, Ding Z, Liang Y, Zhang S.
   Ann Thorac Surg. 2009 Aug;88(2):659-61. doi: 10.1016/j.athoracsur.2008.12.073.
   PMID: 19632436
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☐ [Flexible bronchoscopic excision of a tracheal mass under extracorporeal membrane oxygenation.]

3. Kim JJ, Moon SW, Kim YH, Choi SY, Jeong SC.
   J Thorac Dis. 2015 Mar;7(3):E54-7. doi: 10.3978/j.issn.2072-1439.2015.01.26.
   PMID: 25922751 **Free PMC Article**
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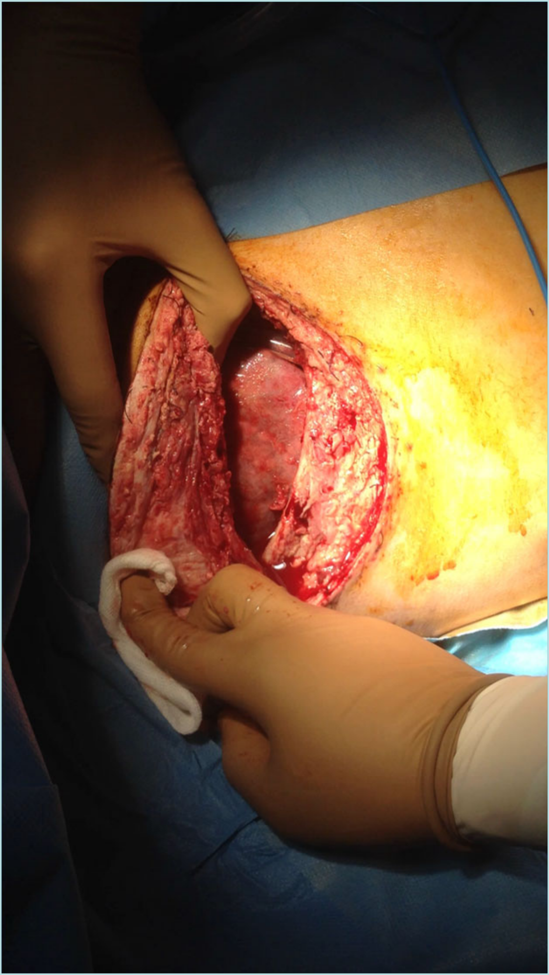
BIOPSIE CHIRURGICALE SOUS ECMO

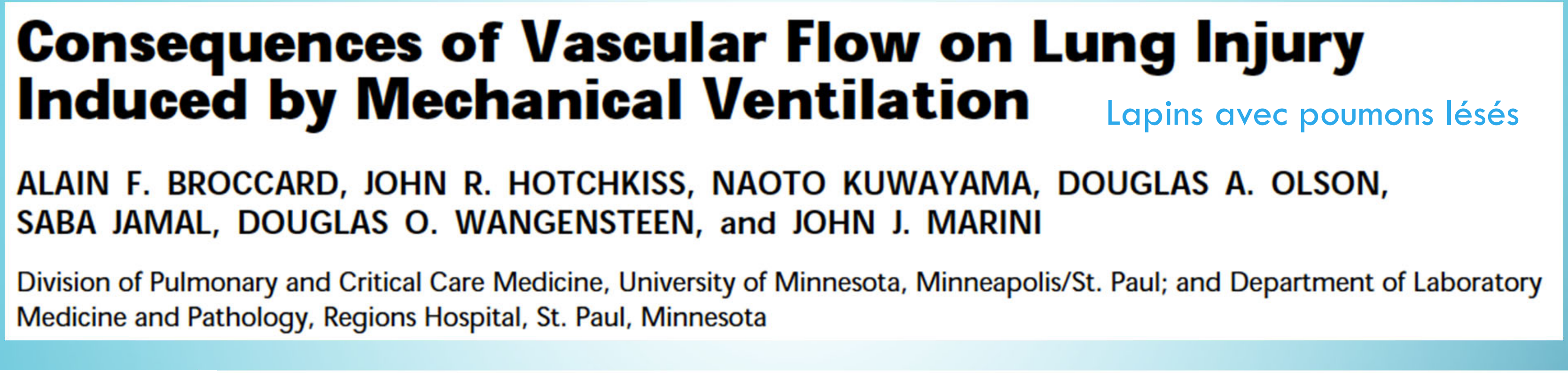
L’objectif est de trouver un diagnostic de défaillance respiratoire
Difficulté et risque des biopsies transbronchiques
ECMO VV posée avant le geste et pour SDRA: Biopsie +LBA
Risque hémorragique donc arrêt des anticoagulants
Peu de barotraumatisme si peu d’aération



Roze et al. Intensive Care Medicine 2014

ASSISTANCE VEINO ARTERIELLE

- Objectif garantir l’hématose: CaO_2, et aussi une assistance du débit TaO_2 avec toujours une extraction du CO_2
- Possibilité de diminuer la ventilation minute: Volume et fréquence
- Possibilité d’être protecteur avec un pression motrice contrôlée
- Possibilité d’etre protecteur de la circulation pulmonaire

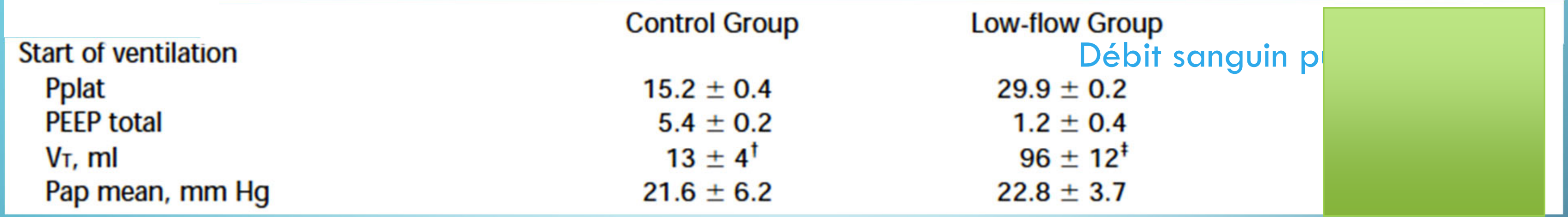


Consequences of Vascular Flow on Lung Injury Induced by Mechanical Ventilation

Lapins avec poumons lésés

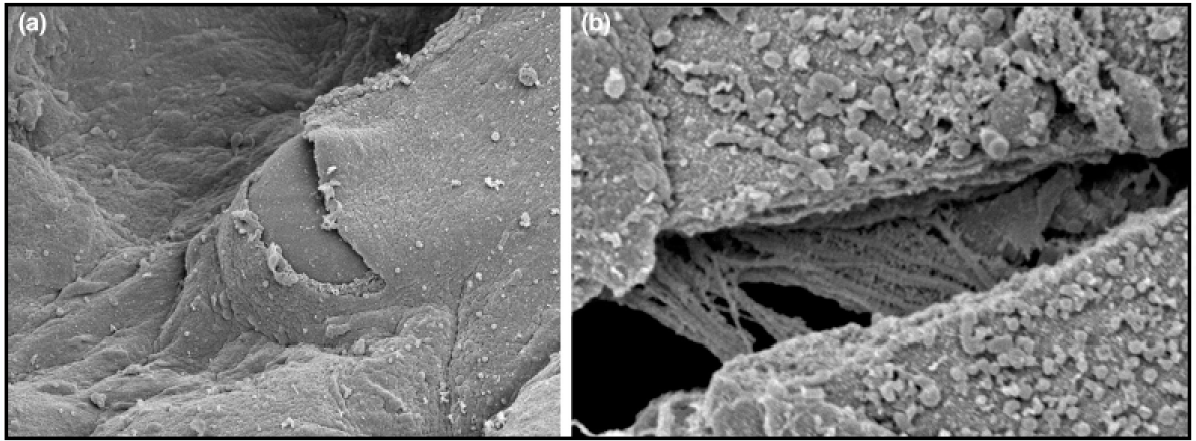
ALAIN F. BROCCARD, JOHN R. HOTCHKISS, NAOTO KUWAYAMA, DOUGLAS A. OLSON, SABA JAMAL, DOUGLAS O. WANGENSTEEN, and JOHN J. MARINI

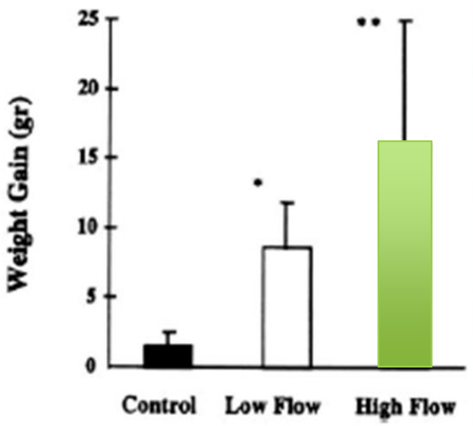
Division of Pulmonary and Critical Care Medicine, University of Minnesota, Minneapolis/St. Paul; and Department of Laboratory Medicine and Pathology, Regions Hospital, St. Paul, Minnesota



Débit sanguin p

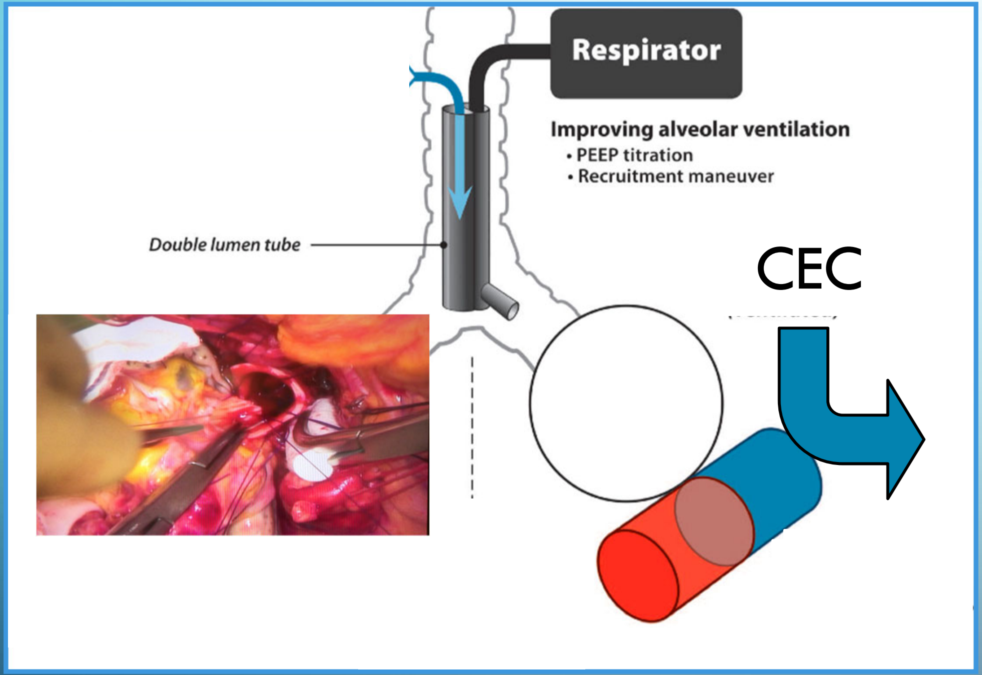
	Control Group	Low-flow Group
Start of ventilation		
Pplat	15.2 ± 0.4	29.9 ± 0.2
PEEP total	5.4 ± 0.2	1.2 ± 0.4
V_T, ml	$13 \pm 4^{\dagger}$	$96 \pm 12^{\ddagger}$
Pap mean, mm Hg	21.6 ± 6.2	22.8 ± 3.7

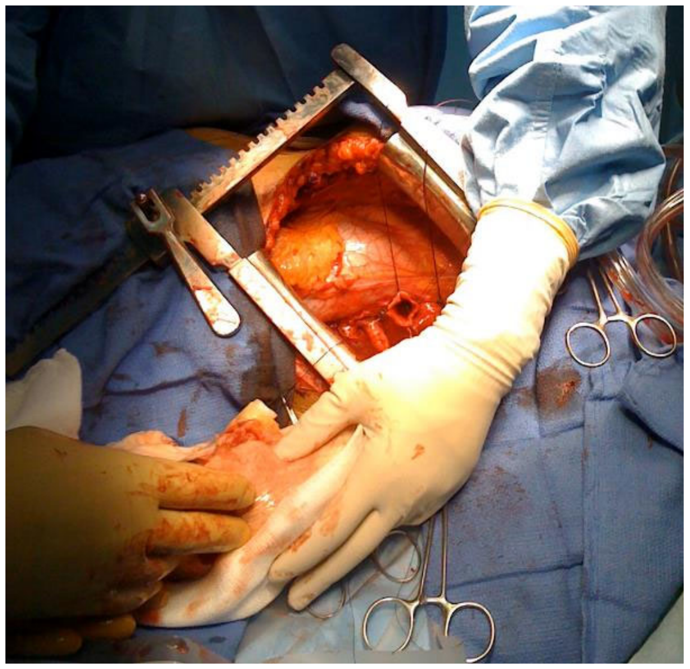




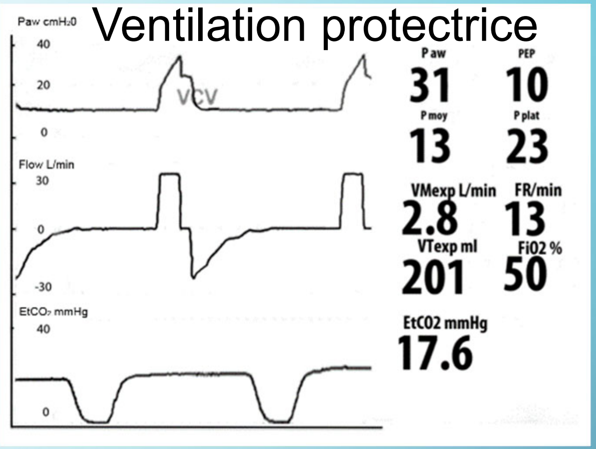
AM J RESPIR CRIT CARE MED 1998;157:1935–1942.

VENTILATION ET PERFUSION PROTECTRICES


Respirator
Improving alveolar ventilation
• PEEP titration
• Recruitment maneuver
Double lumen tube
CEC

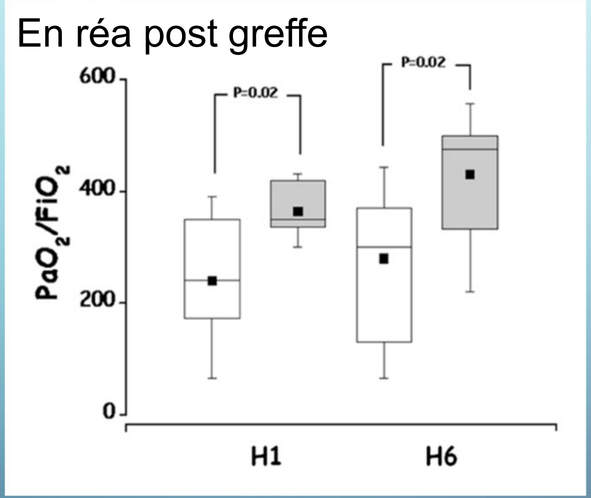


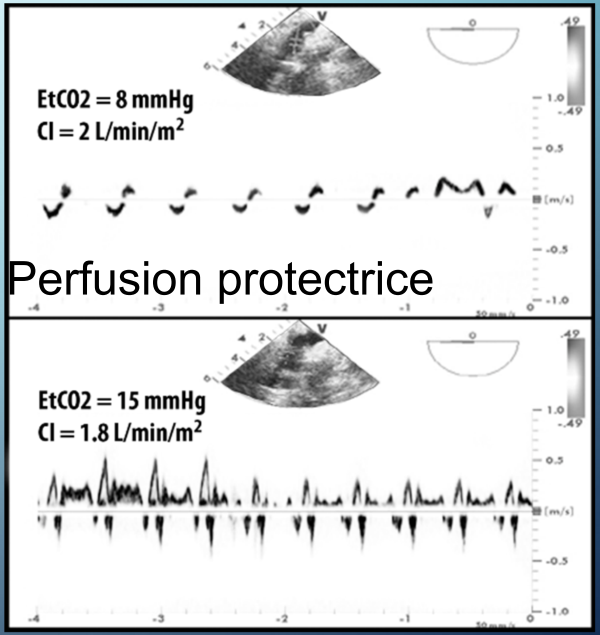
Contrôler le débit de perfusion du premier greffon



Ventilation protectrice

En réa post greffe



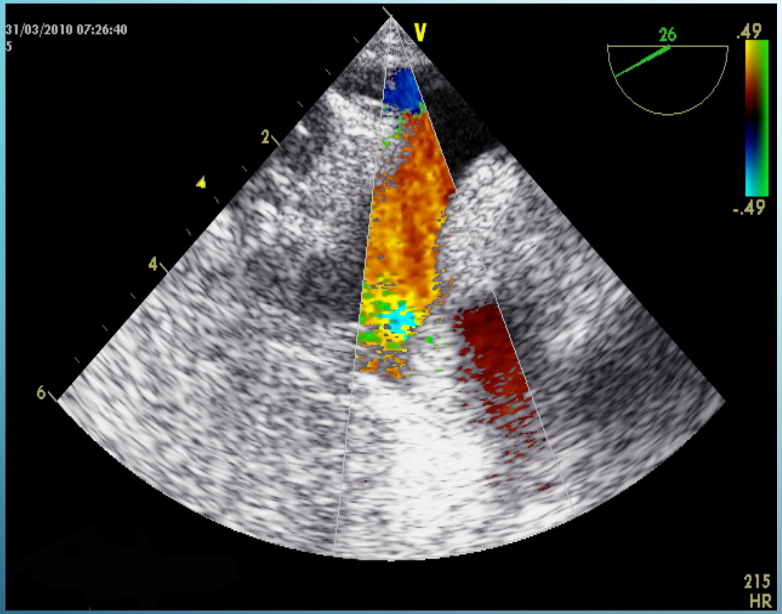


Perfusion protectrice

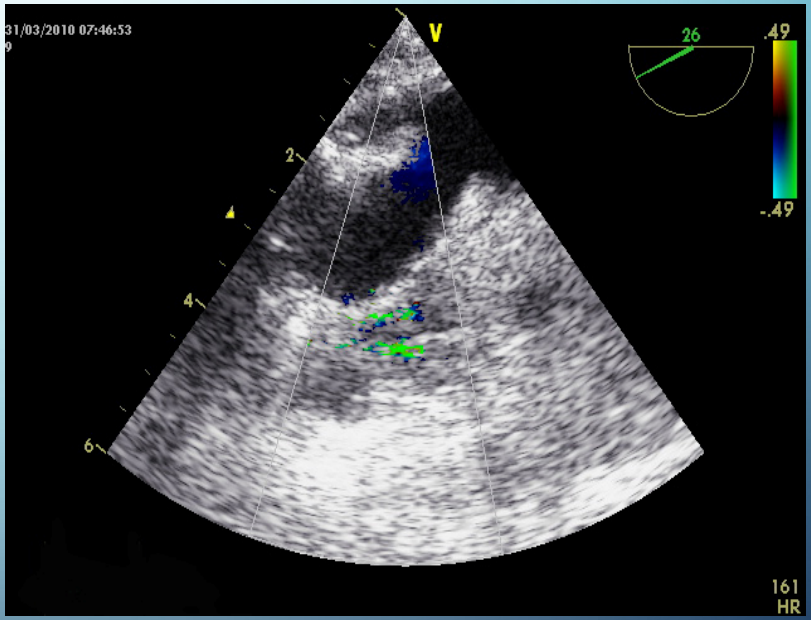
EtCO2 = 8 mmHg
CI = 2 L/min/m²
EtCO2 = 15 mmHg
CI = 1.8 L/min/m²
1.0
0.5
[m/s]
-0.5
-1.0

Roze et al. J Cardiothorac Vasc Anesth. 2013;27:467-73.

RETOUR VEINEUX PULMONAIRE CONTRÔLÉ

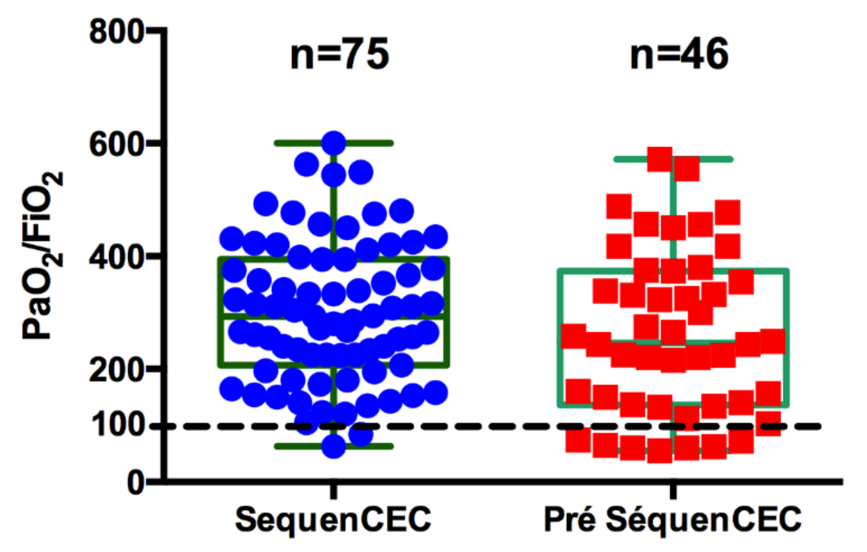

31/03/2010 07:26:40
5
V
26
.49
-.49
2
4
6
215
HR

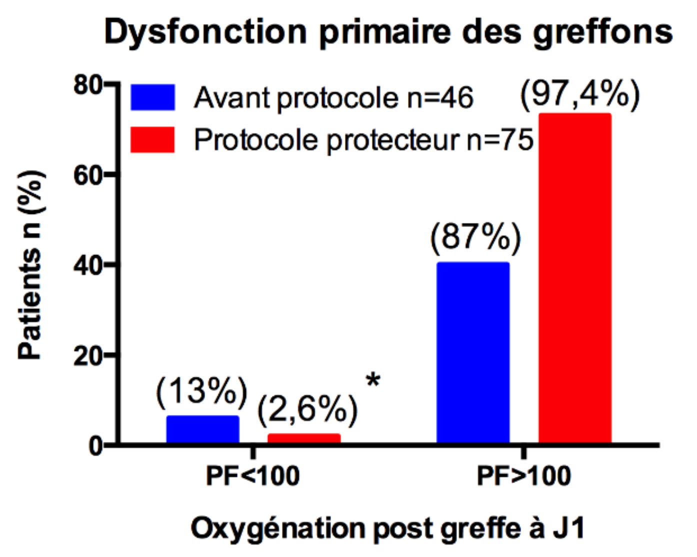
Avant CEC


31/03/2010 07:46:53
9
V
26
.49
-.49
2
4
6
161
HR

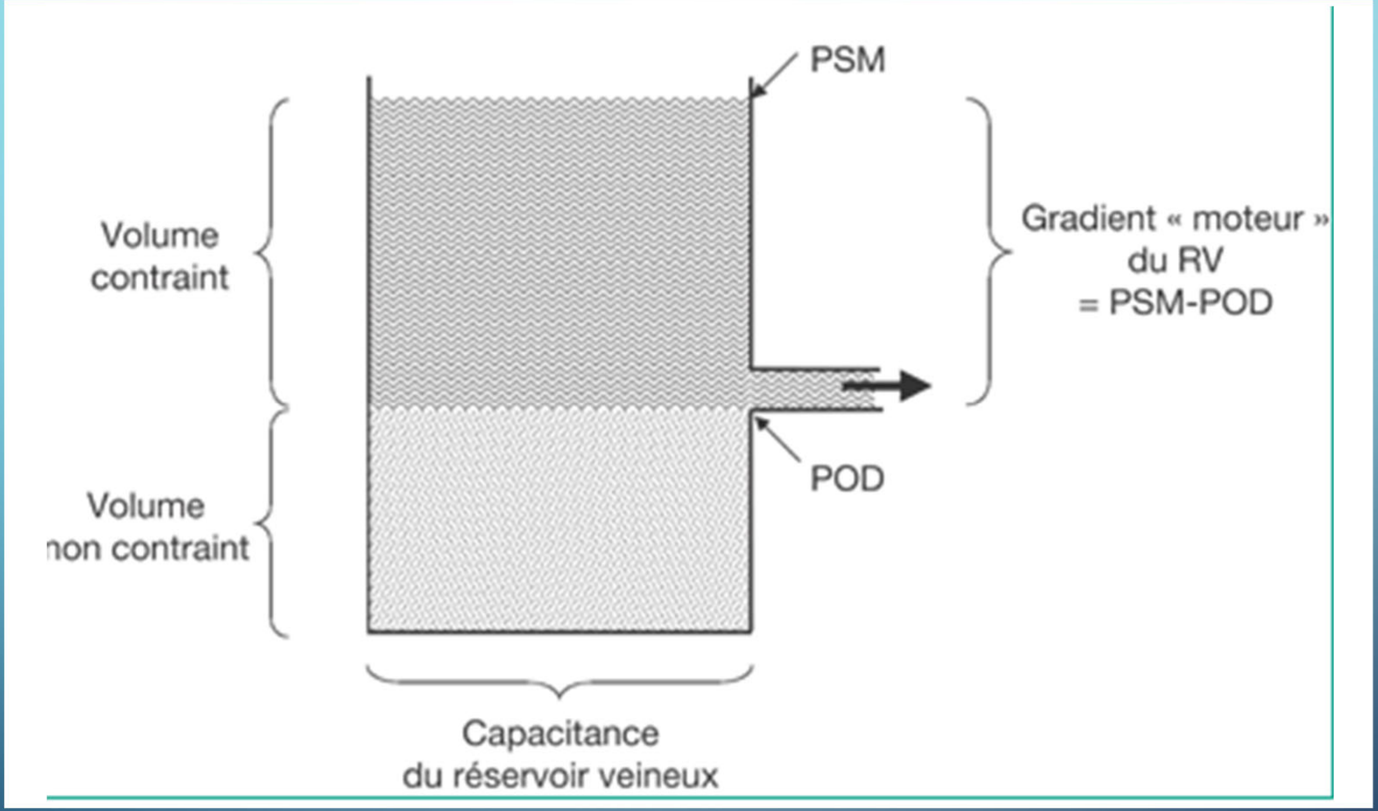
Sous CEC

CEC ET GREFFE PULMONAIRE EN 2017 (N=131)



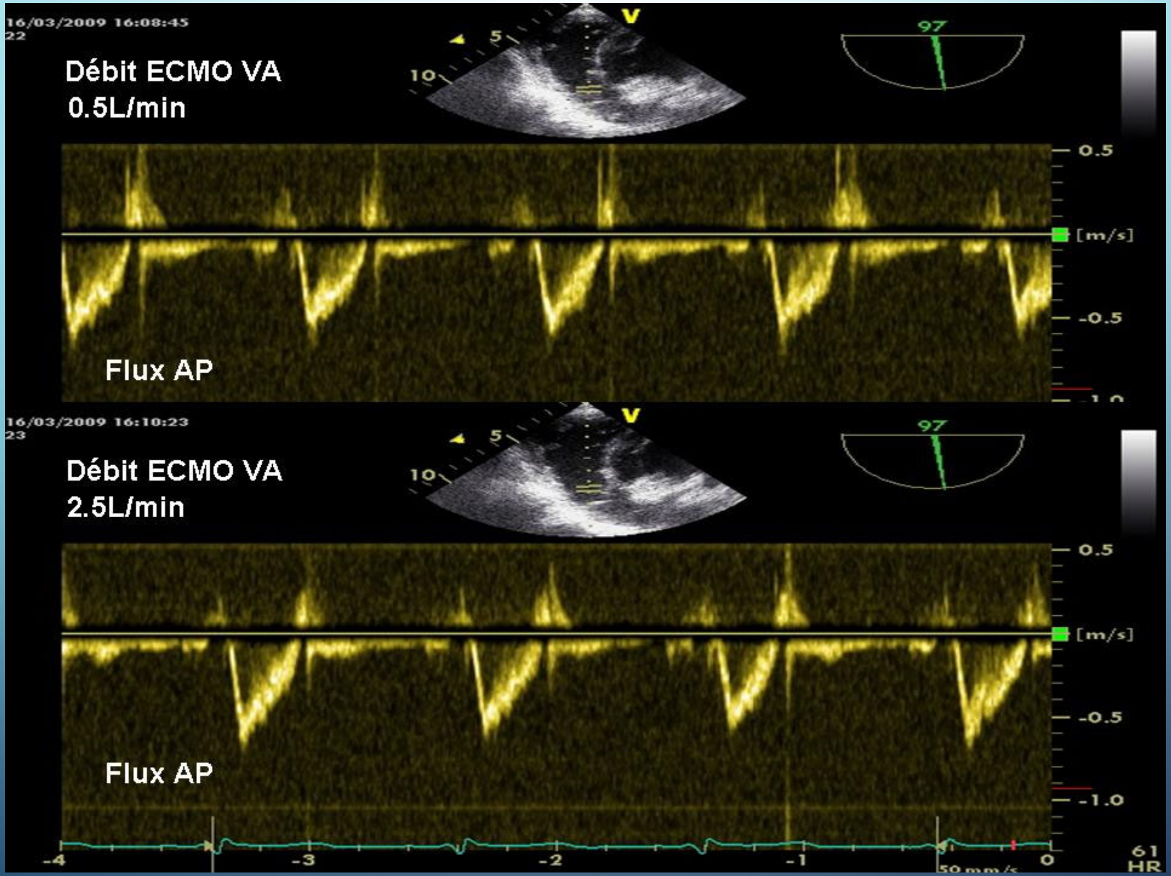


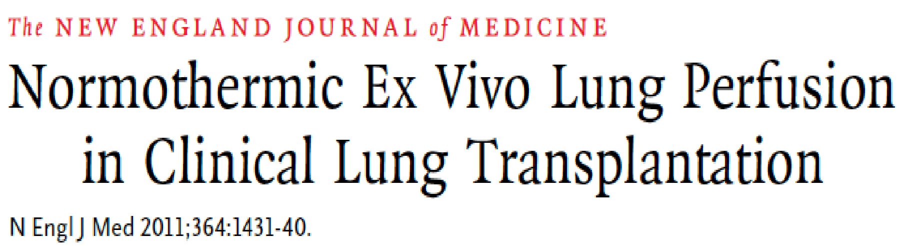
POMPES CENTRIFUGES


PSM
Volume contraint
Gradient « moteur » du RV = PSM-POD
Volume non contraint
POD
Capacitance du réservoir veineux

La pompe centrifuge est un accélérateur de flux lié à un gradient de pression

ITV SOUS 2 DEBITS D'ECMO CHEZ UN MUCO


16/03/2009 16:08:45
22
Débit ECMO VA
0.5L/min
Flux AP
0.5
[m/s]
-0.5
16/03/2009 16:10:23
23
Débit ECMO VA
2.5L/min
Flux AP
0.5
[m/s]
-0.5
-1.0
-4
-3
-2
-1
0
61
HR

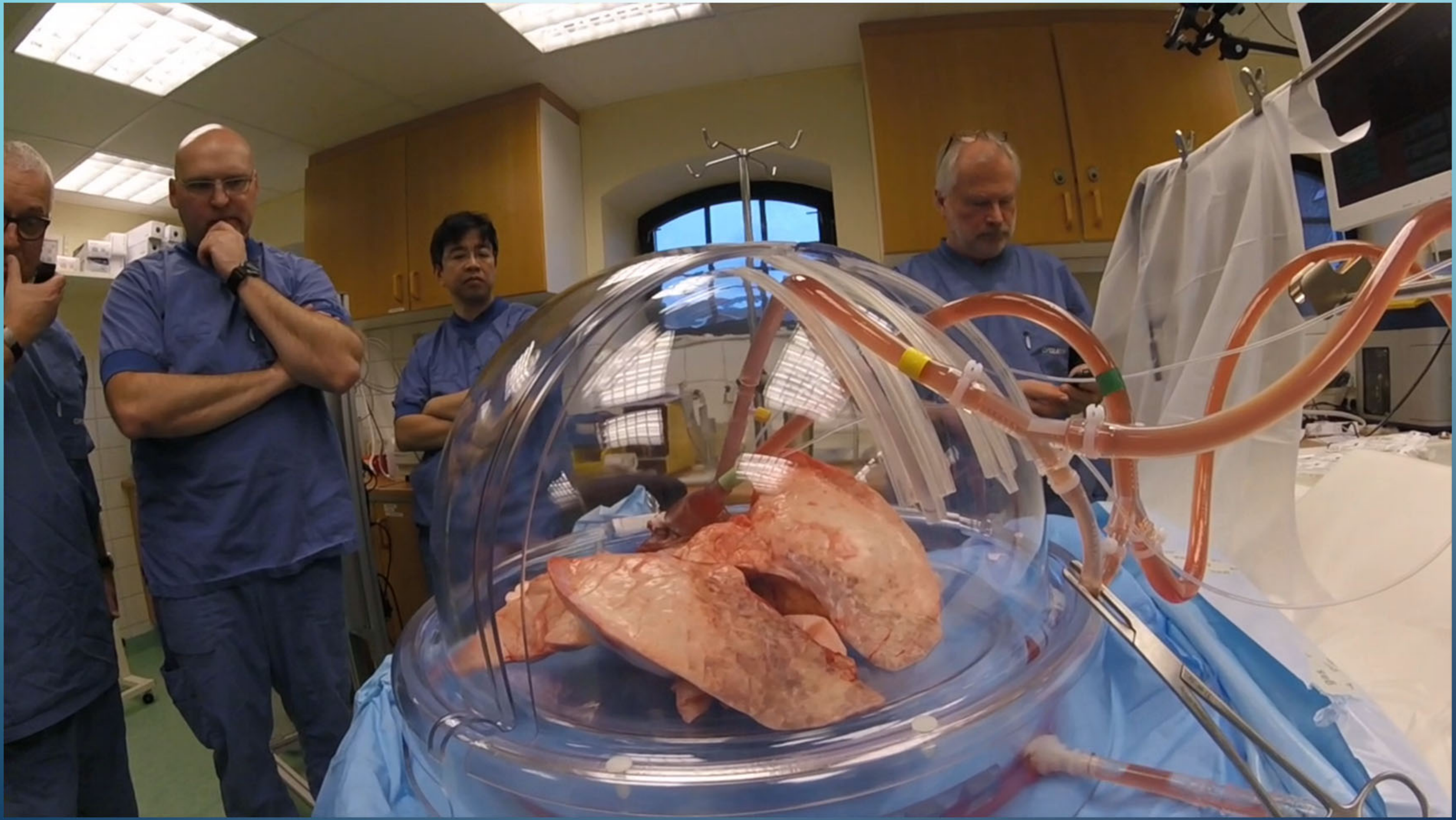


The NEW ENGLAND JOURNAL of MEDICINE

Normothermic Ex Vivo Lung Perfusion in Clinical Lung Transplantation

N Engl J Med 2011;364:1431-40.

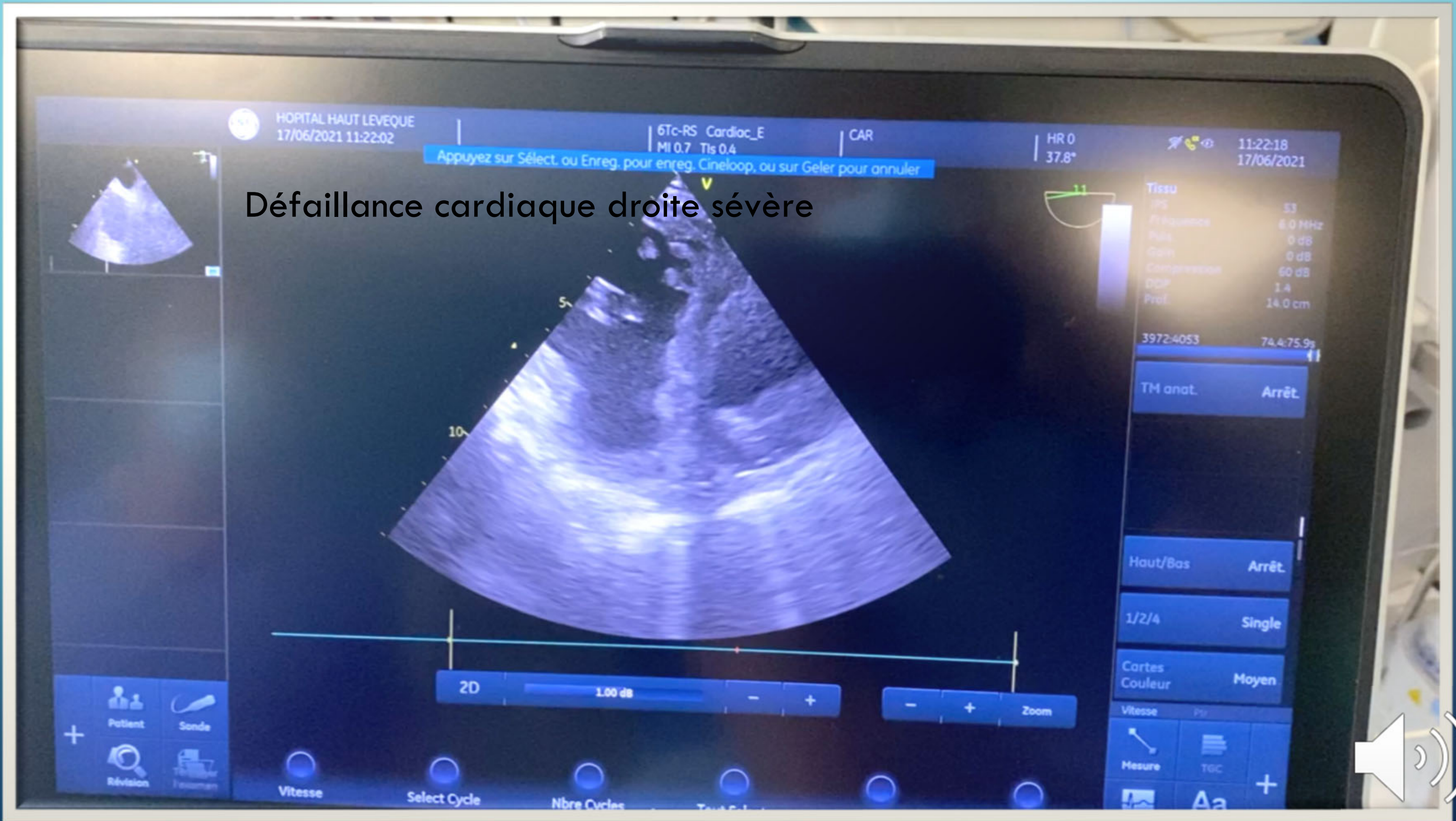
CEC EX VIVO PRE GREFFE PULMONAIRE



HTAP EN CHIRURGIE THORACIQUE

- Contre indication a la chirurgie d'exérèse du poumon
- Autres chirurgie, recours à l'assistance ou pas …
- Transplantation pulmonaire pour HTAP: ECMO VA pre induction si septum paradoxal PAPs > 90 mmHg
- Protection de la circulation pulmonaire (TBP) post greffe

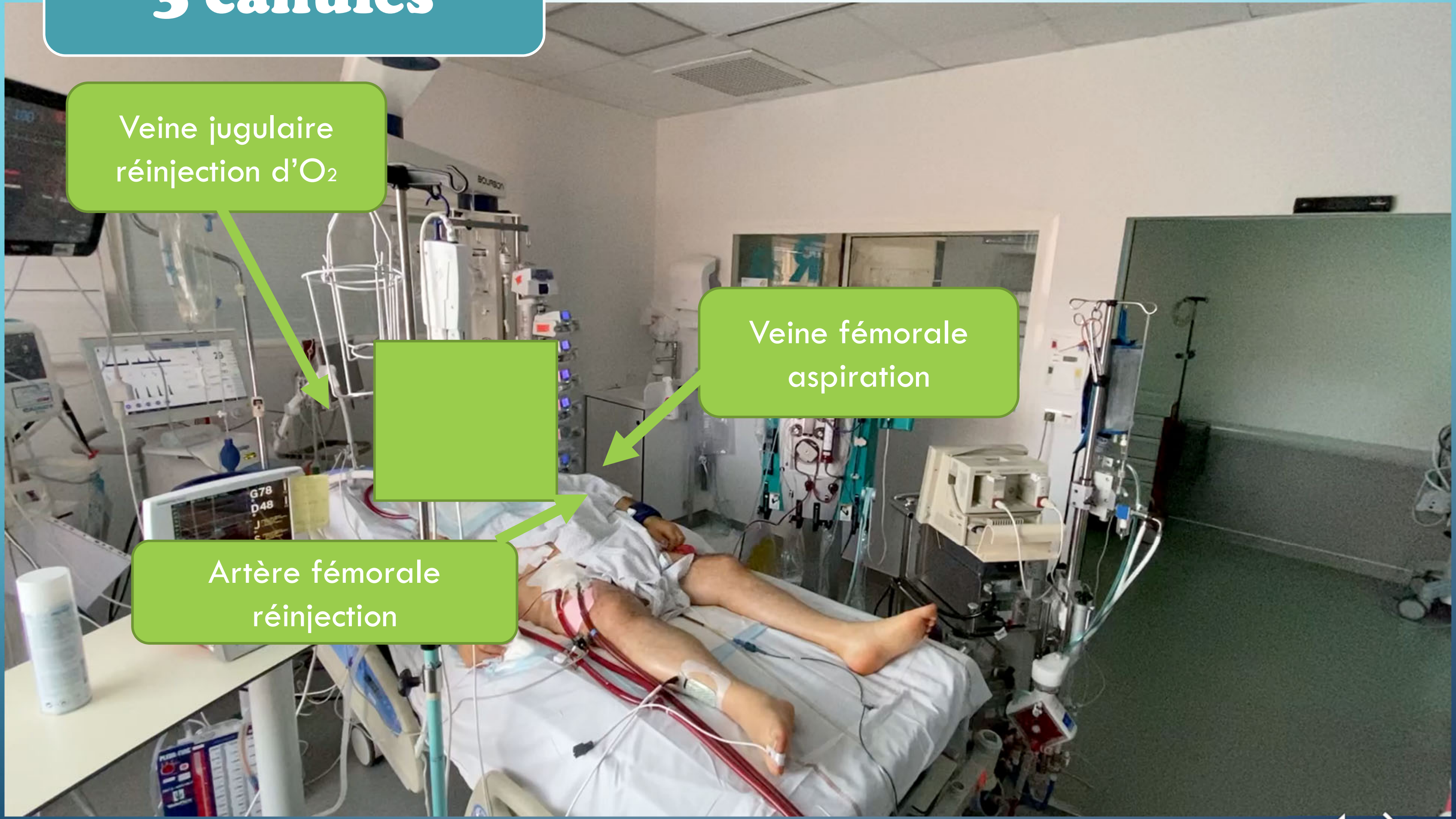
ECMO Hybride VV + VA



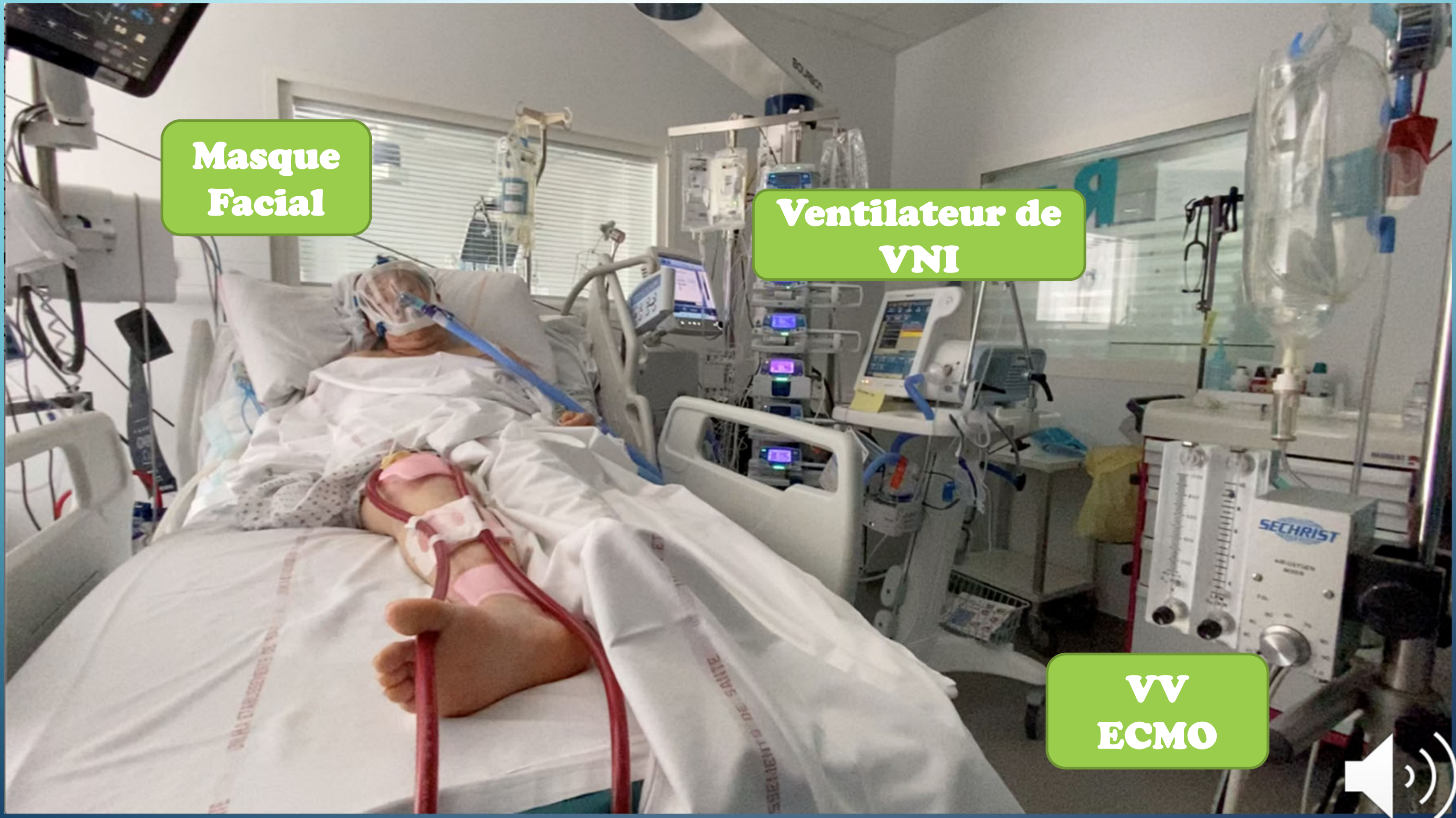
Défaillance cardiaque droite sévère

HOPITAL HAUT LEVEQUE
17/06/2021 11:22:02
6Tc-RS Cardiac_E
MI 0.7 TIs 0.4
CAR
HR 0
37.8°
11:22:18
17/06/2021
Appuyez sur Sélect. ou Enreg. pour enreg. Cineloop, ou sur Geler pour annuler
Tissu
14.0 cm
5
10
TM anat. Arrêt
Haut/Bas Arrêt
1/2/4 Single
Cartes Couleur Moyen
2D
1.00 dB
Zoom
Patient
Sonde
Révision
Vitesse
Select Cycle
Nbre Cycles
Mesure

3 canules

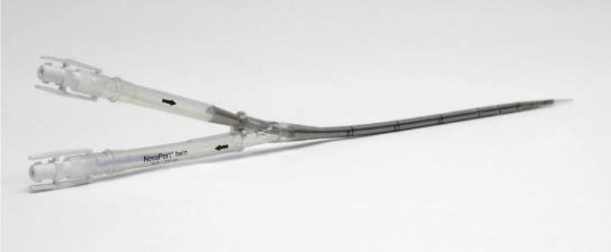

Veine jugulaire réinjection d'O_2
Veine fémorale aspiration
Artère fémorale réinjection

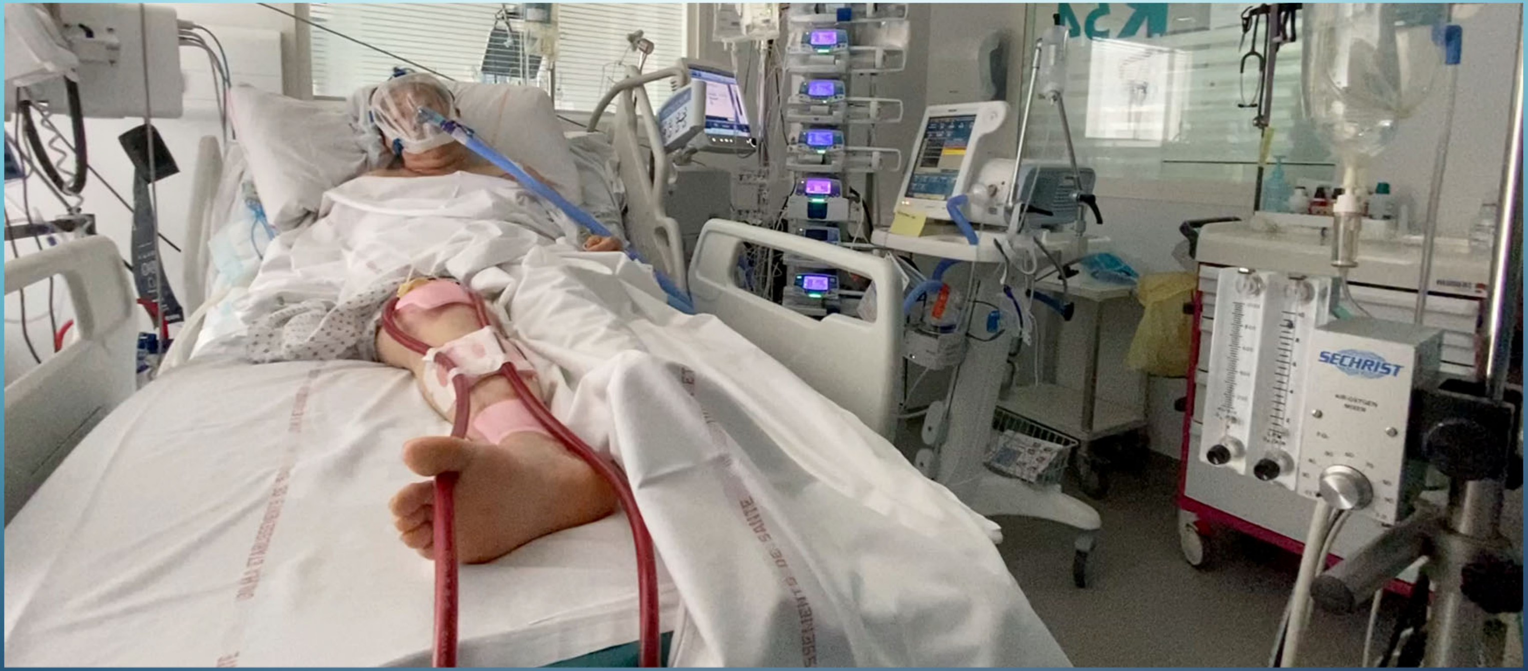
ECMO et VNI



Masque Facial
Ventilateur de VNI
VV ECMO
SECHRIST

Canule double courant (fémorale)


NovaPort twin

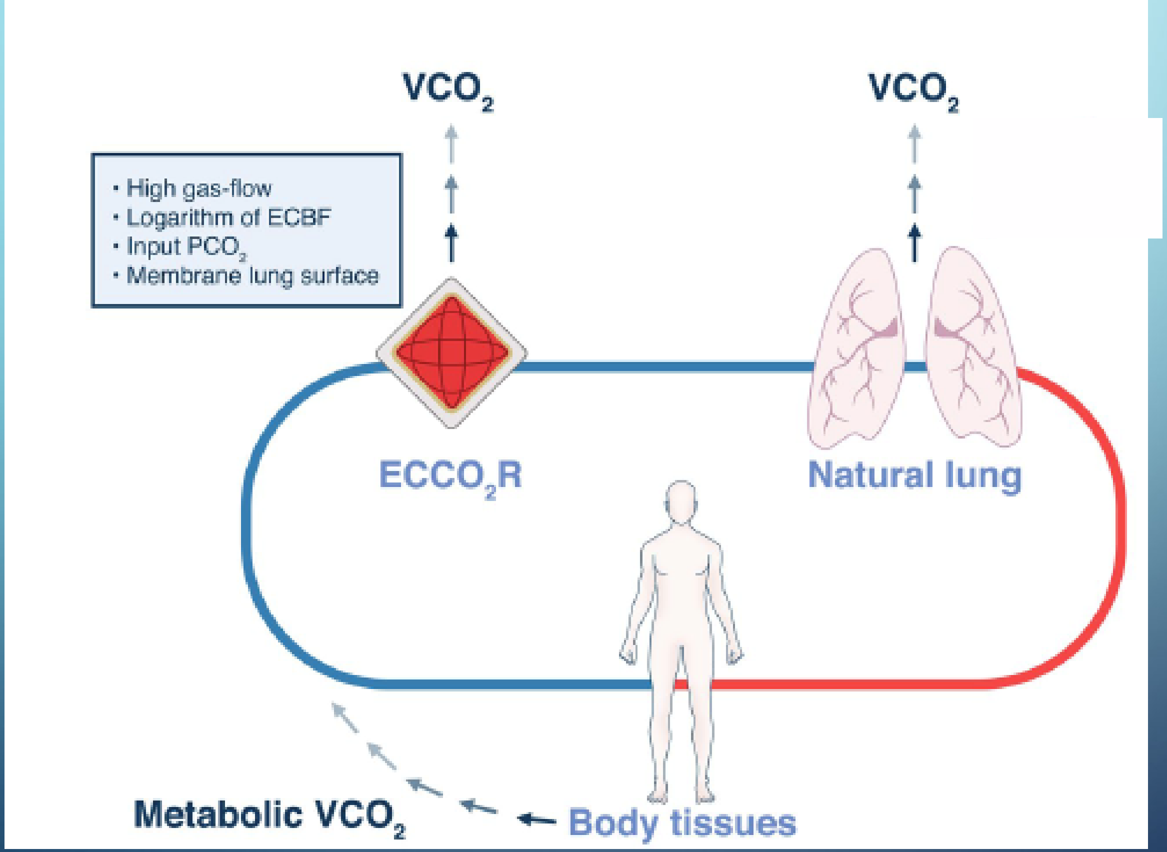


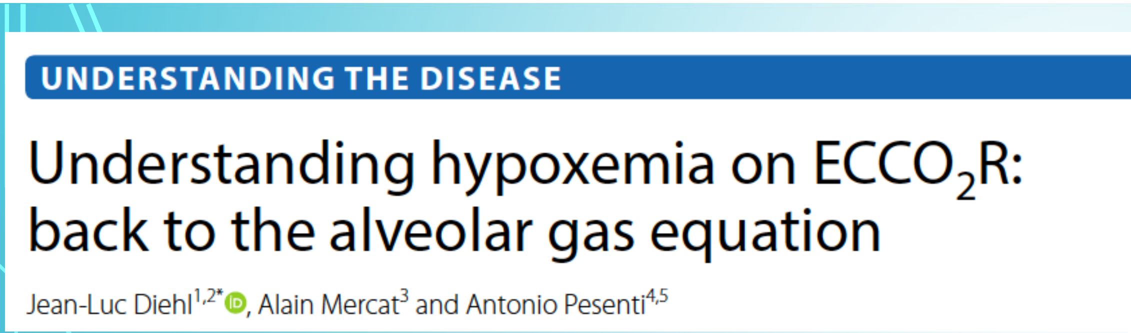
Intensive Care Med
https://doi.org/10.1007/s00134-022-06827-6

SPECIAL ISSUE INSIGHT

Physiology of extracorporeal CO_2 removal

Luciano Gattinoni[1*], Silvia Coppola[2] and Luigi Camporota[3]


VCO_2
VCO_2
· High gas-flow
· Logarithm of ECBF
· Input PCO_2
· Membrane lung surface
$ECCO_2R$
Natural lung
Metabolic VCO_2
Body tissues



UNDERSTANDING THE DISEASE

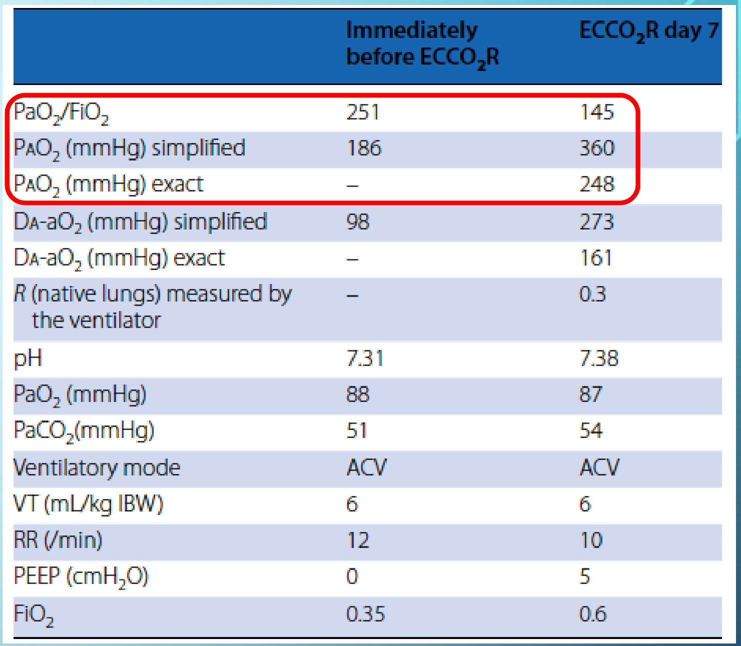
Understanding hypoxemia on $ECCO_2R$: back to the alveolar gas equation

Jean-Luc Diehl[1,2*], Alain Mercat[3] and Antonio Pesenti[4,5]

CrossMark

R =0,8

R =0,3



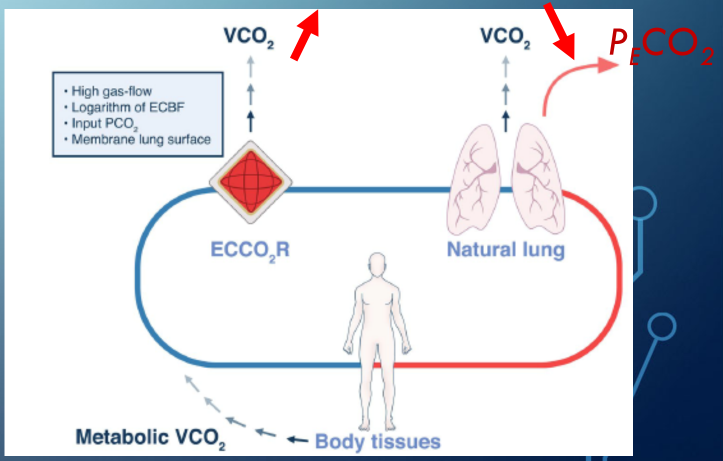
	Immediately before $ECCO_2R$	$ECCO_2R$ day 7
PaO_2/FiO_2	251	145
P_AO_2 (mmHg) simplified	186	360
P_AO_2 (mmHg) exact	–	248
$D_{A\text{-}a}O_2$ (mmHg) simplified	98	273
$D_{A\text{-}a}O_2$ (mmHg) exact	–	161
R (native lungs) measured by the ventilator	–	0.3
pH	7.31	7.38
PaO_2 (mmHg)	88	87
$PaCO_2$(mmHg)	51	54
Ventilatory mode	ACV	ACV
VT (mL/kg IBW)	6	6
RR (/min)	12	10
PEEP (cmH_2O)	0	5
FiO_2	0.35	0.6

$$\downarrow P_AO_2 = P_iO_2 - \frac{P_ACO_2}{R\downarrow}$$

R le quotient respiratoire peut être << 0,8

$$\downarrow R = \frac{\downarrow P_ECO_2 \, x \, (1-FiO_2)}{P_iO_2 - PEO_2 - \downarrow(PECO_2 x F^iO_2)}$$

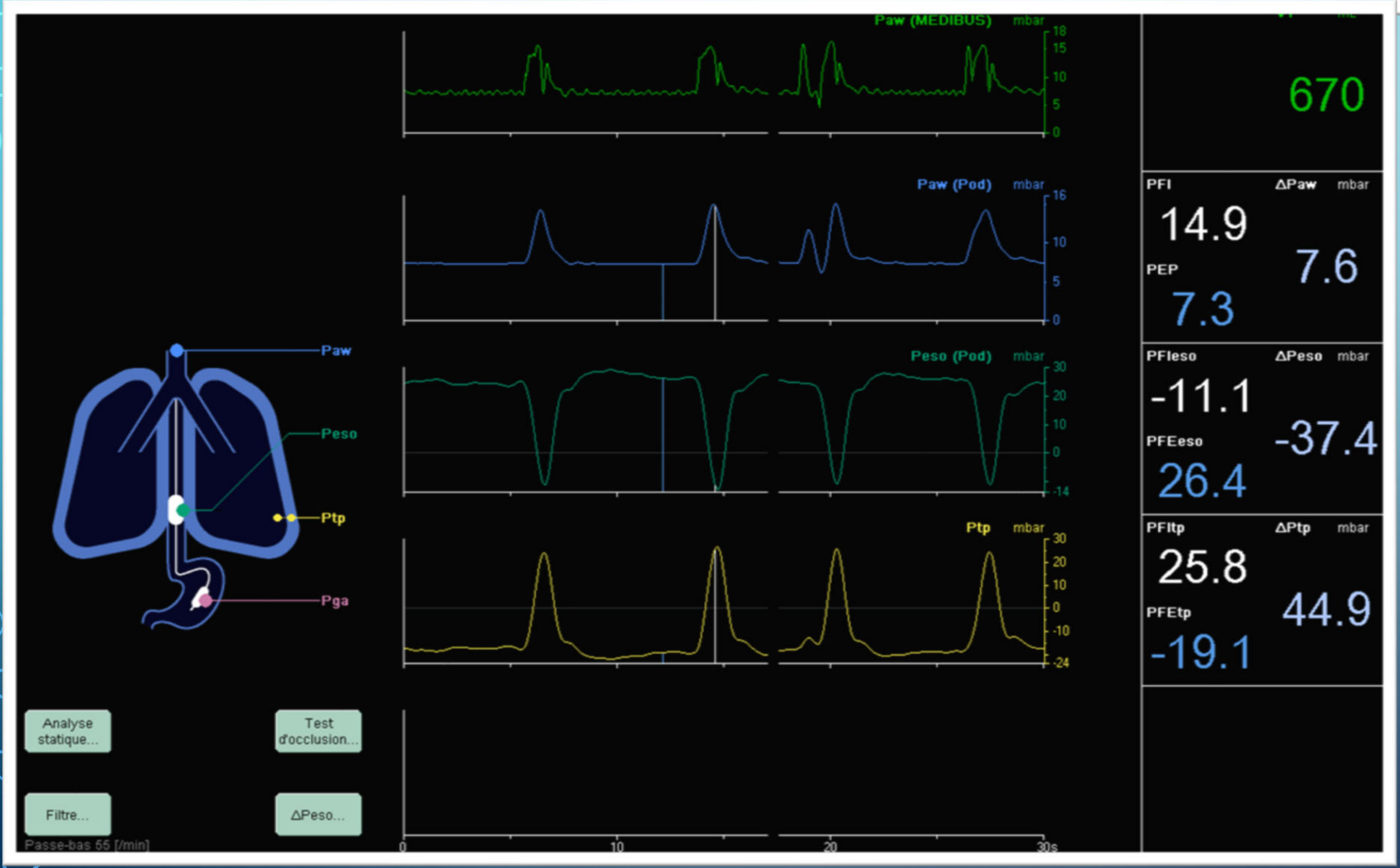
R diminue avec la PAO_2 puis la PaO_2



VCO_2 ↑
VCO_2 ↓
P_ECO_2
• High gas-flow
• Logarithm of ECBF
• Input PCO_2
• Membrane lung surface
$ECCO_2R$
Natural lung
Metabolic VCO_2
Body tissues

Intensive Care Med (2019) 45:255–256

Compliance TP courbe PV débit lent PEEP 6 à 20 $ml.cmH_2O^{-1}$


Paw (MEDIBUS) mbar
18
15
10
5
0
Paw (Pod) mbar
16
10
5
0
Peso (Pod) mbar
30
20
10
0
-14
Ptp mbar
30
20
10
0
-10
-24
Paw
Peso
Ptp
Pga
Analyse statique...
Test d'occlusion...
Filtre...
ΔPeso...
Passe-bas 55 [/min]
0
10
20
30s

670

PFI 14.9

PEP 7.3

ΔPaw mbar 7.6

PFIeso -11.1

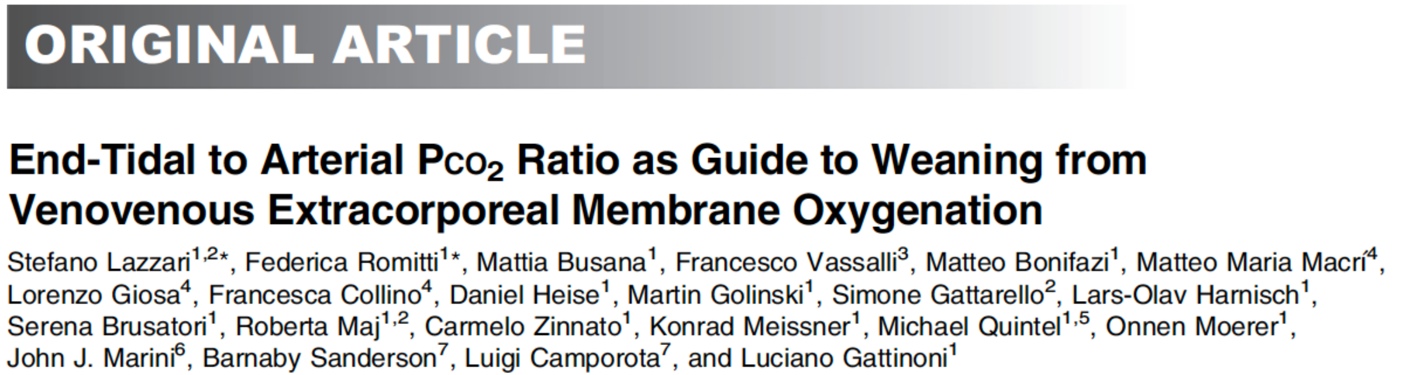
PFEeso 26.4

ΔPeso mbar -37.4

PFItp 25.8

PFEtp -19.1

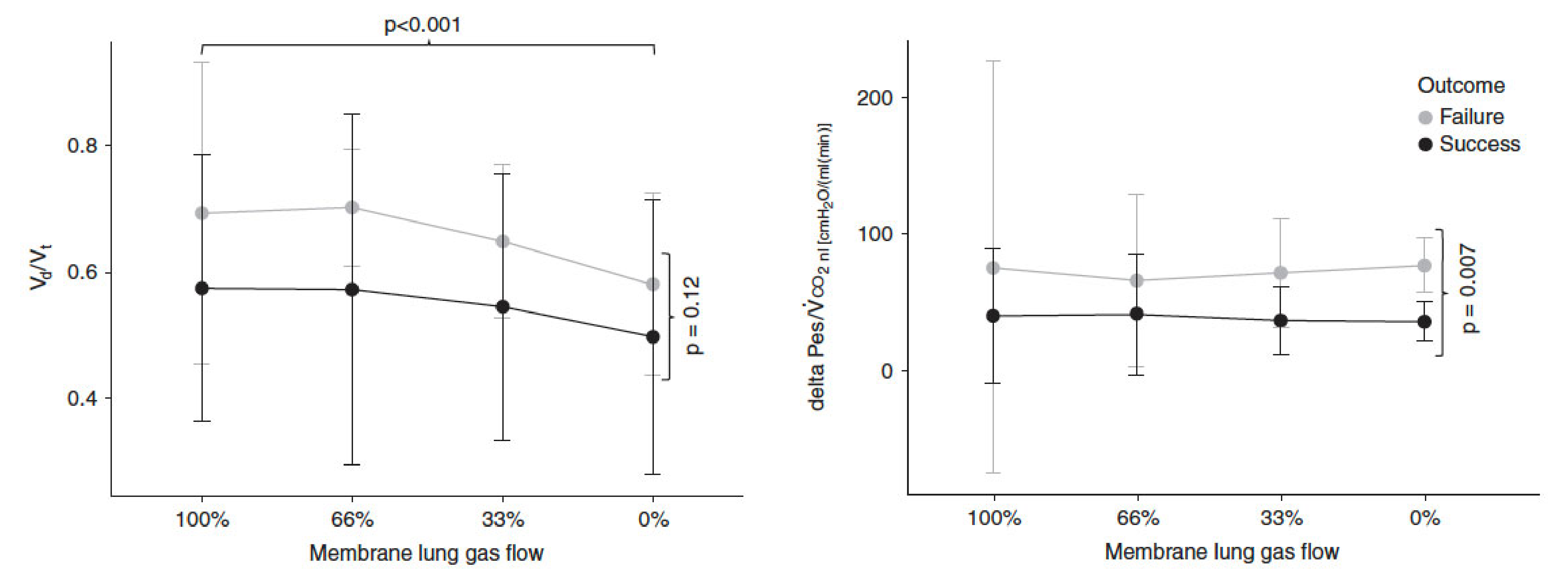
ΔPtp mbar 44.9



ORIGINAL ARTICLE

End-Tidal to Arterial P_{CO_2} Ratio as Guide to Weaning from Venovenous Extracorporeal Membrane Oxygenation

Stefano Lazzari[1,2]*, Federica Romitti[1]*, Mattia Busana[1], Francesco Vassalli[3], Matteo Bonifazi[1], Matteo Maria Macrí[4], Lorenzo Giosa[4], Francesca Collino[4], Daniel Heise[1], Martin Golinski[1], Simone Gattarello[2], Lars-Olav Harnisch[1], Serena Brusatori[1], Roberta Maj[1,2], Carmelo Zinnato[1], Konrad Meissner[1], Michael Quintel[1,5], Onnen Moerer[1], John J. Marini[6], Barnaby Sanderson[7], Luigi Camporota[7], and Luciano Gattinoni[1]



Am J Respir Crit Care Med Vol 206, Iss 8, pp 973–980, Oct 15, 2022

AU FINAL

- Cas par cas, indications, objectifs, type d'assistance, Timing de la pose.
- Sevrage sur table ou en réanimation
- Anticoagulation sous ECMO en Réa post op peut etre stoppée si saignement puis on cible 200 ui/kg/j on ne regarde pas trop l'activité AntiXa (nuage de points).