Centre Hospitalier de la Côte Basque

université de BORDEAUX

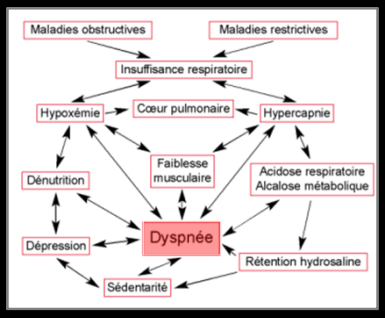
# Physiopathologie respiratoire
# Ventilation artificielle

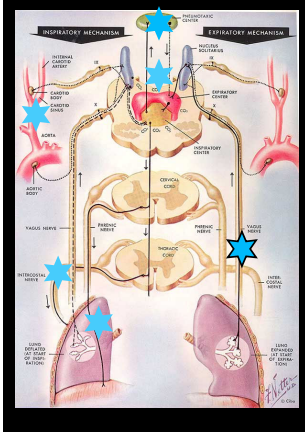
*Pr Hadrien Rozé*

iVentilate

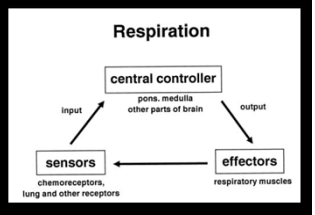
## Référentiels


## Physiopathologie respiratoire



## Innervation
## Contrôle ventilatoire




CHEST 2000; 117:205–225

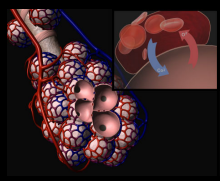
## Acidose respiratoire
## post opératoire

## Muscles accessoires

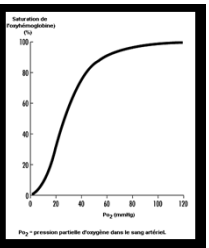
## Définition

- Incapacité du poumon à assurer une oxygénation satisfaisante et/ou de prévenir une rétention de $CO_2$ :
  - Hypoxie < 60 mmHg
  - Hypercapnie > 50 mmHg

  Ces valeurs limites dépendent de l'histoire clinique



## Maintenir CaO2



Contenu $O_2$ ml

15

10

5

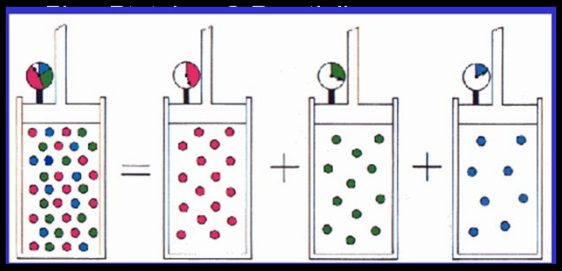
$CaO_2$= POxHbxSaO$_2$+ 0,003 $PaO_2$

200 400 600 $PaO_2$ mmHg

## 4 Causes de l'hypoxémie

- L'hypoventilation
- L'anomalie de diffusion
- Le shunt
- L'inégalité des rapports ventilation/perfusion

## Loi des gaz



## Hypoventilation

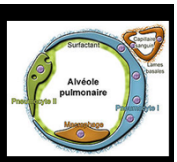


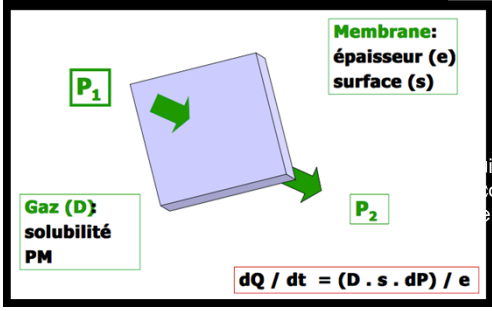
- Hypercapnie:
  - PaCO2 =K x $VCO_2$ / $V_A$
- Hypoxémie:
  - $P_AO_2$ = $PiO_2$ - $P_ACO_2$ / R
  - $PiO_2$ = $FiO_2$ x (Pb - $PH_2O$)
  - $P_AO_2$ = $FiO_2$ x (Pb - $PH_2O$)- $P_ACO_2$ / R

## Etiologies

- Dépression des centres respiratoires : médicaments
- Atteinte du bulbe rachidien : encéphalite, TC, hémorragie, tumeur…
- Atteinte de la corne antérieure : poliomyélite
- Atteinte des nerfs des muscles respiratoires : Guillain Barré, diphtérie
- Atteinte des muscles respiratoires : dystrophie musculaire progressive
- Lésions de la cage thoracique : volet costal
- Obstruction des voies aériennes supérieures : tumeurs

## Anomalies de diffusion

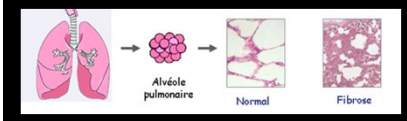


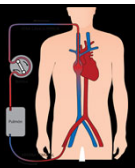

ilibre au 1/3.
coeur droit
ntation

## Etiologie

- Asbestose, sarcoidose, granulomatoses, fibrose interstitielle pulmonaire, sclerodermie , lupus ...




## Le shunt

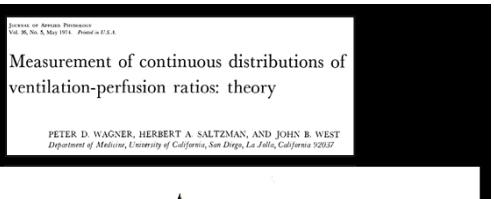



- Du sang veineux atteint le système artériel :
  Calcul : $Q_S/Q_T=(Cc' - Ca)/(Cc' -Cv)$
  - Cc ' calculé sous $O_2$ pur (Sc ' $O_2$=100%)
  - Ca GDS et Cv KT dans l ' AP
    normale < 10%

$PaCO_2$ rarement élevée car hyperventilation

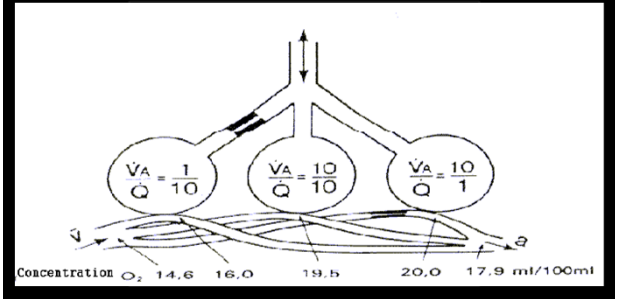
## Etiologies

- shunt vrai
  - Fistules artério-veineuses Syndrome hépatopulmonaire des Cirrhoses
  - Canal artériel, CIV, CIA et HTAP
- effet shunt
  - = $V_A/Q \rightarrow 0$ correspond à une inégalité des rapports ventilation / perfusion
  - Atélectasies de l ' anesthésie générale, PFLA,SDRA etc ...

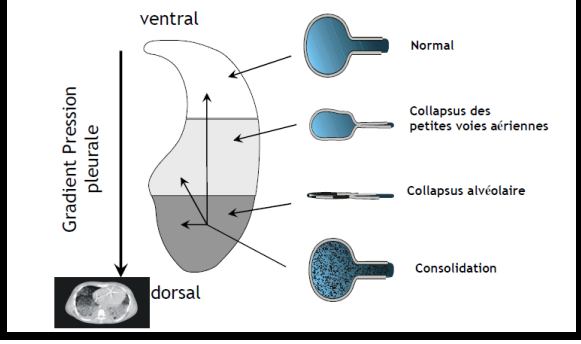


Measurement of continuous distributions of ventilation-perfusion ratios: theory

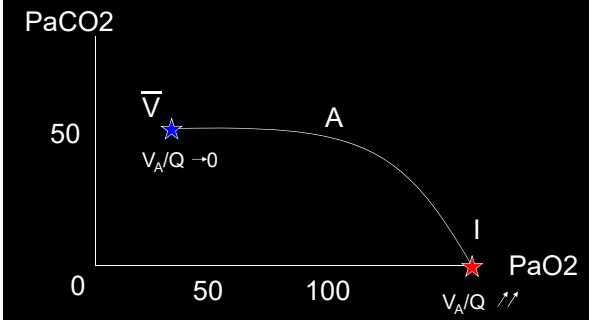
PETER D. WAGNER, HERBERT A. SALTZMAN, AND JOHN B. WEST
*Department of Medicine, University of California, San Diego, La Jolla, California 92037*



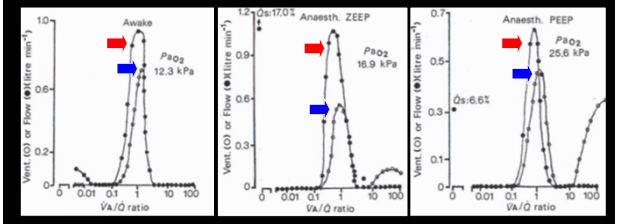

## Inégalités des $V_A/Q$



## Inégalités des $V_A/Q$




## MESURE DES $V_A/Q$



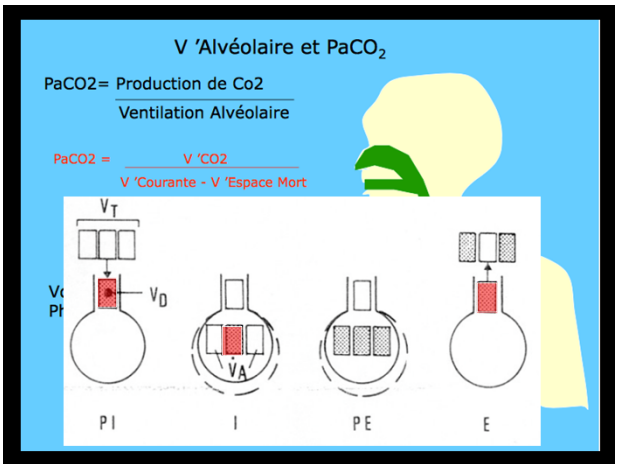

Wagner PD, Saltzman HA, West JB.
Measurement of continuous distributions of ventilation-perfusion ratios: theory.
*J Appl Physiol. 1974 May;36(5):588-99.*

## ADAPTATION

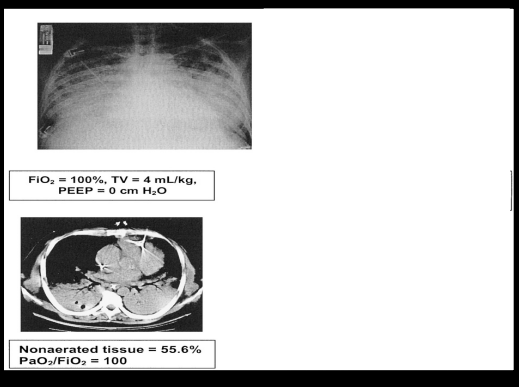
- $V_A/Q \searrow \Rightarrow PaO_2 \searrow PaCO_2 \nearrow$
- Stimulation des chémorécepteurs périphériques et centraux : Hyperventilation, VPH, agents vaso actifs, système nerveux autonome…
- $PaO_2 \nearrow$ $PaCO_2 \searrow$

## Etiologies

- Pneumopathie infectieuse
- Embolie pulmonaire,embolie graisseuse, chest syndrome, TRALI
- OAP
- SDRA pulmonaires et extrapulmonaires
- Insuffisance respiratoire chronique décompensée, surinfection, bronchospasme: aggravation des inégalité des $V_A/Q$ augmentation du W respiratoire.
- Atélectasies, inhalation, pneumo-hémothorax, contusion pulmonaire

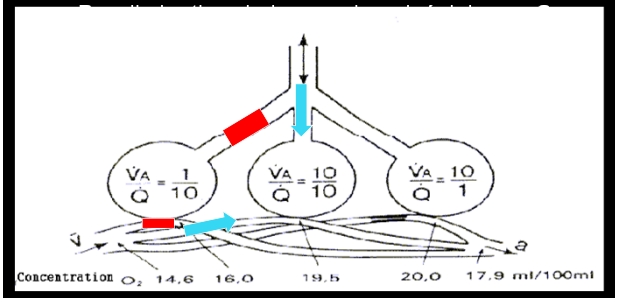



## Améliorer la ventilation alvéolaire



## Trouble de la ventilation

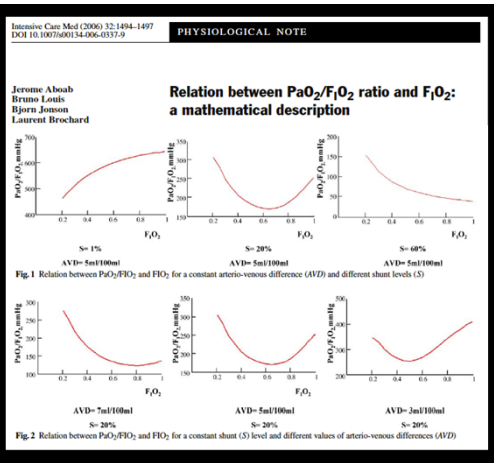
## Stimulation de la VPH




## Débit cardiaque et $V_a/q$

Il y peut y avoir en pratique clinique une amélioration de la $PaO_2$ sans recrutement alvéolaire :
-La diminution du débit cardiaque entraine une diminution de l'effet shunt (ex verticaliser un patient en ARDS)
redistribution du sang des zones de hauts vers bas Va/Q (effet du NO inhalé) .On observe alors une augmentation de l'espace mort et donc de la $PaCO_2$.

Par contre à ventilation alvéolaire constante une diminution de la $PaCO_2$ correspond plus spécifiquement à un recrutement alvéolaire.


Intensive Care Med (2006) 32:1494–1497
DOI 10.1007/s00134-006-0337-9

PHYSIOLOGICAL NOTE

Jerome Aboab
Bruno Louis
Bjorn Jonson
Laurent Brochard

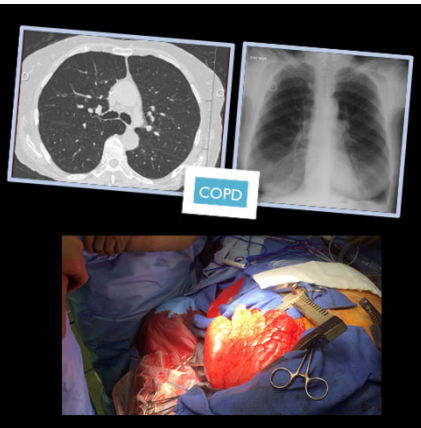
**Relation between $PaO_2/F_IO_2$ ratio and $F_IO_2$: a mathematical description**

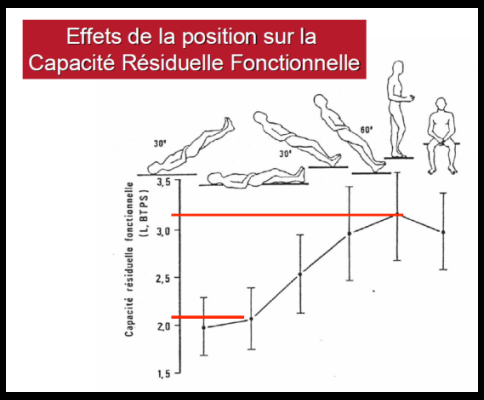
Fig. 1 Relation between $PaO_2/FIO_2$ and $FIO_2$ for a constant arterio-venous difference (*AVD*) and different shunt levels (*S*)

Fig. 2 Relation between $PaO_2/FIO_2$ and $FIO_2$ for a constant shunt (*S*) level and different values of arterio-venous differences (*AVD*)

## Capacités pulmonaires

- Capacité pulmonaire totale =
  capacité vitale + volume résiduel
  =3,6 à 4,8 L + 1,2 à 2,4 L
- Capacité vitale = VRE + VC + VRI
  =1 à 1,2 L + 0,5 L + 2,1 à 3,1L
- CRF = VR + VRE
  = 1,2 à 2,4 L + 1 à 1,2 L






## GDS

- Ph
- PaO2
- PaCO2
- HCO-
- SaO2
- Hypoxémie, Hyper Hypocapnie, Acidose Alcalose, métabolique, respiratoire

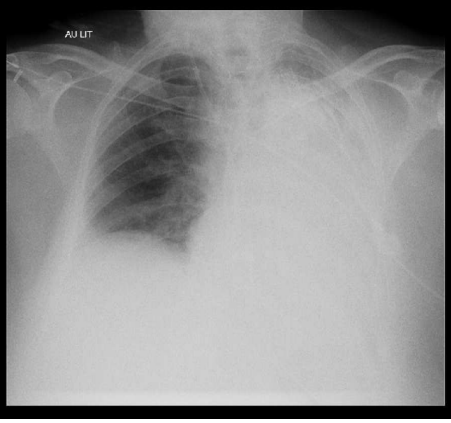
## Cas clinique N° 1

- Mr X. Toxicomane
- Admis au SAU pour coma par overdose.
- FR : 10
- GDS en AA:
  - PO2 : 50 mmHg
  - PCO2 : 60 mmHg
  - pH : 7,25
  - Bicar : 22 mmol/l
  - BE : - 2

## Analyse GDS

- Hypoventilation alvéolaire
  - Hypoxie
  - Hypercapnie
- Acidose mixte
  - Hypercapnie
  - Souffrance tissulaire (faible)
- Cause :
  - Bradypnée
  - PNP ?

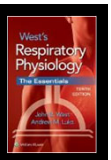
- Injection de Narcan.
- FR : 32
- GDS en AA:
  - PO2 : 60 mmHg
  - PCO2: 25 mmHg
  - pH : 7, 46
  - Bicar : 22 mmol/l
- RT



## Analyse des GDS

- Hypoxie
- Hypocapnie par hyperventilation
- Hétérogénéité des rapports ventilation perfusion
- RT: PNP poumon G

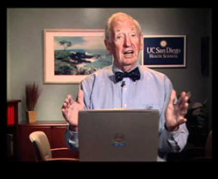
## RÉFÉRENCES



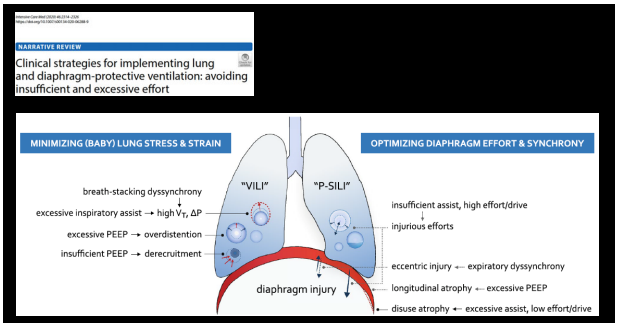


- West JB. Pulmonary Pathophysiologie - the essential. *1995 édition Pradel*.

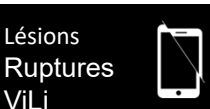

https://www.youtube.com/watch?v=qLroD-Qcg4o

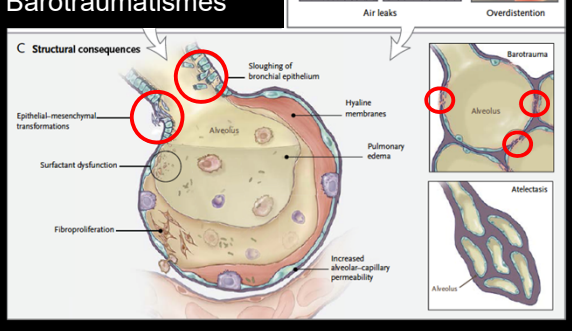


## Les lésions induites par la ventilation



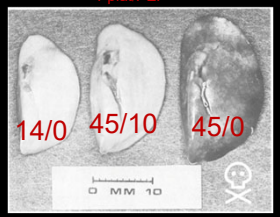

## Lésions
## Ruptures
## ViLi
## Barotraumatismes

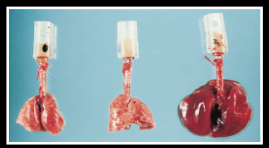





## Lésions induites par la ventilation

Pplat/PEP



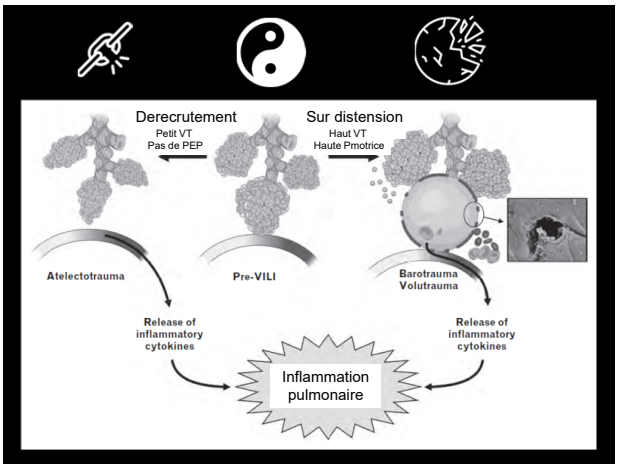



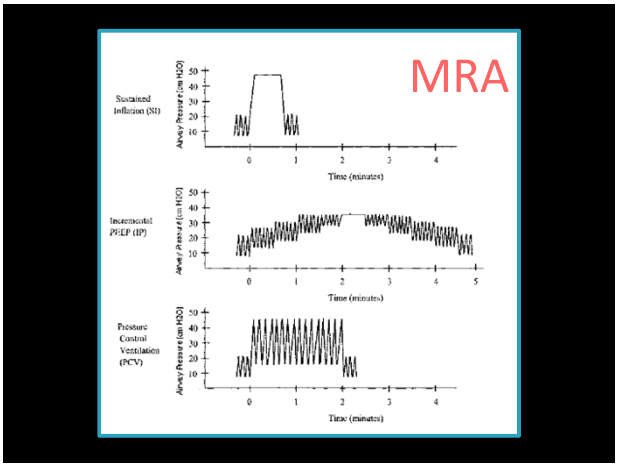
Dreyfuss D, Saumon G
Ventilator-induced lung injury: lessons from experimental studies. *Am J Respir Crit Care Med. 1998 ;157:294-323. Review.*

**Experimental Pulmonary Edema due to Intermittent Positive Pressure Ventilation with High Inflation Pressures. Protection by Positive End-Expiratory Pressure**

HERBERT H. WEBB and DONALD F. TIERNEY

AMERICAN REVIEW OF RESPIRATORY DISEASE, VOLUME 110, 1974

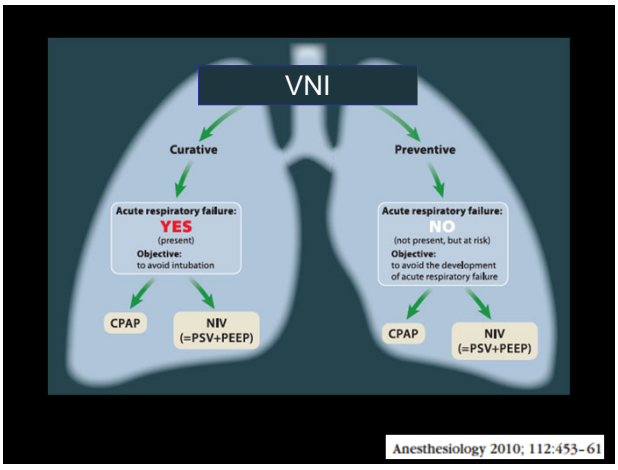



Temps 40 secondes

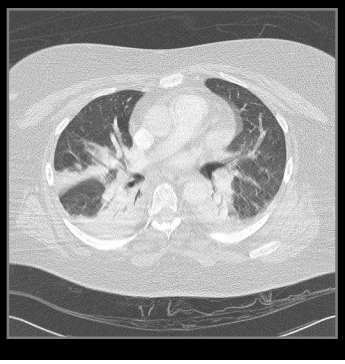
## Bénéfices/Risques

- Bénéfices:
  - Augmenter le volume pulmonaire aéré
  - Améliorer l'oxygénation
- Risques:
  - Surdistension
  - Barotraumatisme
  - Dégradation hémodynamique

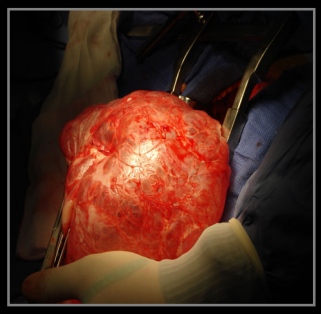


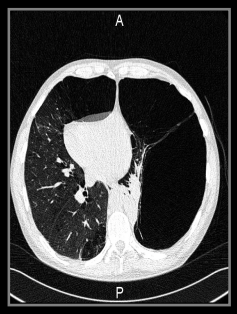

## Atelectasies de l'obésité

J2 Post Op
Anneau
Gastrique
coelio

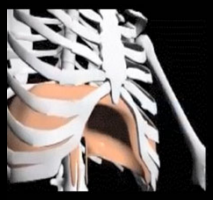


## Chirurgie l'emphysème





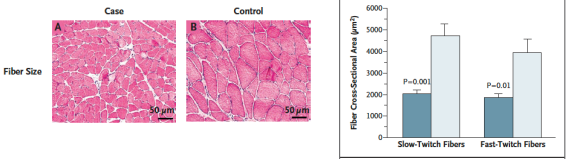

## Dysfonction Diaphragmatique



The NEW ENGLAND JOURNAL of MEDICINE
ESTABLISHED IN 1812 MARCH 27, 2008 VOL. 358 NO. 13

### Rapid Disuse Atrophy of Diaphragm Fibers in Mechanically Ventilated Humans

Sanford Levine, M.D., Taitan Nguyen, B.S.E., Nyali Taylor, M.D., M.P.H., Michael E. Friscia, M.D., Murat T. Budak, M.D., Ph.D., Pamela Rothenberg, B.A., Jianliang Zhu, M.D., Rajeev Sachdeva, M.D., Seema Sonnad, Ph.D., Larry R. Kaiser, M.D., Neal A. Rubinstein, M.D., Ph.D., Scott K. Powers, Ph.D., Ed.D., and Joseph B. Shrager, M.D.



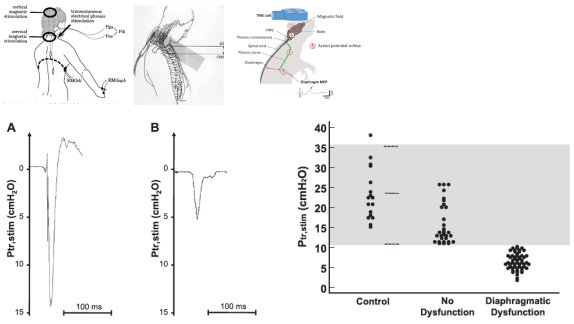




### Diaphragm Dysfunction on Admission to the Intensive Care Unit

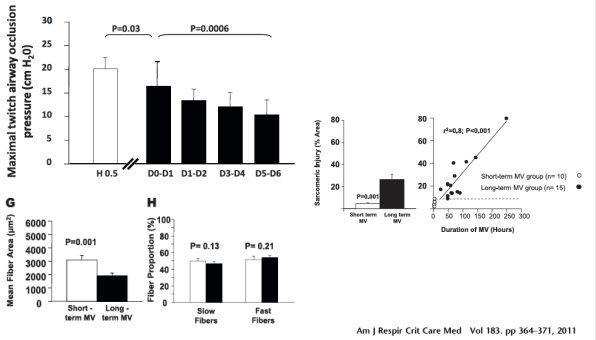
#### Prevalence, Risk Factors, and Prognostic Impact—A Prospective Study

Alexandre Demoule[1,2,3], Boris Jung[4,5], Hélène Prodanovic[2], Nicolas Molinari[6], Gerald Chanques[4,5], Catherine Coirault[3], Stefan Matecki[3,7], Alexandre Duguet[1,2], Thomas Similowski[1,2*], and Samir Jaber[4,5*]




### Rapidly Progressive Diaphragmatic Weakness and Injury during Mechanical Ventilation in Humans

Samir Jaber[1,2,6], Basil J. Petrof[3], Boris Jung[1,2], Gérald Chanques[1,2], Jean-Philippe Berthet[4], Christophe Rabuel[5], Hassan Bouyabrine[6], Patricia Courouble[1,2], Christelle Koechlin-Ramonatxo[7], Mustapha Sebbane[1,2], Thomas Similowski[8], Valérie Scheuermann[9], Alexandre Mebazaa[6], Xavier Capdevila[1,2], Dominique Mornet[5], Jacques Mercier[2,10], Alain Lacampagne[4], Alexandre Philips[5], and Stefan Matecki[2,10]

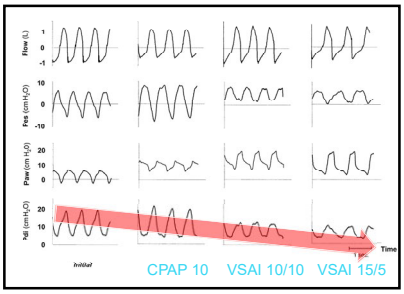



Am J Respir Crit Care Med Vol 183. pp 364-371, 2011

## CPAP vs VSAI: (PEP ou PEP+Aide)

Pression

Effort




AJRCCM (2005) 172:1112

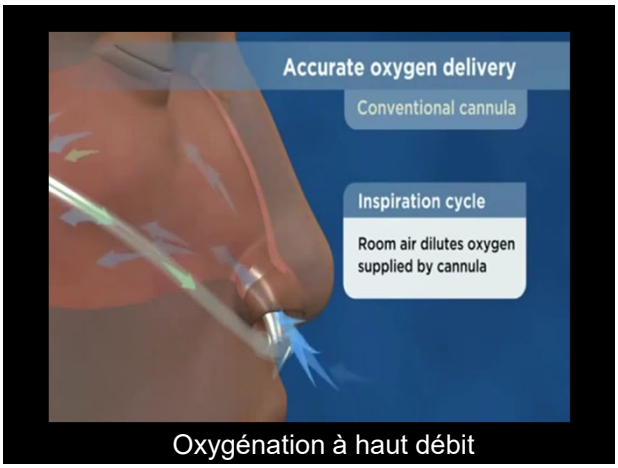
| | CON Group (n = 22) | NPPV Group (n = 22) | NPPV+RM Group (n = 22) | Overall Group Effect |
|---|---|---|---|---|
| $P_{max}$, cm $H_2O$ | 35 [32–39] | 32 [29–36] | 29 [28–34]* | $P = 0.03$ |
| | | | | $P < 0.001$ |
| $E_{rs}$, cm $H_2O$ $ml^{-1}$ | 34 [27–39] | 20 [17–25]* | 13 [11–20]*† | $P < 0.001$ |
| VTe, ml | 485 [430–546] | 458 [420–550] | 475 [425–550] | $P = 0.94$ |
| RR, c $min^{-1}$ | 20 [18–20] | 20 [20–20] | 20 [20–21] | $P = 0.15$ |

**Noninvasive Ventilation and Alveolar Recruitment Maneuver Improve Respiratory Function during and after Intubation of Morbidly Obese Patients**

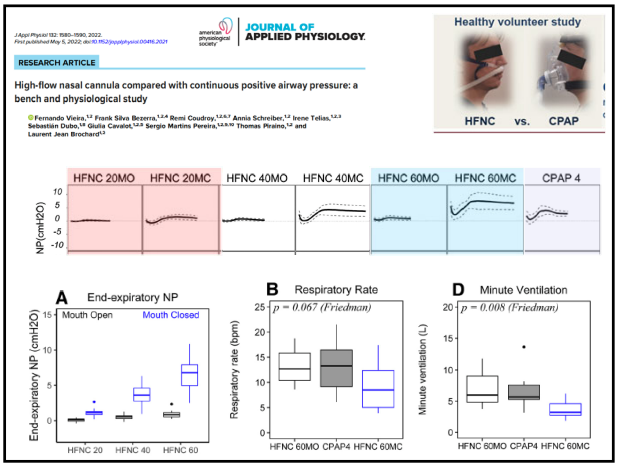
*A Randomized Controlled Study*

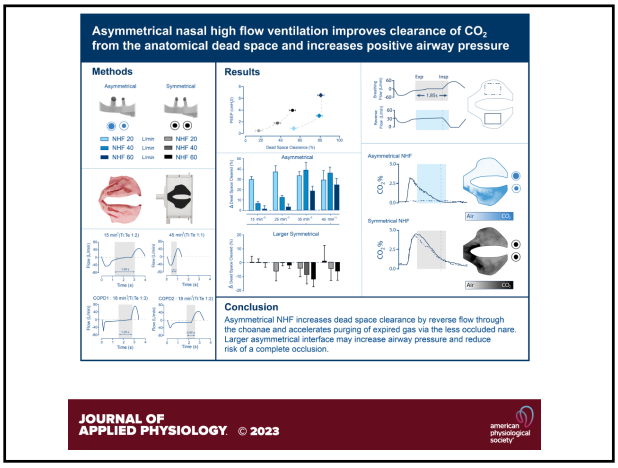
Emmanuel Futier, M.D.,* Jean-Michel Constantin, M.D., Ph.D.,† Paolo Pelosi, M.D., Ph.D.,‡ Gerald Chanques, M.D., Ph.D.,§ Alexandre Massone, M.D.,‖ Antoine Petit, M.D.,# Fabrice Kwiatkowski, Ph.D.,** Jean-Etienne Bazin, M.D., Ph.D.,†† Samir Jaber, M.D., Ph.D.‡‡

Anesthesiology 2011; 114:1354–63




Oxygénation à haut débit



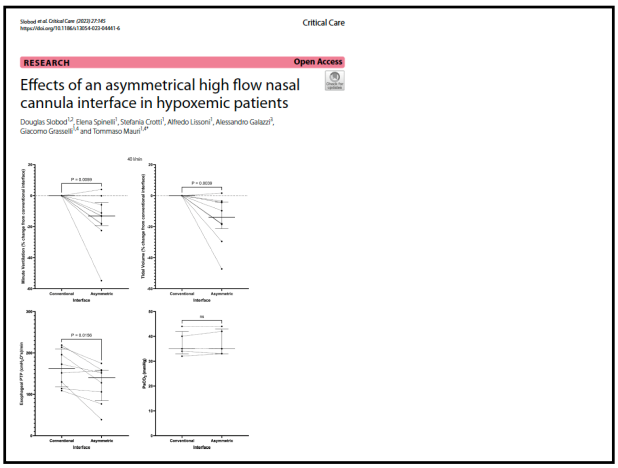



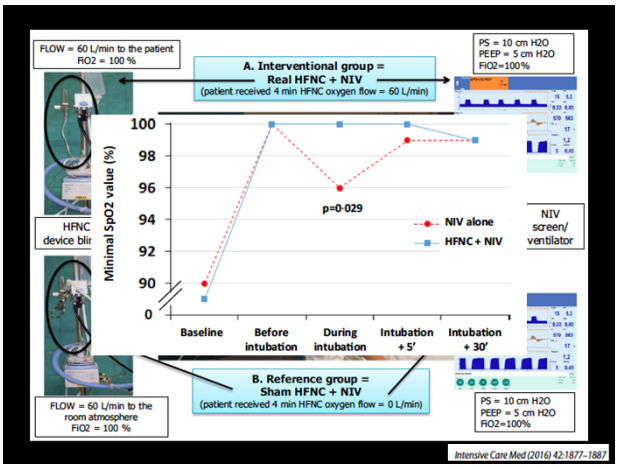

## ROX Index

$ROX = (SpO_2/FIO_2)/respiratory\ rate$

| Success : ROX ≥ 4.88 | Consider Intubation: < 3.85 |
|---|---|
| $SpO_2$: 94% | $SpO_2$: 92% |
| $FIO_2$: 0.6 | $FIO_2$: 0.8 |
| $SpO_2/FIO_2$: 157 | $SpO_2/FIO_2$: 115 |
| Rate: 25 | Rate: 35 |
| ROX: 6.27 | ROX: 3.29 |

*Roca, Am J Respir Crit Care Med Epub 2018*





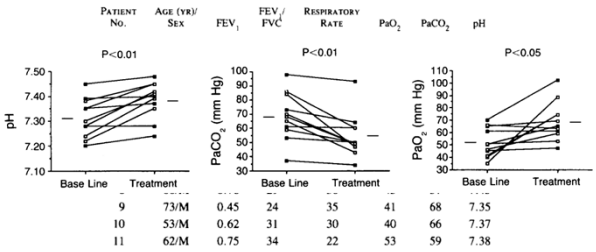

## Eviter l'intubation et ses complications (PAVM)

- VNI curative du BPCO:
  diminuer le W et l'acidose hypercapnique

| Incidences des pneumonies | VI | VNI | p |
|---|---|---|---|
| Brochard, NEJM, 1995 | 7/42 17% | 2/43 5% | 0,009 |
| Antonelli, NEJM, 1998 | 8/32 25% | 1/32 3% | 0,03 |
| Nava, Ann Intern Med, 1998 | 7/25 28% | 0/25 0% | 0,01 |

The NEW ENGLAND JOURNAL of MEDICINE

**Reversal of acute exacerbation of chronic obstructive lung disease by inspiratory assistance with a face mask**




**Brochard** et al. **NEJM 1990**;323:1523-30

The NEW ENGLAND JOURNAL of MEDICINE

**Noninvasive ventilation for acute exacerbation of chronic obstructive pulmonary disease.**

**85** patients BPCO VNI : masque facial, Aide inspiratoire

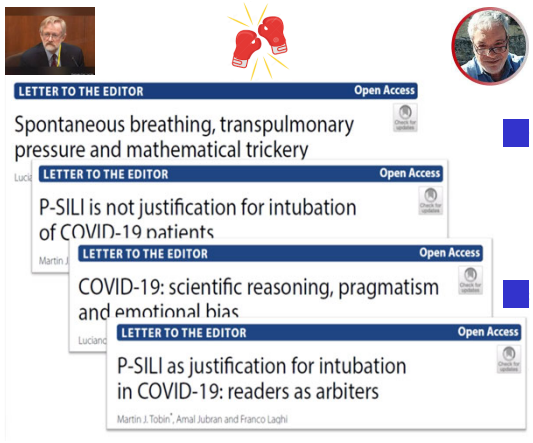
La **VNI** permet de **réduire :**

- l' **intubation** de **74** à **26** %
- la **durée de séjour** hospitalier
- les **complications** en réanimation de 48 à 16 %
- la **mortalité** de **29** à **9** %

**Brochard L**, et al. **NEJM 1995**;333:817-822



## Ventilation spontanée



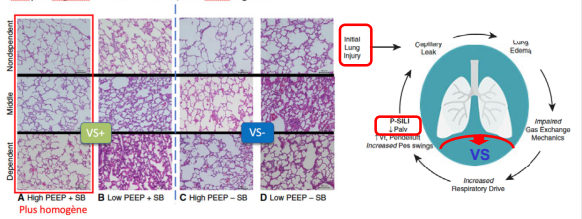
## High Positive End-Expiratory Pressure Renders Spontaneous Effort Noninjurious

Caio C. A. Morais[1*], Yukiko Koyama[2*], Takeshi Yoshida[2,3], Glauco M. Pleni[1], Susimeire Gomes[1], Cristhiano A. S. Lima[1], Ozires P. S. Ramos[1], Sérgio M. Pereira[1], Naomasa Kawaguchi[4], Hirofumi Yamamoto[4], Akinori Uchiyama[4], João B. Borges[5], Marcos F. Vidal Melo[6], Mauro R. Tucci[1], Marcelo B. P. Amato[1], Brian P. Kavanagh[3], Eduardo L. V. Costa[1], and Yuji Fujino[2]

Am J Respir Crit Care Med Vol 197, Iss 10, pp 1285–1296, May 15, 2018

Palv = PEEP + VT/Crs – Pmus

Palv plus negative si moins de PEEP et/ou si Pmus augmente




Grace à la PEEP, la VNI et la CPAP évitent une pression alvéolaire trop négative (PSiLi)

JAMA | Original Investigation | CARING FOR THE CRITICALLY ILL PATIENT

## Effect of Helmet Noninvasive Ventilation vs High-Flow Nasal Oxygen on Days Free of Respiratory Support in Patients With COVID-19 and Moderate to Severe Hypoxemic Respiratory Failure

### The HENIVOT Randomized Clinical Trial

Domenico Luca Grieco, MD; Luca S. Menga, MD; Melania Cesarano, MD; Tommaso Rosà, MD; Savino Spadaro, MD, PhD; Maria Maddalena Bitondo, MD; Jonathan Montomoli, MD, PhD; Giulia Falò, MD; Tommaso Tonetti, MD; Salvatore L. Cutuli, MD; Gabriele Pintaudi, MD; Elena S. Tanzarella, MD; Edoardo Pierrevocnci, MD; Filippo Bongiovanni, MD; Antonio M. Dell'Anna, MD; Luca Delle Cese, MD; Cecilia Berardi, MD; Simone Carelli, MD; Maria Grazia Bocci, MD; Luca Montini, MD; Giuseppe Bello, MD; Daniele Natalini, MD; Gennaro De Pascale, MD; Matteo Velardo, PhD; Carlo Alberto Volta, MD; V. Marco Ranieri, MD; Giorgio Conti, MD; Salvatore Maurizio Maggiore, MD, PhD; Massimo Antonelli, MD; for the COVID-ICU Gemelli Study Group

**POPULATION**

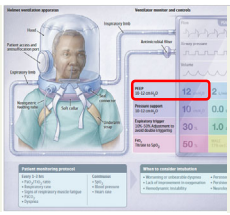
88 Men
21 Women

Adults in the intensive care unit with COVID-19 and moderate to severe hypoxemic respiratory failure

Median age: 65 years

**LOCATIONS**

4 ICUs in Italy



**FINDINGS**

Median respiratory support-free days

**Helmet ventilation**

20 Days (IQR, 0-25)

Respiratory support-free

**High-flow oxygen**

18 Days (IQR, 0-22)

Respiratory support-free

Mean between-group difference was not statistically significant:

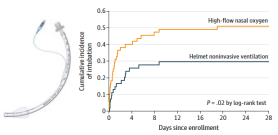
2 days (95% CI, −2 to 6)

JAMA | Original Investigation | CARING FOR THE CRITICALLY ILL PATIENT

## Effect of Helmet Noninvasive Ventilation vs High-Flow Nasal Oxygen on Days Free of Respiratory Support in Patients With COVID-19 and Moderate to Severe Hypoxemic Respiratory Failure

### The HENIVOT Randomized Clinical Trial

Domenico Luca Grieco, MD; Luca S. Menga, MD; Melania Cesarano, MD; Tommaso Rosà, MD; Savino Spadaro, MD, PhD; Maria Maddalena Bitondo, MD; Jonathan Montomoli, MD, PhD; Giulia Falò, MD; Tommaso Tonetti, MD; Salvatore L. Cutuli, MD; Gabriele Pintaudi, MD; Elena S. Tanzarella, MD; Edoardo Pierrevocnci, MD; Filippo Bongiovanni, MD; Antonio M. Dell'Anna, MD; Luca Delle Cese, MD; Cecilia Berardi, MD; Simone Carelli, MD; Maria Grazia Bocci, MD; Luca Montini, MD; Giuseppe Bello, MD; Daniele Natalini, MD; Gennaro De Pascale, MD; Matteo Velardo, PhD; Carlo Alberto Volta, MD; V. Marco Ranieri, MD; Giorgio Conti, MD; Salvatore Maurizio Maggiore, MD, PhD; Massimo Antonelli, MD; for the COVID-ICU Gemelli Study Group




| Outcome | No. (%) Helmet noninvasive ventilation (n = 54)[a] | High-flow nasal oxygen (n = 55)[b] | Absolute or mean difference (95% CI)[c] | Odds ratio (95% CI) | P value[d] |
|---|---|---|---|---|---|
| **Secondary outcomes** | | | | | |
| Intubation within 28 d from enrollment | 16 (30) | 28 (51) | −21 (−38 to −3) | 0.41 (0.18 to 0.89) | .03 |
| Intubation within 28 d from enrollment, after adjudication of intubation criteria by external experts | 15 (28) | 28 (51) | −23 (−39 to −5) | 0.37 (0.17 to 0.82) | .02 |
| Causes of endotracheal intubation | | | | | |
| Hypoxemia[f] | 15 (28) | 27 (49) | −21 (−38 to −3) | 0.40 (0.18 to 0.88) | .03 |
| Signs of respiratory muscles fatigue | 13 (24) | 24 (44) | −20 (−36 to −2) | 0.41 (0.18 to 0.93) | .04 |
| Intolerance to treatment | 11 (20) | 5 (9) | 11 (−2 to 25) | 2.56 (0.82 to 7.94) | .11 |
| Worsening or unbearable dyspnea | 9 (17) | 25 (45) | −29 (−44 to −11) | 0.24 (0.10 to 0.59) | .002 |
| $SpO_2$ <90% for >5 min[g] | 9 (17) | 23 (42) | −25 (−40 to −8) | 0.28 (0.11 to 0.68) | .006 |

Plus de PEEP avec la casque moins d'hypoxémies et moins d'intubations

## Effect of Noninvasive Ventilation Delivered by Helmet vs Face Mask on the Rate of Endotracheal Intubation in Patients With Acute Respiratory Distress Syndrome

### A Randomized Clinical Trial

Bhakti K. Patel, MD; Krysta S. Wolfe, MD; Anne S. Pohlman, MSN; Jesse B. Hall, MD; John P. Kress, MD

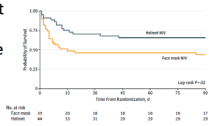



Table 2. Primary and Secondary Outcomes and Adverse Events

| | Face Mask (n = 39) | Helmet (n = 44) | Absolute Difference (95% CI) | P Value |
|---|---|---|---|---|
| Primary outcome, No. (%) | | | | |
| Endotracheal intubation | 24 (61.5) | 8 (18.2) | −43.3 (−62.4 to −24.3) | <.001 |
| Reason for intubation | | | | |
| Respiratory failure | 20 (83.3) | 3 (37.5) | −45.3 (−82.5 to −9.1) | .01 |
| Circulatory failure | 3 (12.5) | 0 (0) | −12.5 (−25.7 to 0.7) | .55 |
| Neurologic failure | 1 (4.2) | 5 (62.5) | 58.3 (24.8 to 92.8) | .001 |
| Secondary outcomes, median (IQR), d | | | | |
| Ventilator-free days | 12.5 (0.49-28) | 28 (13.7-28) | 8.4 (13.4 to 3.4) | <.001 |
| ICU length of stay | 7.8 (3.9-13.8) | 4.7 (2.5-8.7) | −2.76 (−6.07 to 0.54) | .04 |
| Hospital length of stay | 15.2 (7.8-19.7) | 10.1 (6.5-15.9) | −2.92 (−8.47 to 2.63) | .16 |
| Mortality, No. (%) | | | | |
| Hospital | 19 (48.7) | 12 (27.3) | −21.4 (−41.9 to −1.0) | .04 |
| 90 d[h] | 22 (56.4) | 15 (34.1) | −22.3 (−43.3 to −1.4) | .02 |
| Adverse events | | | | |
| Mask deflation | 0 (0) | 2 (4.5) | | |
| Skin ulceration | 3 (7.6) | 3 (6.8) | | |

| | Noninvasive Ventilation, Median (IQR) Face Mask (n = 39) | Helmet (n = 44) | P Value |
|---|---|---|---|
| Respiratory support with NIV[a] | | | |
| Duration of NIV, h | 26.4 (7.0-60.0) | 19.8 (8.4-45.6) | .58 |
| PEEP, cm $H_2O$ | 5.1 (5.0-8.0) | 8 (5.0-10.0) | .006 |
| Pressure support, cm $H_2O$ | 11.7 (10.0-14.5) | 8 (5.0-10.0) | <.001 |
| $F_{IO_2}$, % | 60 (50.0-68.6) | 50 (40.0-60.0) | .02 |
| $SpO_2$, % | 95.3 (92.3-96.7) | 96.2 (94.8-98.4) | .13 |
| Respiratory rate, breaths/min | | | |
| Baseline | 28.3 (22.1-34.6)[b] | 27.7 (21.5-34.6)[b] | |
| After randomization | 29.1 (22.1-37.6) | 24.5 (20.4-30.5) | |

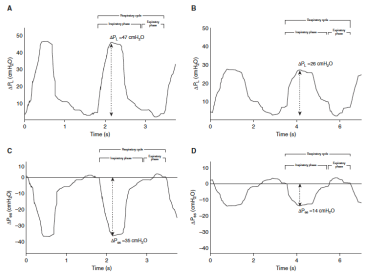
Plus de PEEP avec la casque évitent une pression alvéolaire trop négative (PSiLi)

JAMA. 2016;315(22):2435-2441.

## Early Inspiratory Effort Assessment by Esophageal Manometry Predicts Noninvasive Ventilation Outcome in *De Novo* Respiratory Failure

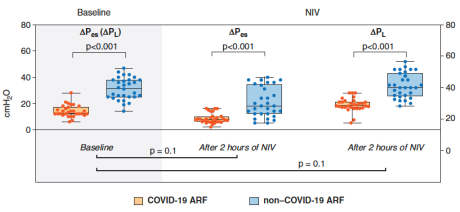
### A Pilot Study

Roberto Tonelli[1,2], Riccardo Fantini[1], Luca Tabbì[1], Ivana Castaniere[1,2], Lara Pisani[3], Maria Rosaria Pellegrino[1], Giovanni Della Casa[4], Roberto D'Amico[5], Massimo Girardis[6], Stefano Nava[3], Enrico M. Clini[1], and Alessandro Marchioni[1]




Am J Respir Crit Care Med Vol 202, Iss 4, pp 558–567, Aug 15, 2020

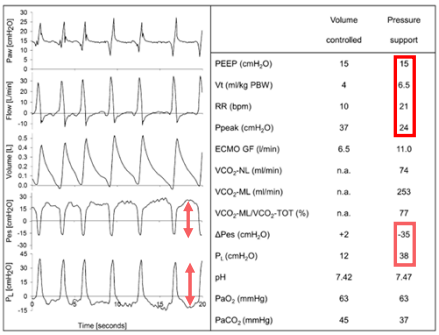
## Inspiratory Effort and Lung Mechanics in Spontaneously Breathing Patients with Acute Respiratory Failure due to COVID-19: A Matched Control Study




American Journal of Respiratory and Critical Care Medicine Volume 204 Number 6 | September 15 2021

## Extremely high transpulmonary pressure in a spontaneously breathing patient with early severe ARDS on ECMO

Tommaso Mauri[1], Thomas Langer[2], Alberto Zanella[1], Giacomo Grasselli[1] and Antonio Pesenti[1,2*]



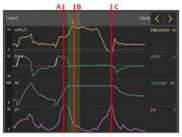

| | Volume controlled | Pressure support |
|---|---|---|
| PEEP ($cmH_2O$) | 15 | 15 |
| Vt (ml/kg PBW) | 4 | 6.5 |
| RR (bpm) | 10 | 21 |
| Ppeak ($cmH_2O$) | 37 | 24 |
| ECMO GF (l/min) | 6.5 | 11.0 |
| $VCO_2$-NL (ml/min) | n.a. | 74 |
| $VCO_2$-ML (ml/min) | n.a. | 253 |
| $VCO_2$-ML/$VCO_2$-TOT (%) | n.a. | 77 |
| ΔPes ($cmH_2O$) | +2 | -35 |
| $P_L$ ($cmH_2O$) | 12 | 38 |
| pH | 7.42 | 7.47 |
| $PaO_2$ (mmHg) | 63 | 63 |
| $PaCO_2$ (mmHg) | 45 | 37 |

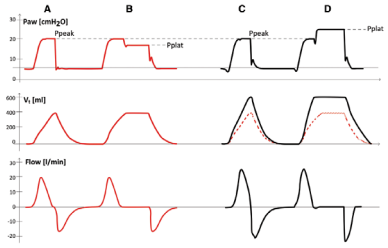
**Aide à 9 $cmH_2O$**

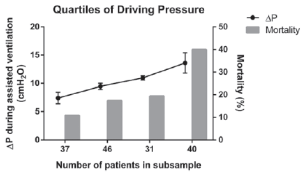
## Driving Pressure Is Associated with Outcome during Assisted Ventilation in Acute Respiratory Distress Syndrome

Giacomo Bellani, M.D., Ph.D., Alice Grassi, M.D., Simone Sosio, M.D., Stefano Gatti, M.D., Brian P. Kavanagh, M.B., Antonio Pesenti, M.D., Giuseppe Foti, M.D.

*Anesthesiology 2019; 131:594–604*





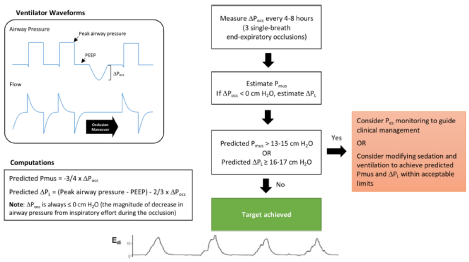

Bertoni *et al. Critical Care* (2019) 23:346
https://doi.org/10.1186/s13054-019-2617-0

Critical Care

RESEARCH — Open Access

## A novel non-invasive method to detect excessively high respiratory effort and dynamic transpulmonary driving pressure during mechanical ventilation

Michele Bertoni[1,2], Irene Telias[3,4], Martin Urner[3,5], Michael Long[6], Lorenzo Del Sorbo[3,5], Eddy Fan[3,5,7], Christer Sinderby[3,8], Jennifer Beck[3,8], Ling Liu[9], Haibo Qiu[9], Jenna Wong[3], Arthur S. Slutsky[3,4], Niall D. Ferguson[3,7,10,11], Laurent J. Brochard[3,4] and Ewan C. Goligher[3,4,10,11*]

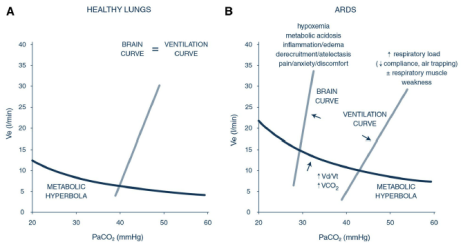


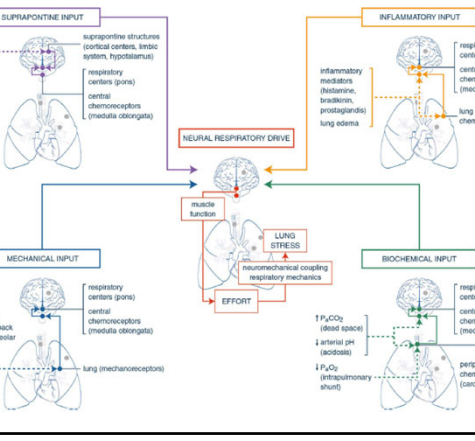

Intensive Care Med (2020) 46:606–618
https://doi.org/10.1007/s00134-020-05942-6

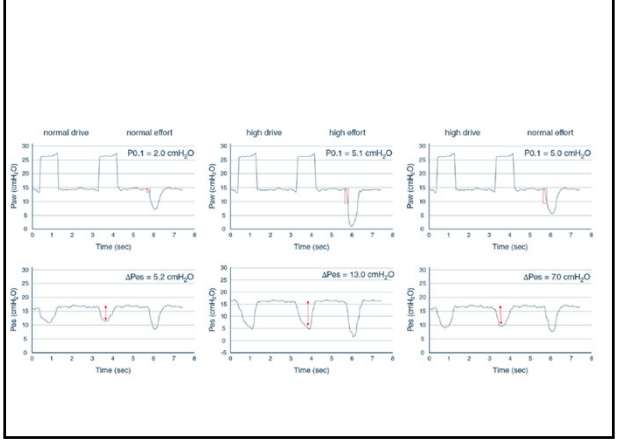
NARRATIVE REVIEW

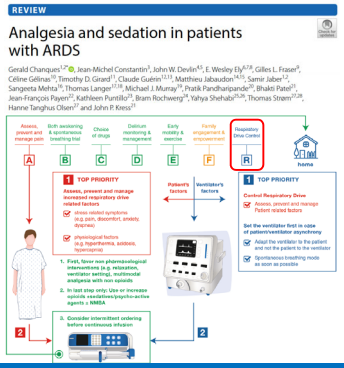
## Respiratory drive in the acute respiratory distress syndrome: pathophysiology, monitoring, and therapeutic interventions

Elena Spinelli[1], Tommaso Mauri[1,2*], Jeremy R. Beitler[3], Antonio Pesenti[1,2] and Daniel Brodie[3]



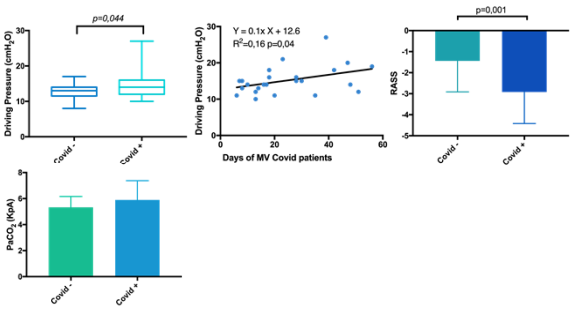



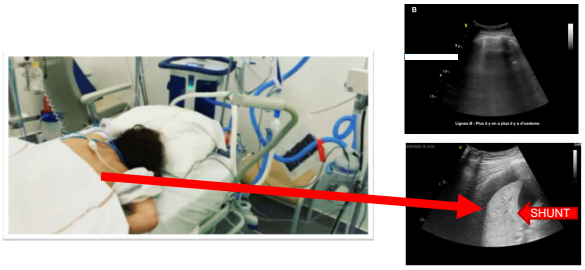


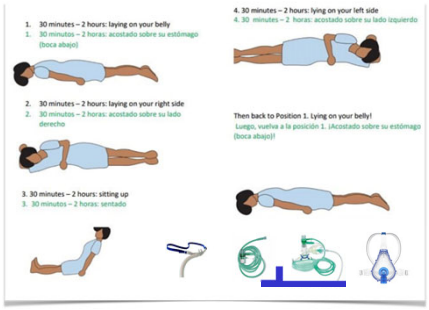

Chanques et al. Intensive Care Med. 2020;46:2342-2356.

# Driving Pressure en VSAI




# DV en VS sous HNF ou VNI



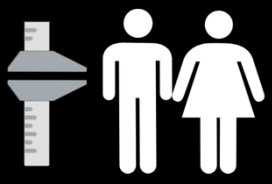




iVentilate

Equation du mouvement du poumon :

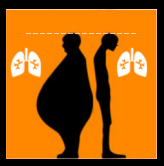
## Le volume courant

- $V_T$ entre 6 et 8 ml.kg-1 Poids Prédit



Taille et sexe

## 2 morphotypes avec les mêmes poumons



2 hommes de même taille

## Ventilation avec le mode VSAI

SimVA
Ventilation Artificielle Virtuelle