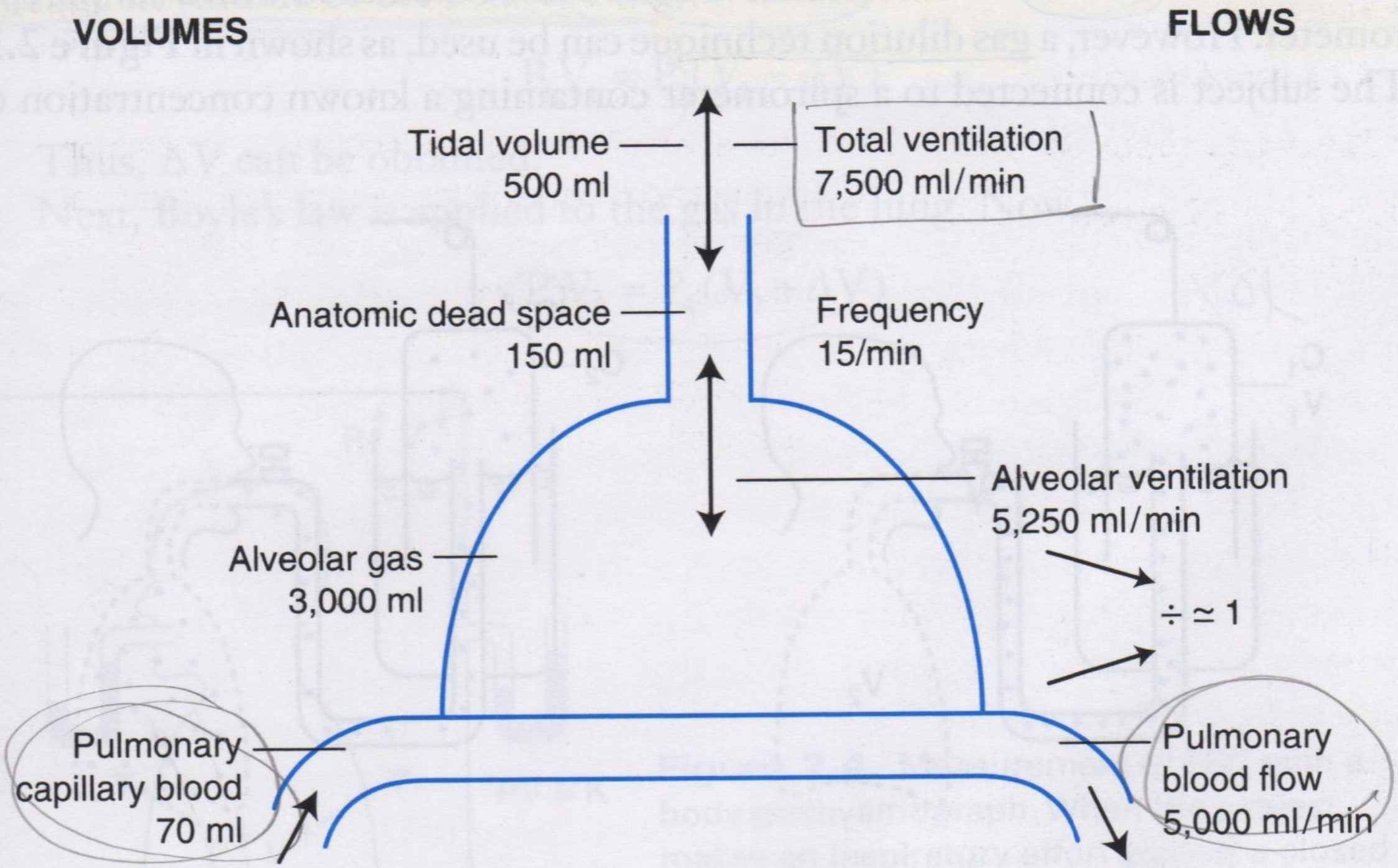
Meeting GiViTI 2023
4 – 6 ottobre
Hotel Baia Flaminia, Pesaro

Angolo della Clinica

11:00 - 12:30 Monitoraggio in ventilazione meccanica: lo spazio morto come indicatore
R Fumagalli, M Mollura (60 min)

What is dead space


VOLUMES
FLOWS
Tidal volume
500 ml
Total ventilation
7,500 ml/min
Anatomic dead space
150 ml
Frequency
15/min
Alveolar ventilation
5,250 ml/min
Alveolar gas
3,000 ml
÷ ≃ 1
Pulmonary
capillary blood
70 ml
Pulmonary
blood flow
5,000 ml/min

$$V_T = V_D + V_A^*$$

therefore,

$$V_T \cdot n = V_D \cdot n + V_A \cdot n$$

where n is the respiratory frequency.

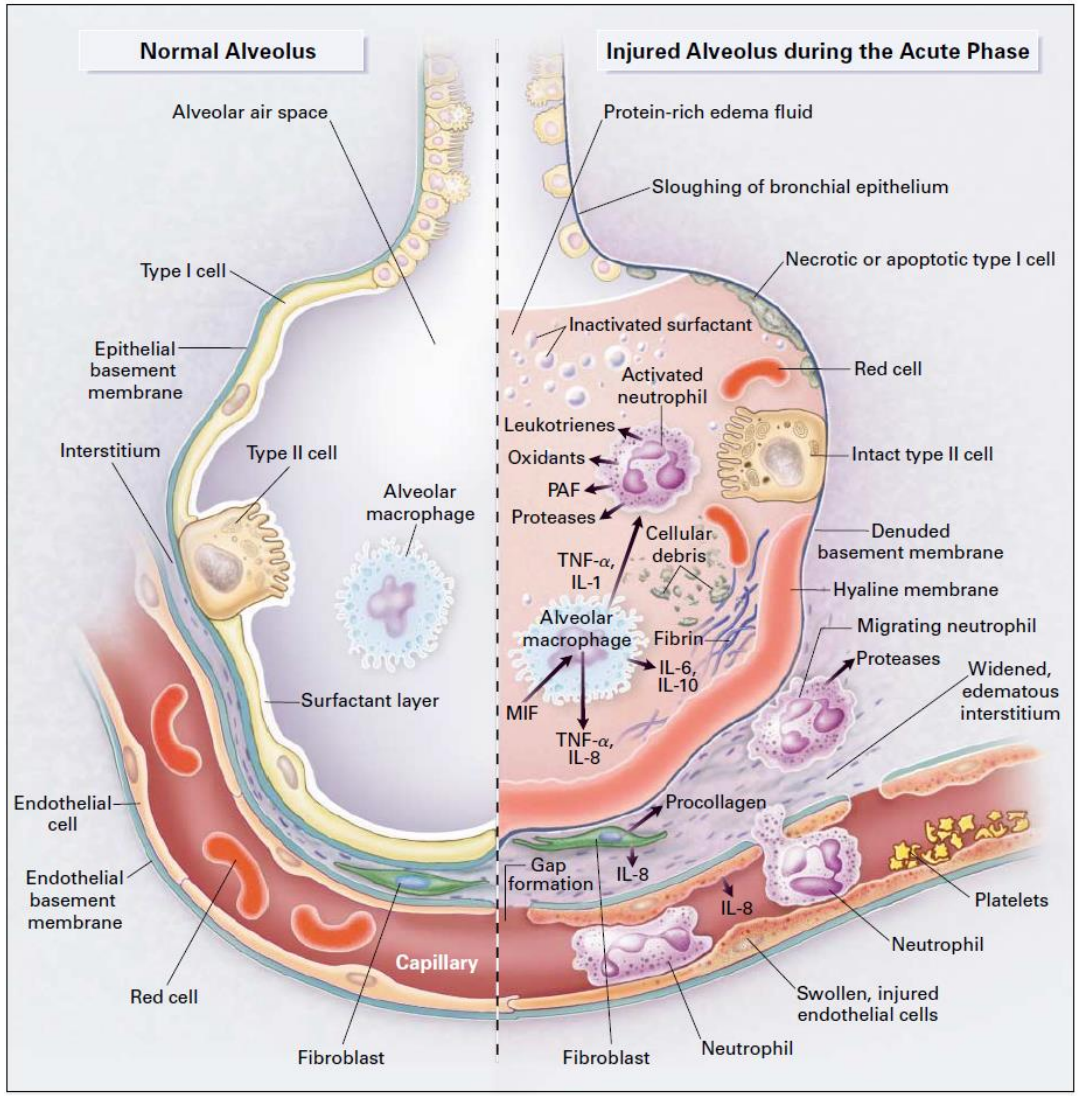
Therefore,

$$\dot{V}_E = \dot{V}_D + \dot{V}_A$$

where $\dot{V}$ means volume per unit time, $\dot{V}_E$ is expired total ventilation, and $\dot{V}_D$ and $\dot{V}_A$ are the dead space and alveolar ventilations, respectively (see Appendix A for a summary of symbols).

Thus,

$$\dot{V}_A = \dot{V}_E - \dot{V}_D$$



The Acute Respiratory Distress Syndrome

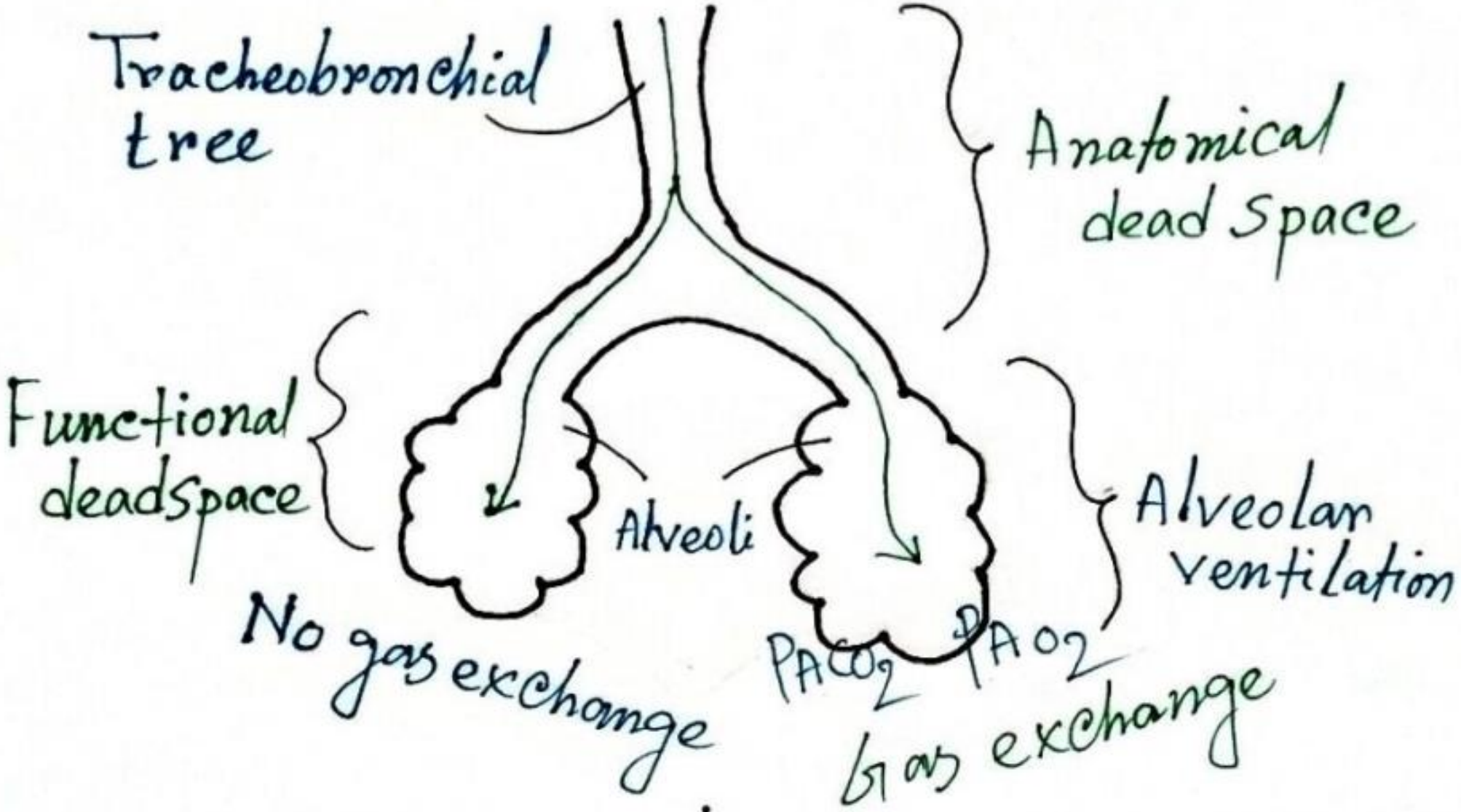
Lorraine B. Ware, M.D.,
and Michael A. Matthay, M.D.

Result of a steroptyped response to inflammatory stimuli, originating primarily from the lung or from other organs (e.g. sepsis)

The New England Journal of Medicine

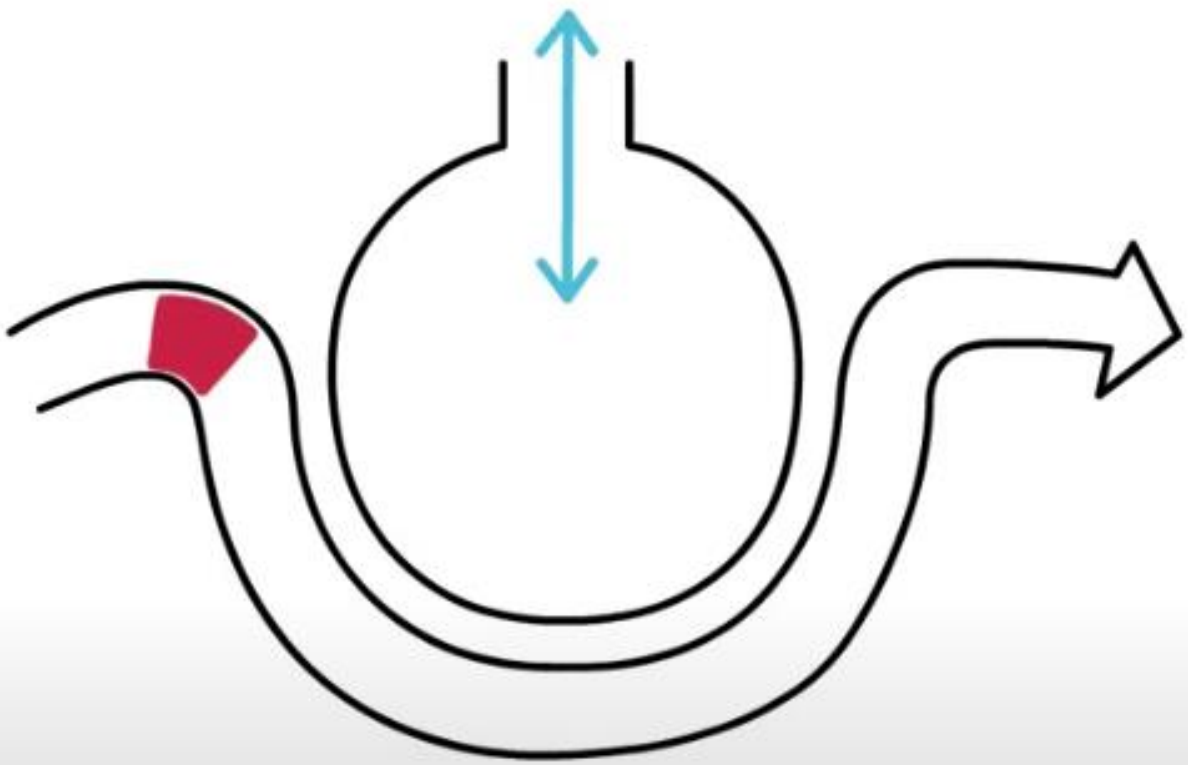
Increased Vd/Vt in ARDS

- High VA/Q regions (alveolar dead space)
- VA/Q heterogeneity
- Increased anatomic dead space
- Increased Qva/Q
- Hyperinflation? Cysts?

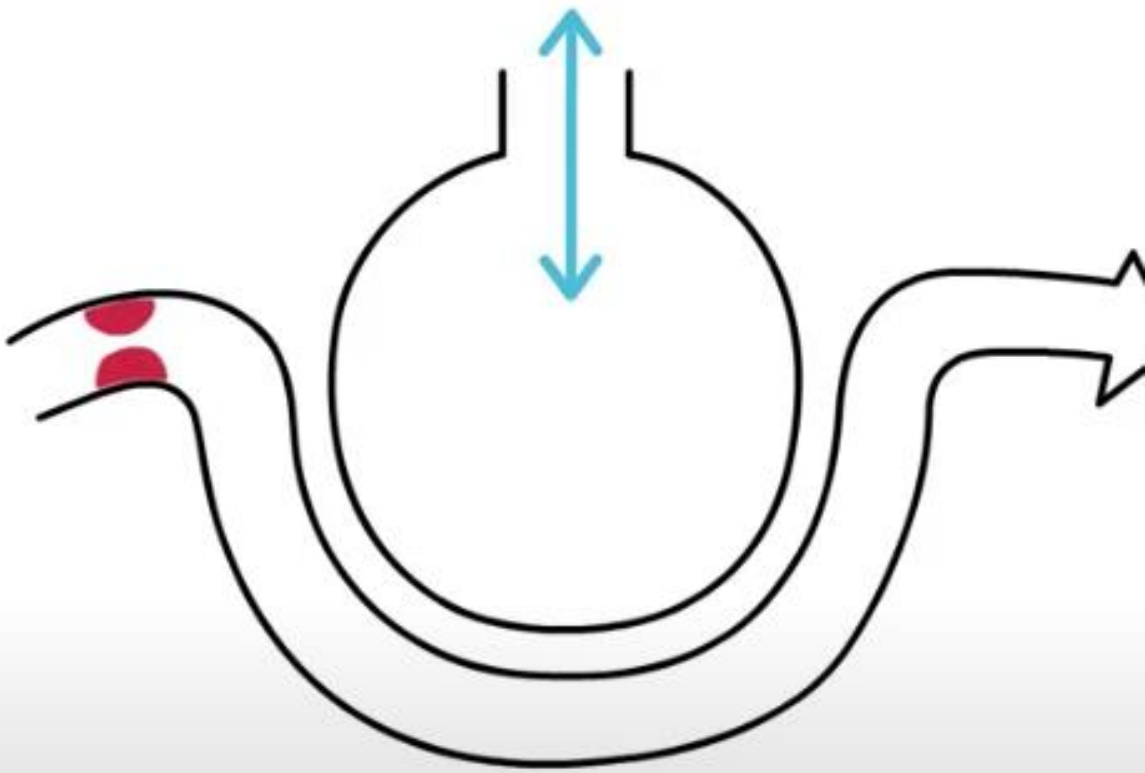

Tracheobronchial tree
Anatomical dead space
Functional deadspace
Alveoli
Alveolar ventilation
No gas exchange
P_{ACO_2}
P_{AO_2}
Gas exchange

Dead Space

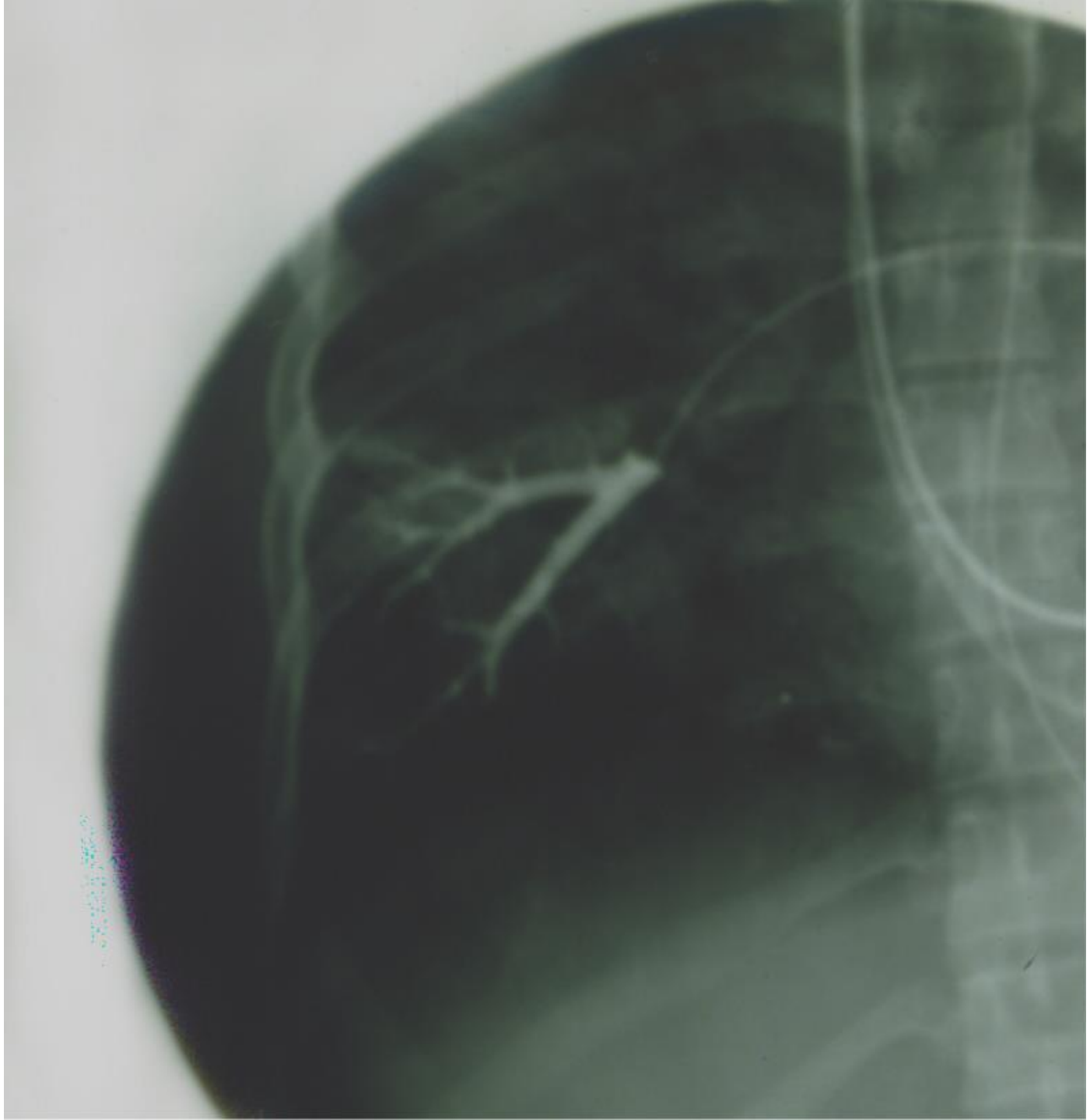
Physiological dead space

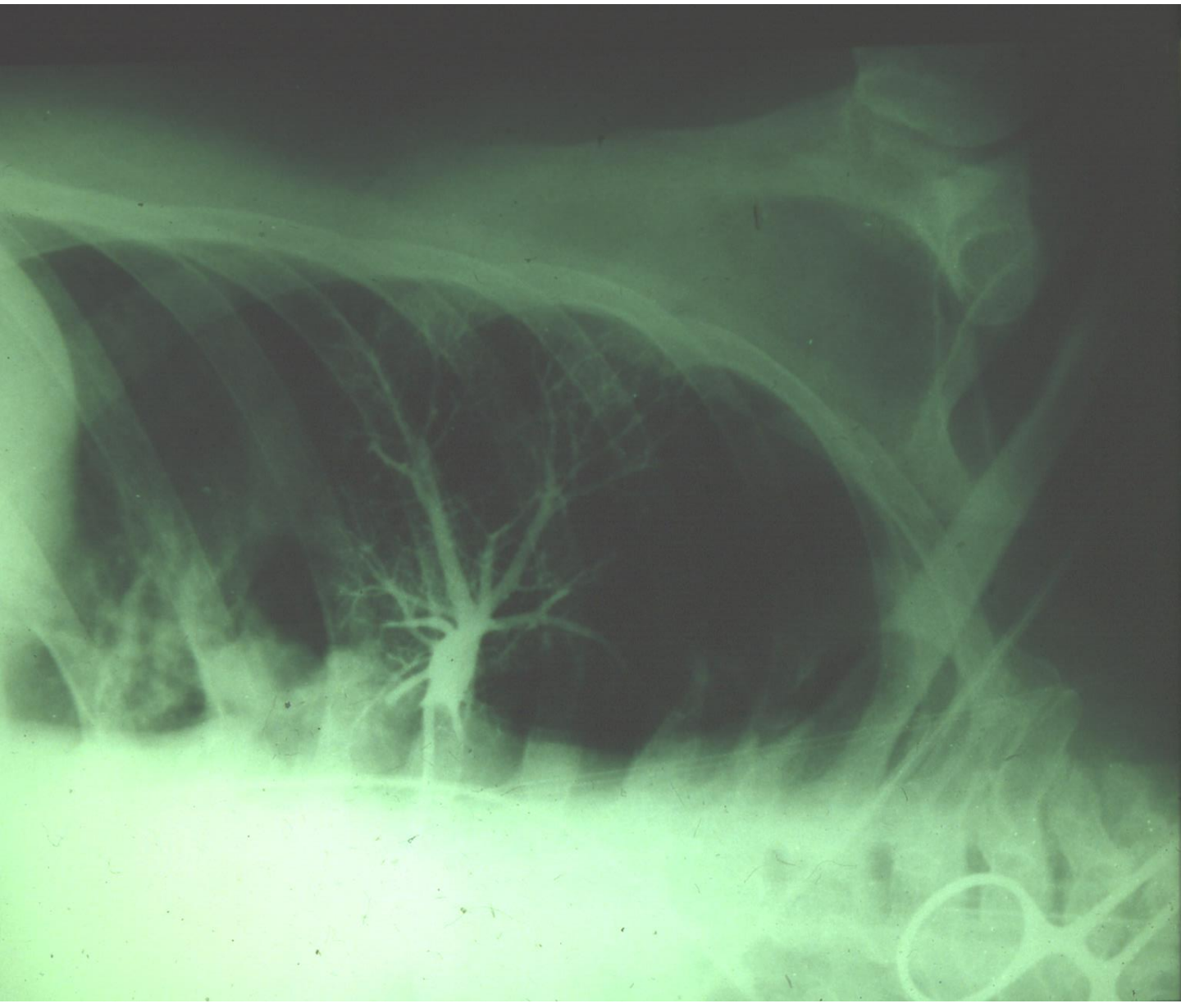


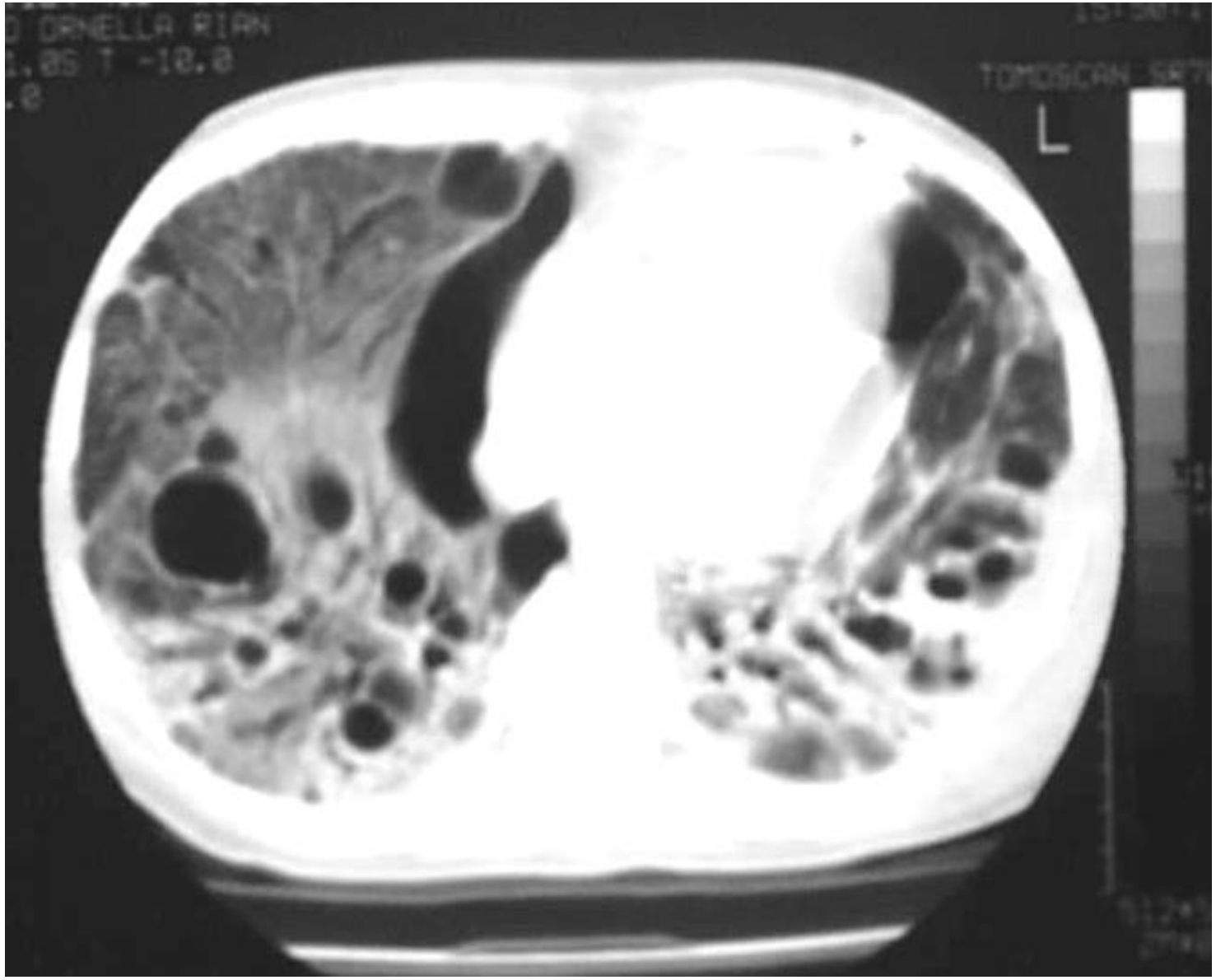
$\dot{V}/\dot{Q} = \infty$



$1 < \dot{V}/\dot{Q} < \infty$





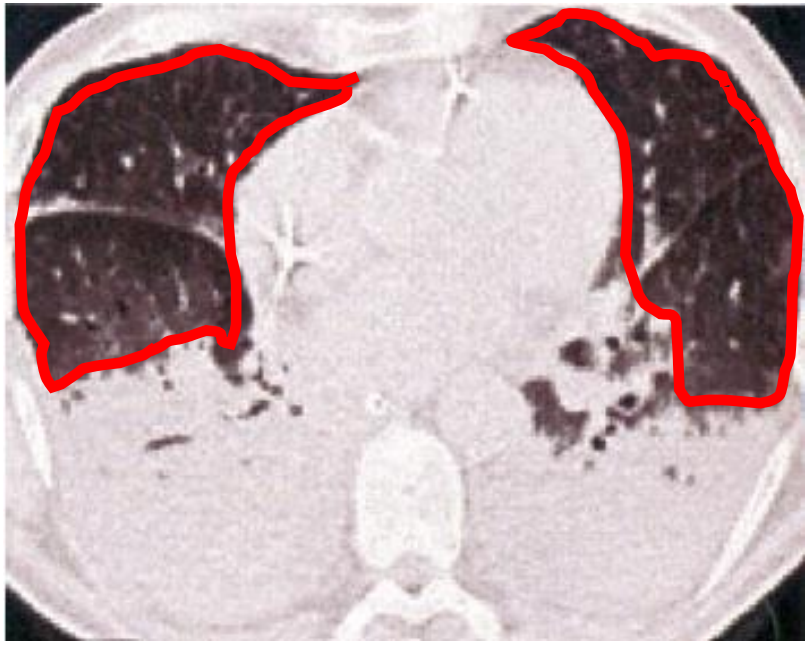

L

Intensive Care Med (2005) 31:776–784
DOI 10.1007/s00134-005-2627-z

SEMINAL STUDY

Luciano Gattinoni
Antonio Pesenti

The concept of "baby lung"



- Inhomogeneity
- Densities concentrated in dependent regions
- *ARDS lung is not stiff but small* (amount of aerated tissue at EE 500-600 gr)

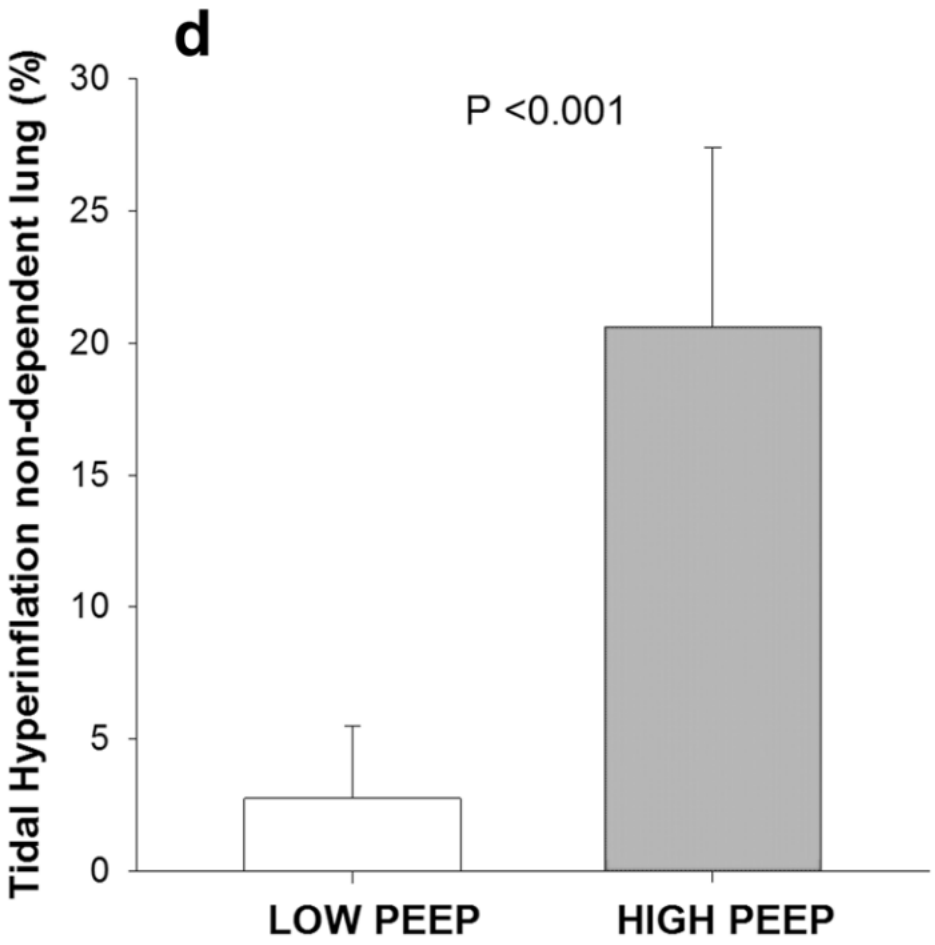
Intensive Care Med (2016) 42:1576–1587
DOI 10.1007/s00134-016-4467-4

ORIGINAL

Bedside assessment of the effects of positive end-expiratory pressure on lung inflation and recruitment by the helium dilution technique and electrical impedance tomography

Tommaso Mauri[1], Nilde Eronia[2], Cecilia Turrini[1], Marta Battistini[1], Giacomo Grasselli[1], Roberto Rona[2], Carlo Alberto Volta[3], Giacomo Bellani[2,4] and Antonio Pesenti[1,5*]

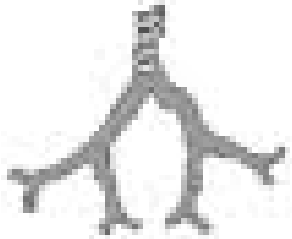
© 2016 Springer-Verlag Berlin Heidelberg and ESICM



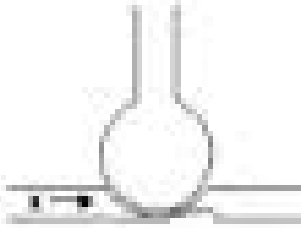
Ah……. I was missing

- Ventilated areas which do not participate in gas exchange

Total Deadspace = Anatomic + Alveolar + Mechanical



+



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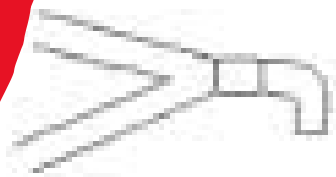
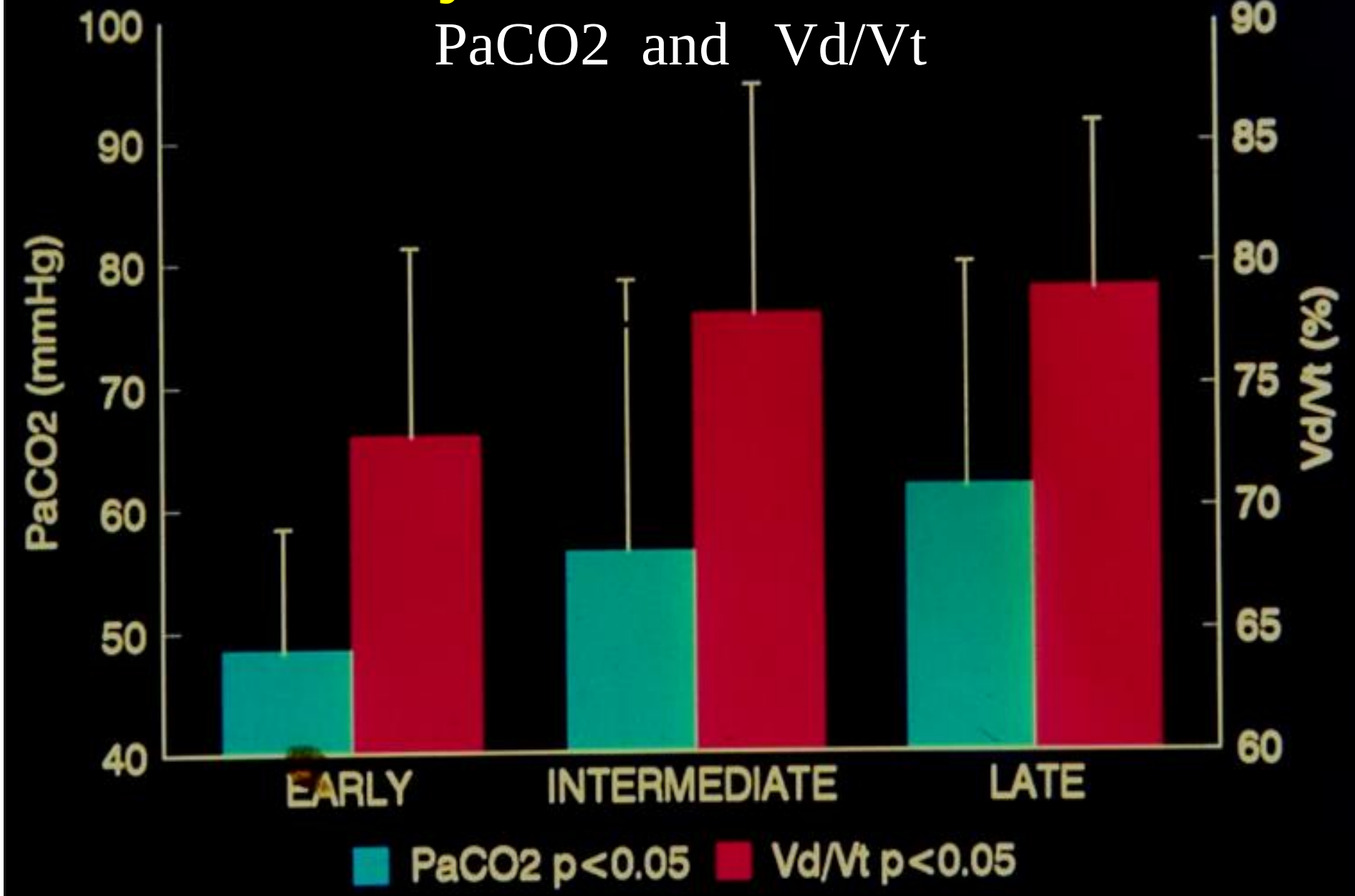


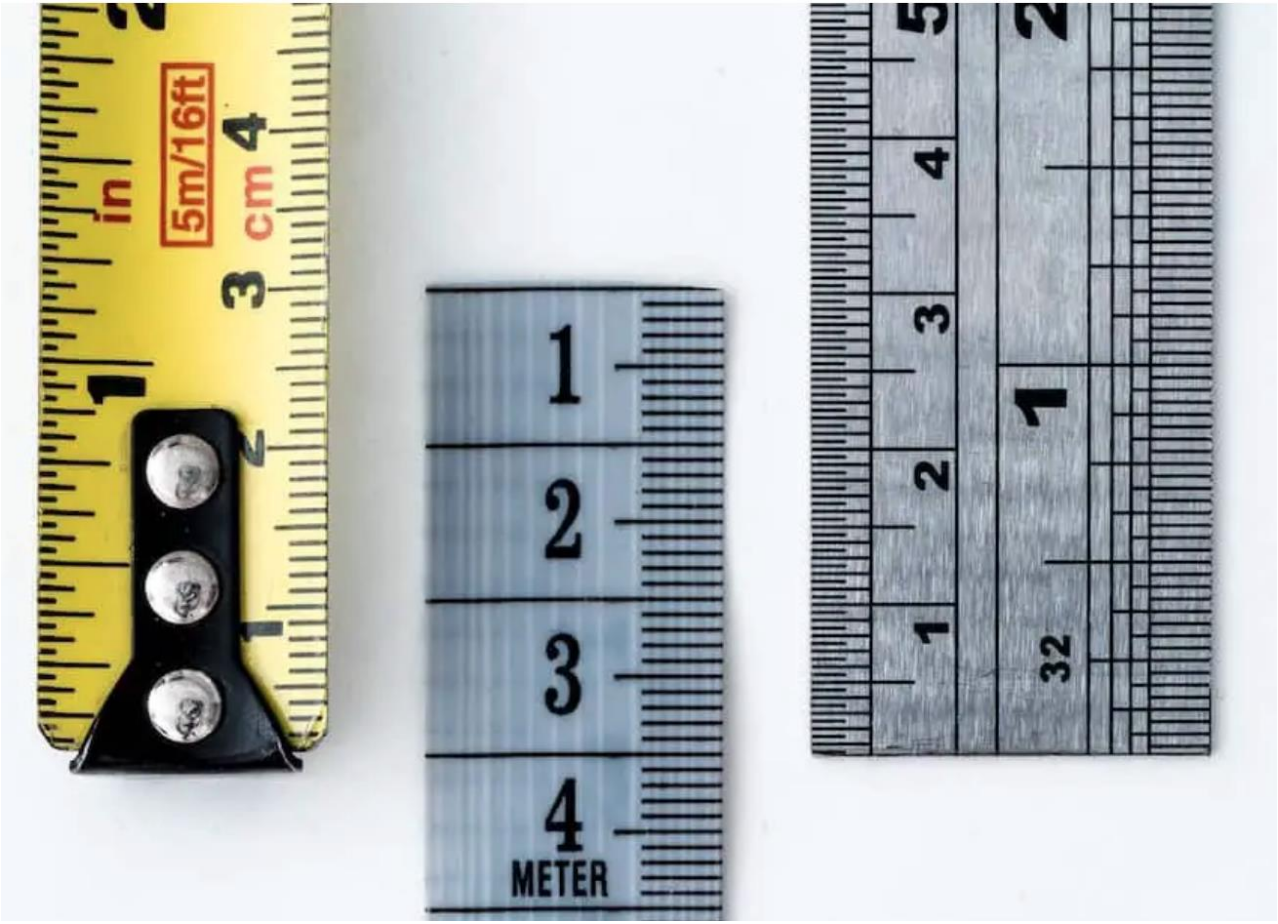
Anatomic Deadspace: airways leading to the alveoli	Alveolar Deadspace: ventilated areas in the lungs without blood flow	Mechanical Deadspace: artificial airways including ventilator circuits

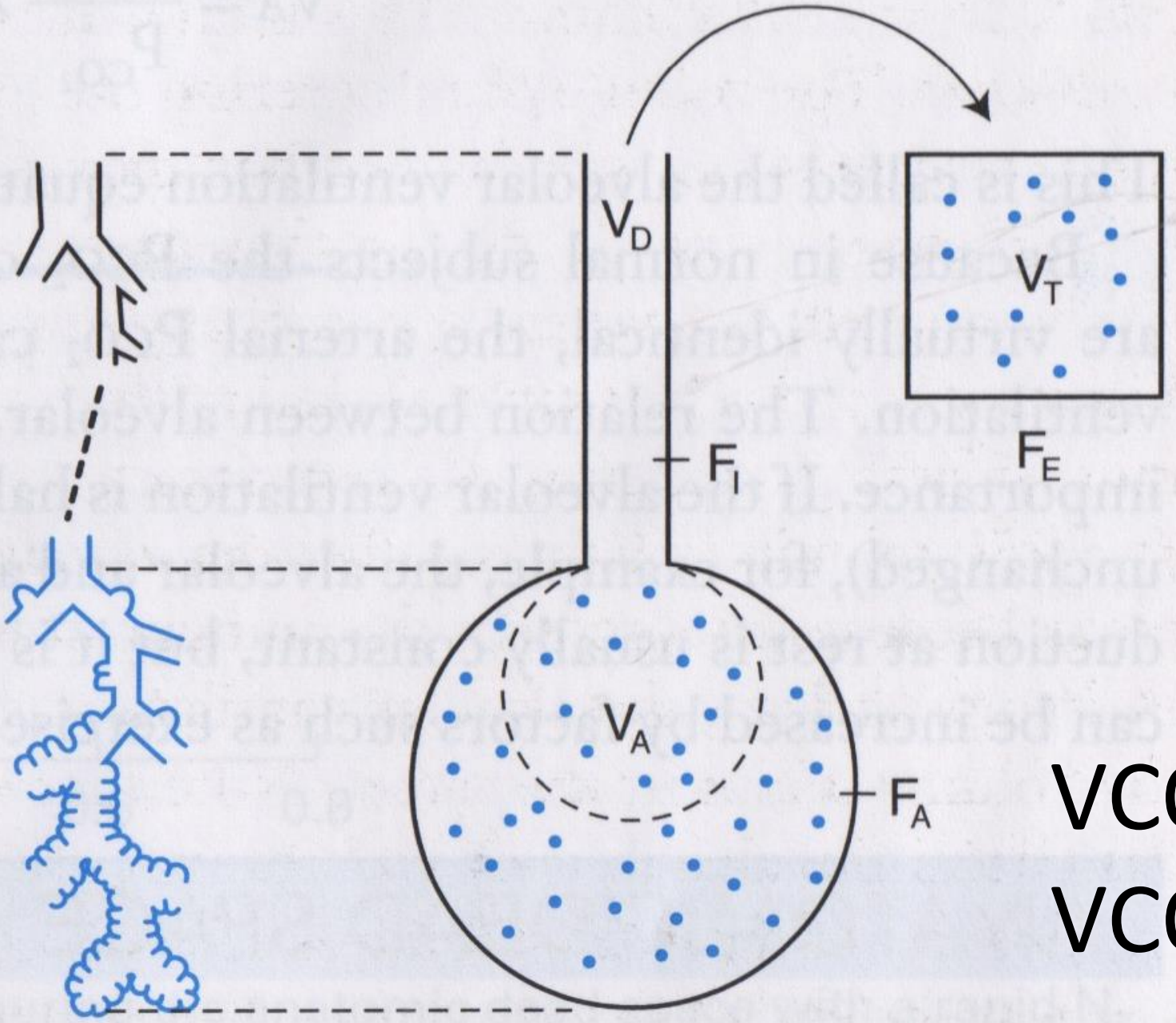
Early vs late ARDS

PaCO2 and Vd/Vt



HOW TO MEASURE

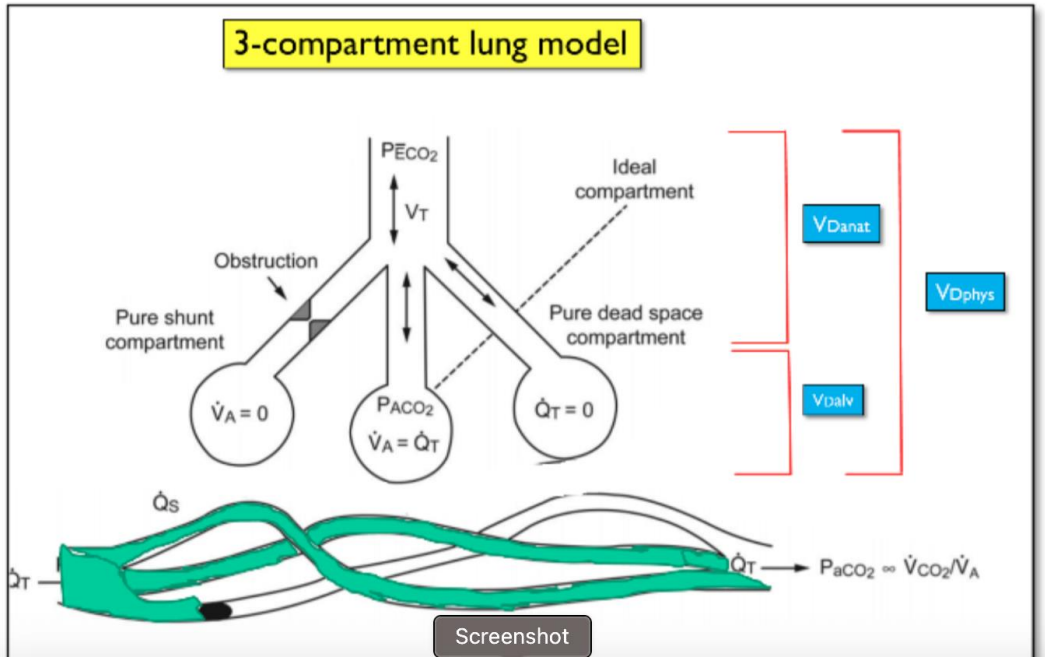




$$VCO_2 = VA \times FACO_2$$

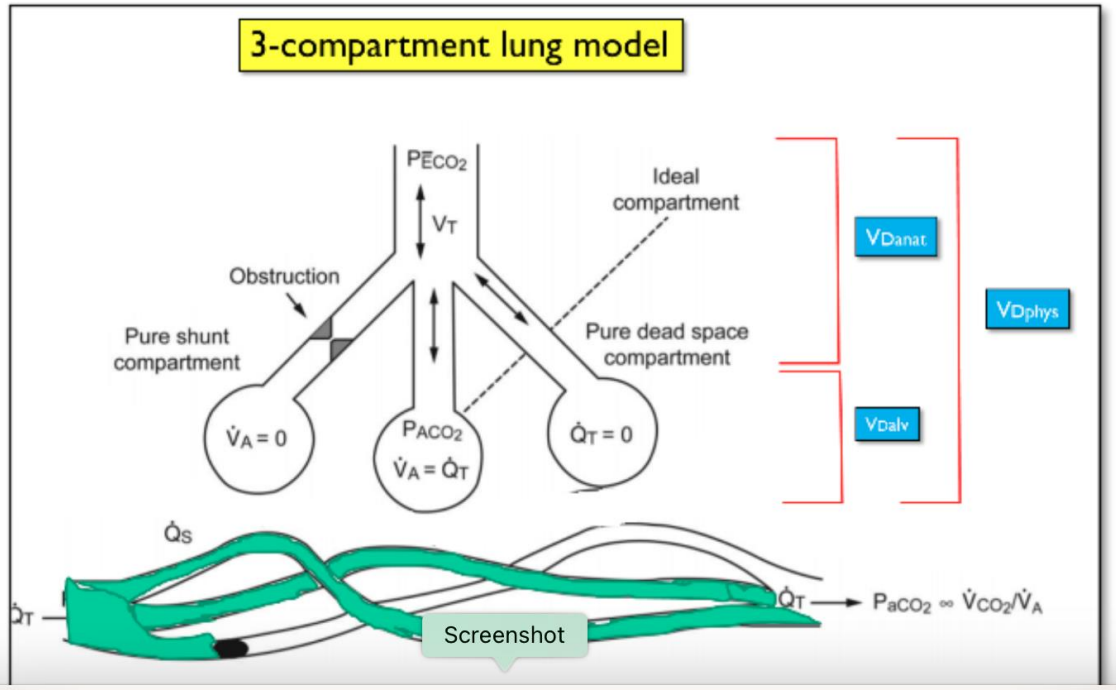
$$VCO_2 = VE \times FECO_2$$

Physiologic Dead Space



$$\frac{(PaCO_2 - P_ECO_2)}{PaCO_2}$$

Alveolar Dead Space



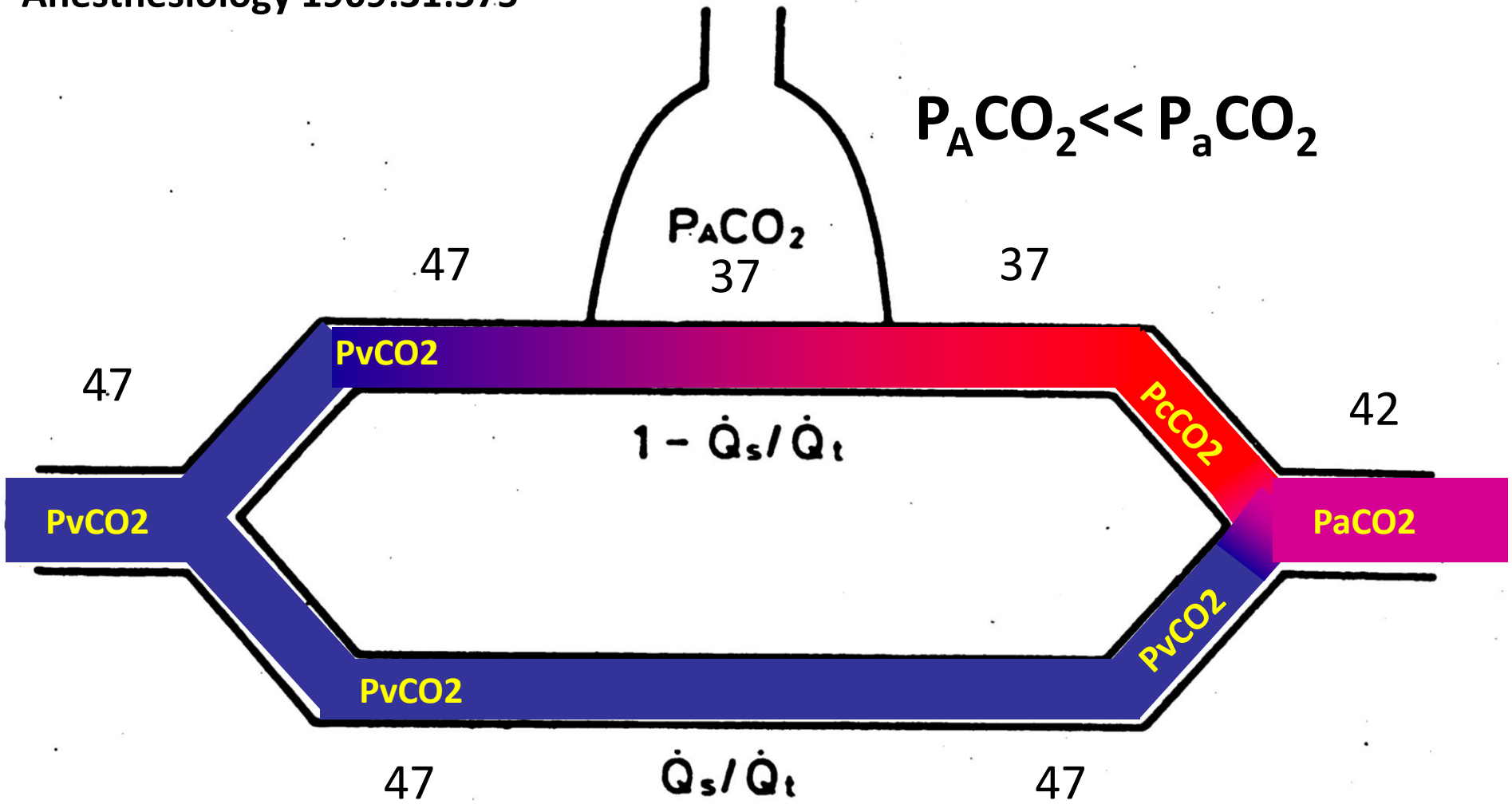
$$\frac{(PaCO_2 - P_{ET}CO_2)}{PaCO_2}$$

Effect of Anatomic Shunt on Physiologic Deadspace-to-Tidal Volume Ratio—A New Equation

SHIGEO KUWABARA, M.D.,* AND DERYCK DUNCALF, M.B., CH.B., F.F.A.R.C.S.†

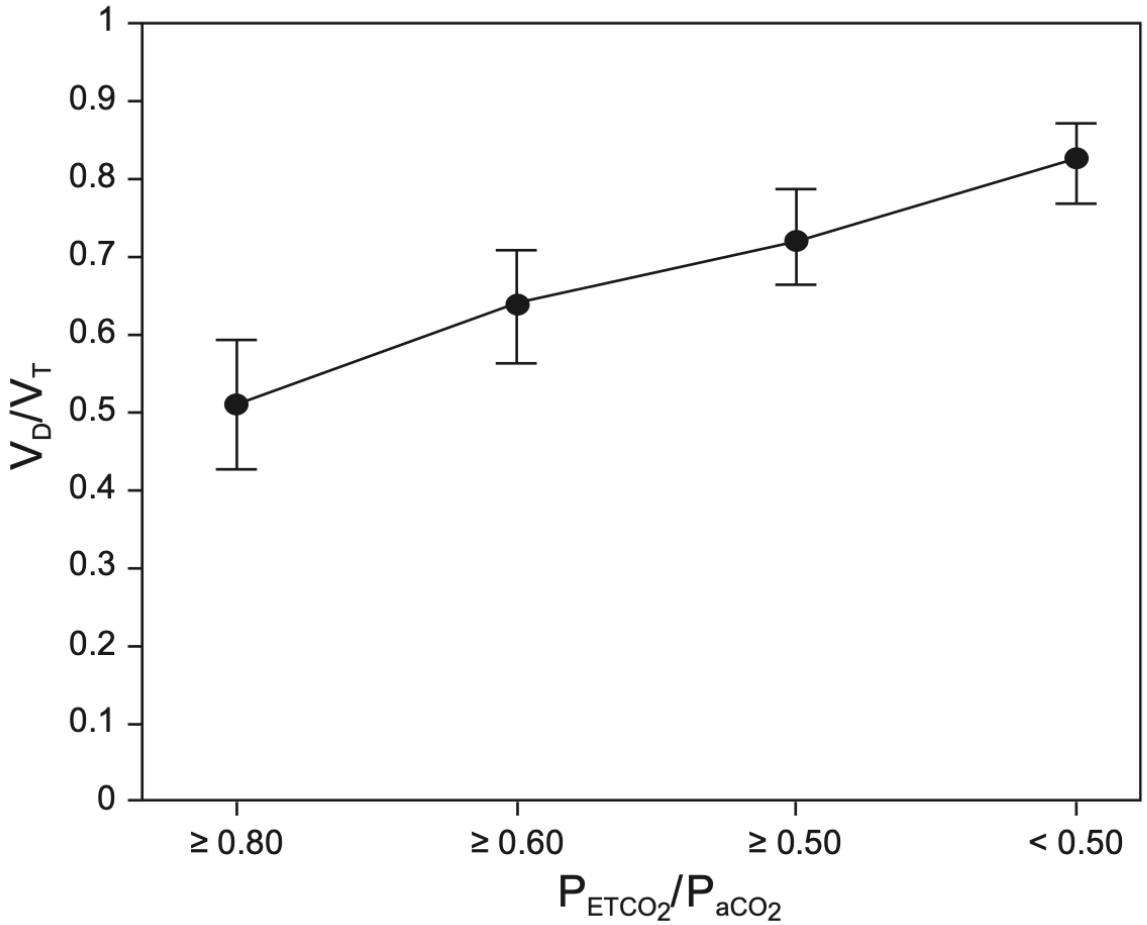
Anesthesiology 1969:31:575

$P_ACO_2 << P_aCO_2$



End-Tidal-to-Arterial P_{CO_2} Ratio as Signifier for Physiologic Dead-Space Ratio and Oxygenation Dysfunction in Acute Respiratory Distress Syndrome

Richard H Kallet and Michael S Lipnick



RESPIRATORY CARE FEBRUARY 2021 VOL 66 NO 2

End-Tidal-to-Arterial P_{CO_2} Ratio as Signifier for Physiologic Dead-Space Ratio and Oxygenation Dysfunction in Acute Respiratory Distress Syndrome

Richard H Kallet and Michael S Lipnick

Conclusions

Our analysis suggests that P_{ETCO_2}/P_{aCO_2} can be used as a surrogate for both V_D/V_T and oxygenation dysfunction in patients with ARDS. Similar to elevated V_D/V_T in early ARDS, decreasing P_{ETCO_2}/P_{aCO_2} is also associated with increasing illness severity and mortality risk. Although P_{ETCO_2}/P_{aCO_2} was recently proposed specifically for monitoring patients with ARDS associated with COVID-19, currently there are no data available to evaluate its potential relevance or utility.

RESPIRATORY CARE FEBRUARY 2021 VOL 66 NO 2

Why it is a matter of concern

- Physiopathologic issue
- Prognostic issue

Dead-Space V
in Acute Respi
A Systematic

KEY POINTS

Question: Is there an association between high dead-space ventilation measures and mortality in adults with acute respiratory distress syndrome (ARDS)?

Findings: In this systematic review and meta-analysis of over 9,000 patients, high pulmonary dead-space fraction or ventilatory ratio is associated with increased mortality.

Meaning: Dead-space ventilation measures could be used to identify adults with ARDS who are at high risk of death for consideration of early adjunctive therapies or for prognostic enrichment in clinical trials.

Screenshot

October 2023 • Volume 51 • Number 10

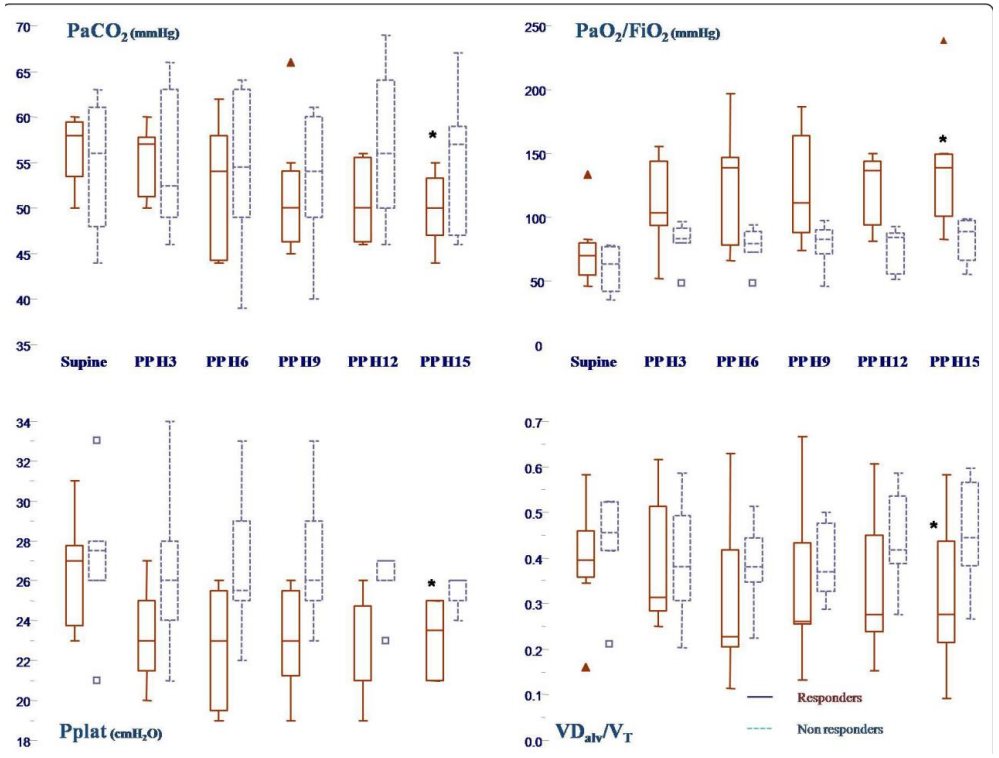
Charron et al. Critical Care 2011, 15:R175
http://ccforum.com/content/15/4/R175

CRITICAL CARE

RESEARCH Open Access

$PaCO_2$ and alveolar dead space are more relevant than PaO_2/FiO_2 ratio in monitoring the respiratory response to prone position in ARDS patients: a physiological study

Cyril Charron[1,2], Xavier Repesse[1,2], Koceïla Bouferrache[1,2], Laurent Bodson[1,2], Samuel Castro[1,2], Bernard Page[1,2], François Jardin[1,2] and Antoine Vieillard-Baron[1,2*]



Contents lists available at ScienceDirect

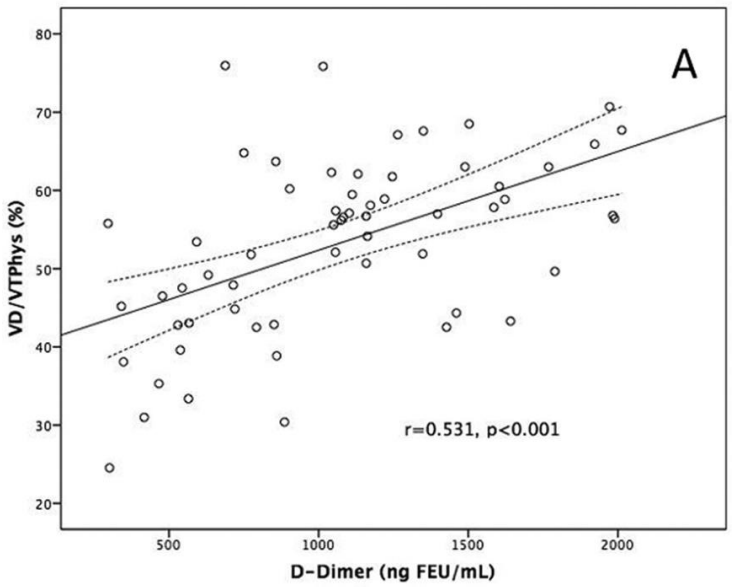
Journal of Critical Care

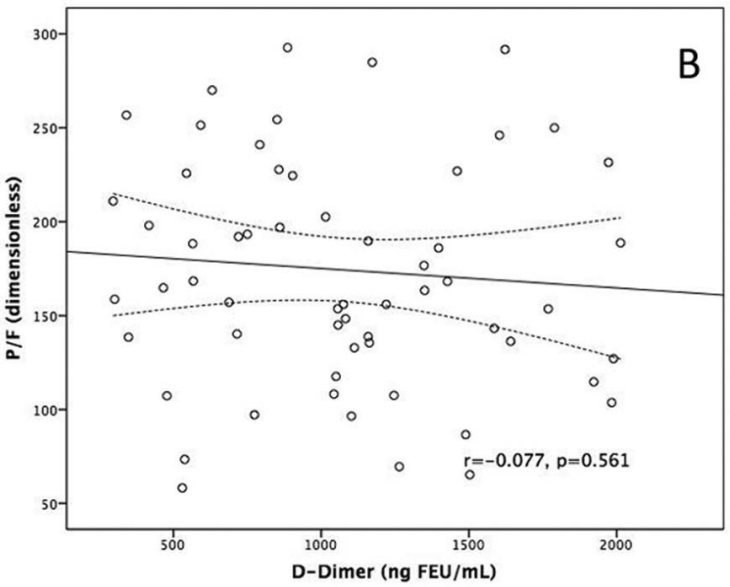
journal homepage: www.journals.elsevier.com/journal-of-critical-care

Increased respiratory dead space could associate with coagulation activation and poor outcomes in COVID-19 ARDS

Jerónimo Graf, MD [a,b], Rodrigo Pérez, RT [a,b], René López, MD [a,b,*]

[a] Departamento de Paciente Crítico, Clínica Alemana de Santiago, Avenida Vitacura 5951, Vitacura, Santiago Zip Code 7650568, Chile
[b] Facultad de Medicina Clínica Alemana, Universidad del Desarrollo, Av. Plaza 680, San Carlos de Apoquindo, Las Condes, Santiago Zip Code 7550000, Chile





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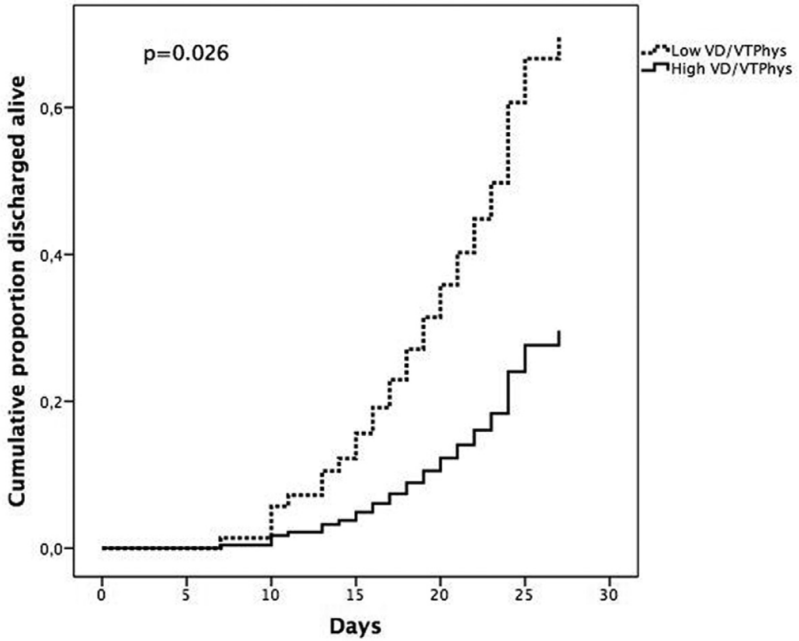


Journal of Critical Care 71 (2022) 154095

Why it is a matter of concern

- Physiopathologic issue
- Prognostic issue

WHY do VD/Vt correlate with mortality?

- It is a marker of severity
- It has a role in the determination of pathological process

AIM OF ARDS TREATMENT

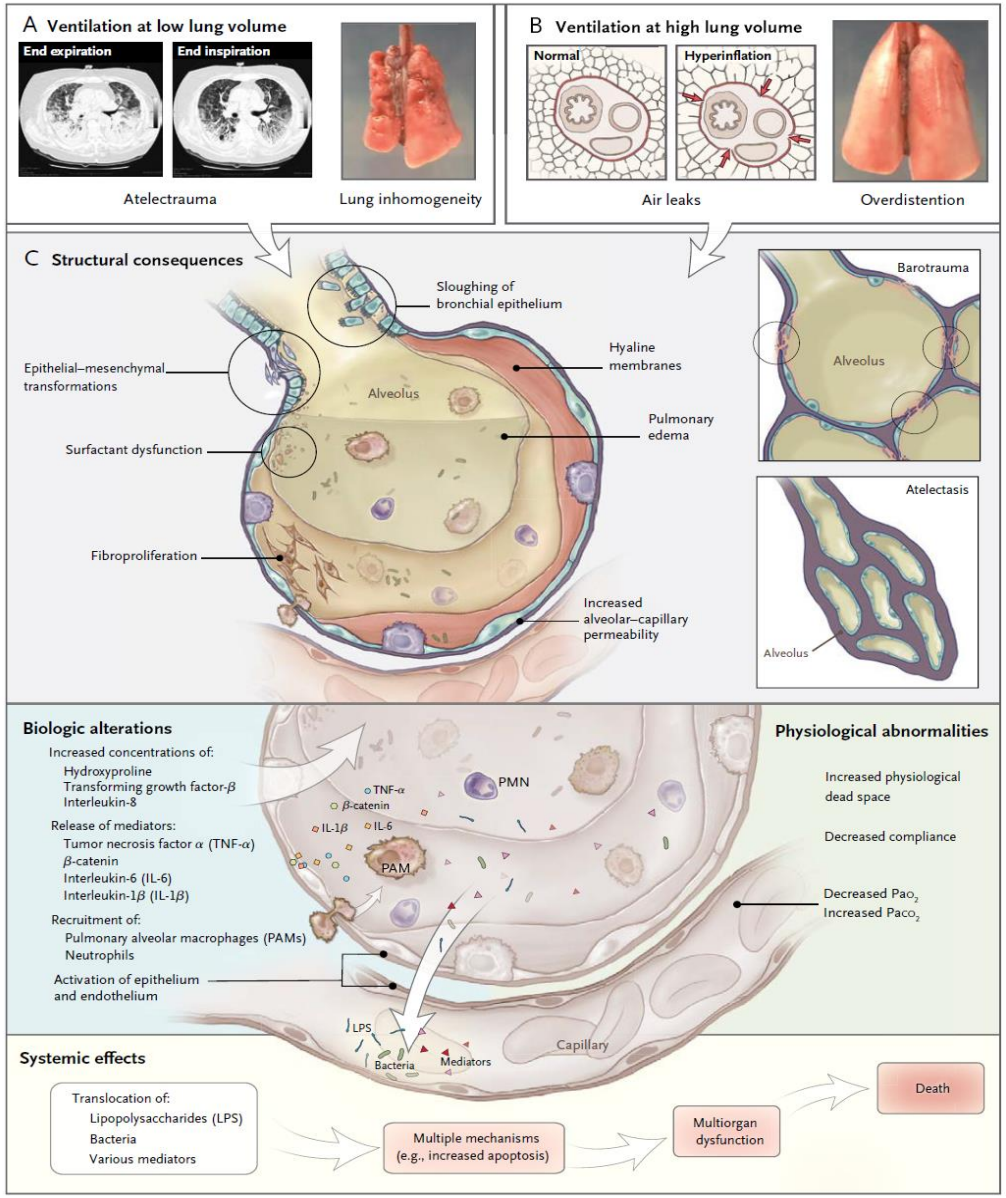
Sat a > 90-92

PaCO2 according pH

Protective ventilation

Prevent VILI

VILI



The NEW ENGLAND JOURNAL of MEDICINE

1. Barotrauma, volutrauma (end-insp lung volume)
2. Atelectrauma
3. Biotrauma

Ranieri, Slutsky NEJM 2013

Intensive Care Med (2012) 38:1573–1582
DOI 10.1007/s00134-012-2682-1

SPECIAL ARTICLE

Niall D. Ferguson
Eddy Fan
Luigi Camporota
Massimo Antonelli
Antonio Anzueto
Richard Beale
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Andrés Esteban
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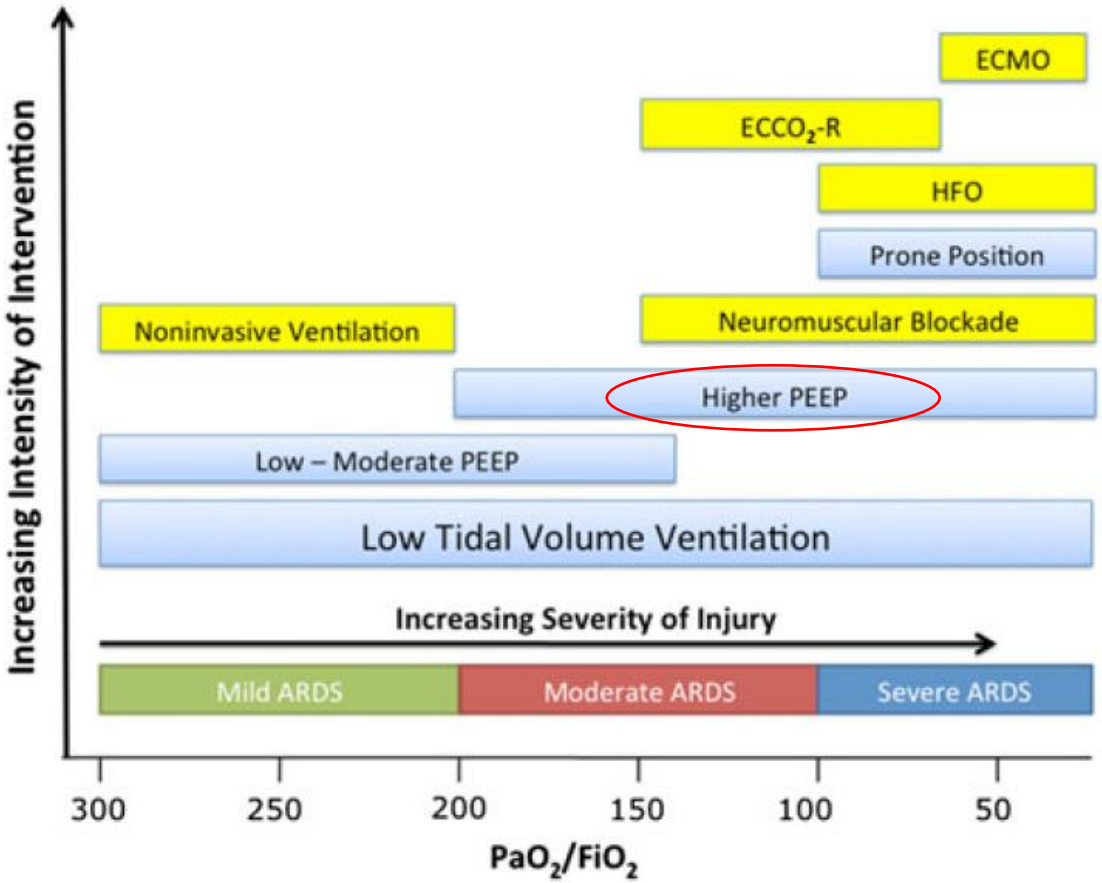
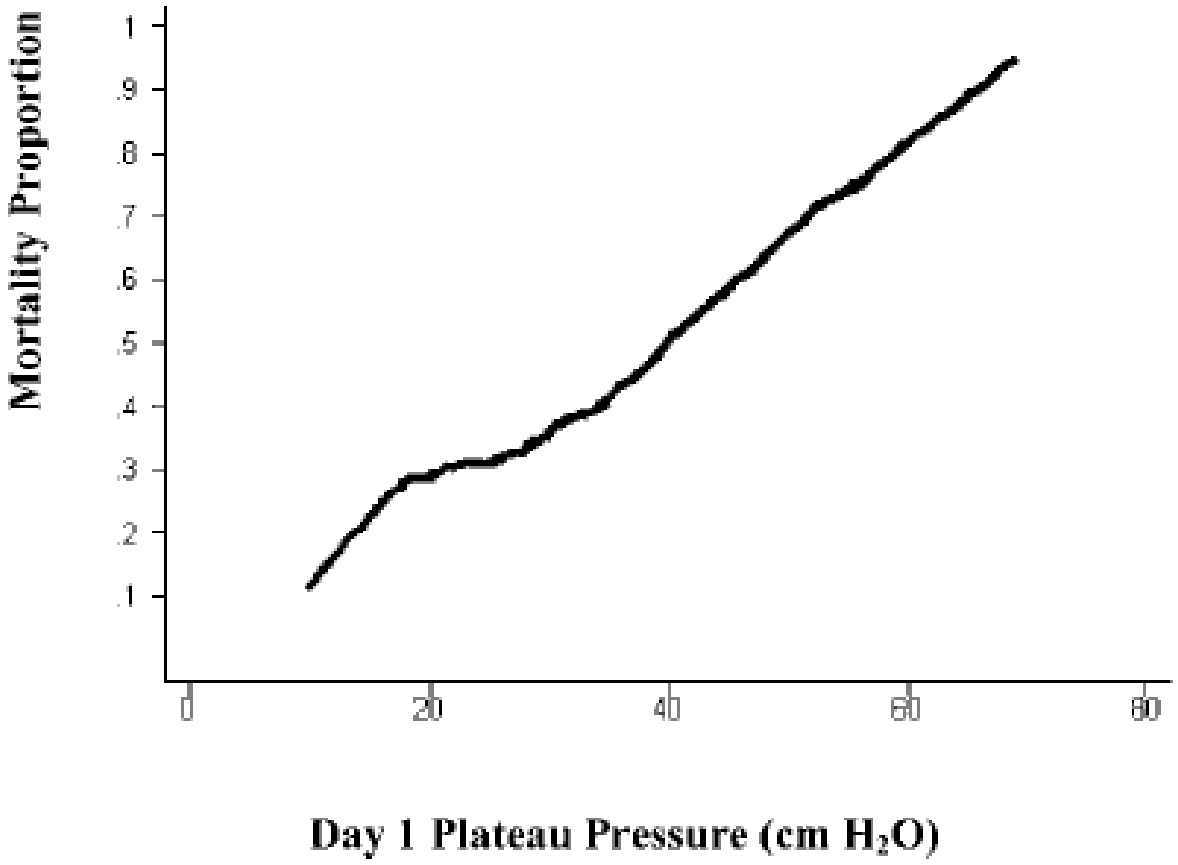
The Berlin definition of ARDS: an expanded rationale, justification, and supplementary material



$$\boxed{P_aCO_2} = K \times \frac{\dot{V}CO_2}{\boxed{(\dot{V}_E - \dot{V}_D)}}$$

- Protective ventilation can hasten PaCO2 control and requires higher airways pressures and respiratory frequency

PLATEAU PRESSURE



Hager et al. AJRCCM 2013

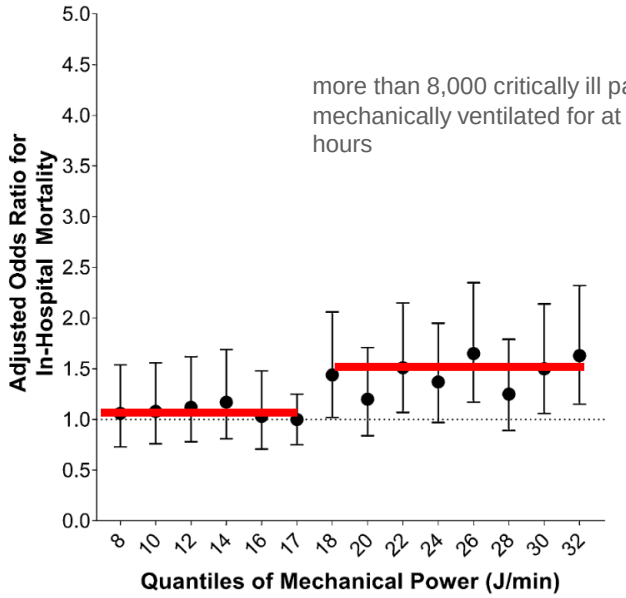
Mechanical Power and mortality

ORIGINAL

Mechanical power of ventilation is associated with mortality in critically ill patients: an analysis of patients in two observational cohorts

Ary Serpa Neto[1,2,3*], Rodrigo Octavio Deliberato[2,3,4], Alistair E. W. Johnson[5], Lieuwe D. Bos[1], Pedro Amorim[6], Silvio Moreto Pereira[6], Denise Carnieli Cazati[2], Ricardo L. Cordioli[2], Thiago Domingos Correa[2], Tom J. Pollard[5], Guilherme P. P. Schettino[2], Karina T. Timenetsky[2], Leo A. Celi[5,7], Paolo Pelosi[8,9], Marcelo Gama de Abreu[10], Marcus J. Schultz[1,11] and for the PROVE Network Investigators

more than 8,000 critically ill patients mechanically ventilated for at least 48 hours



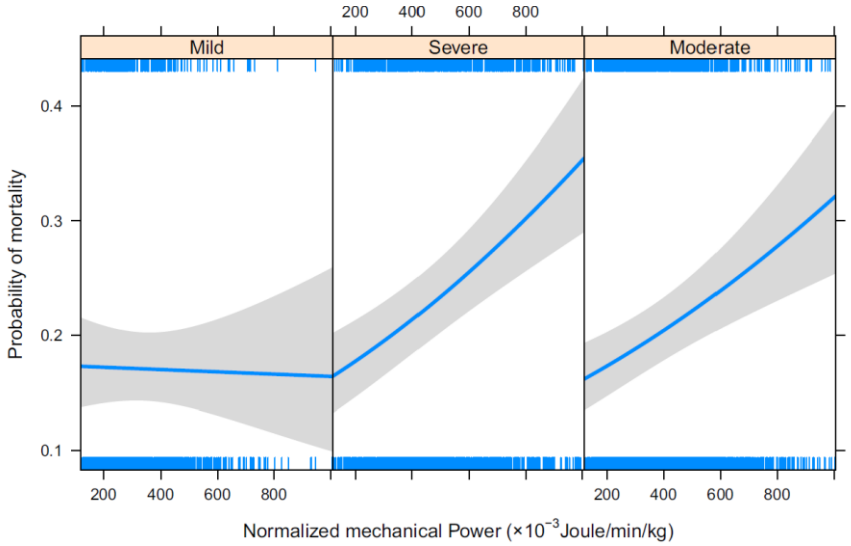
Intensive Care Med (2018) 44:1914–1922
https://doi.org/10.1007/s00134-018-5375-6

ORIGINAL

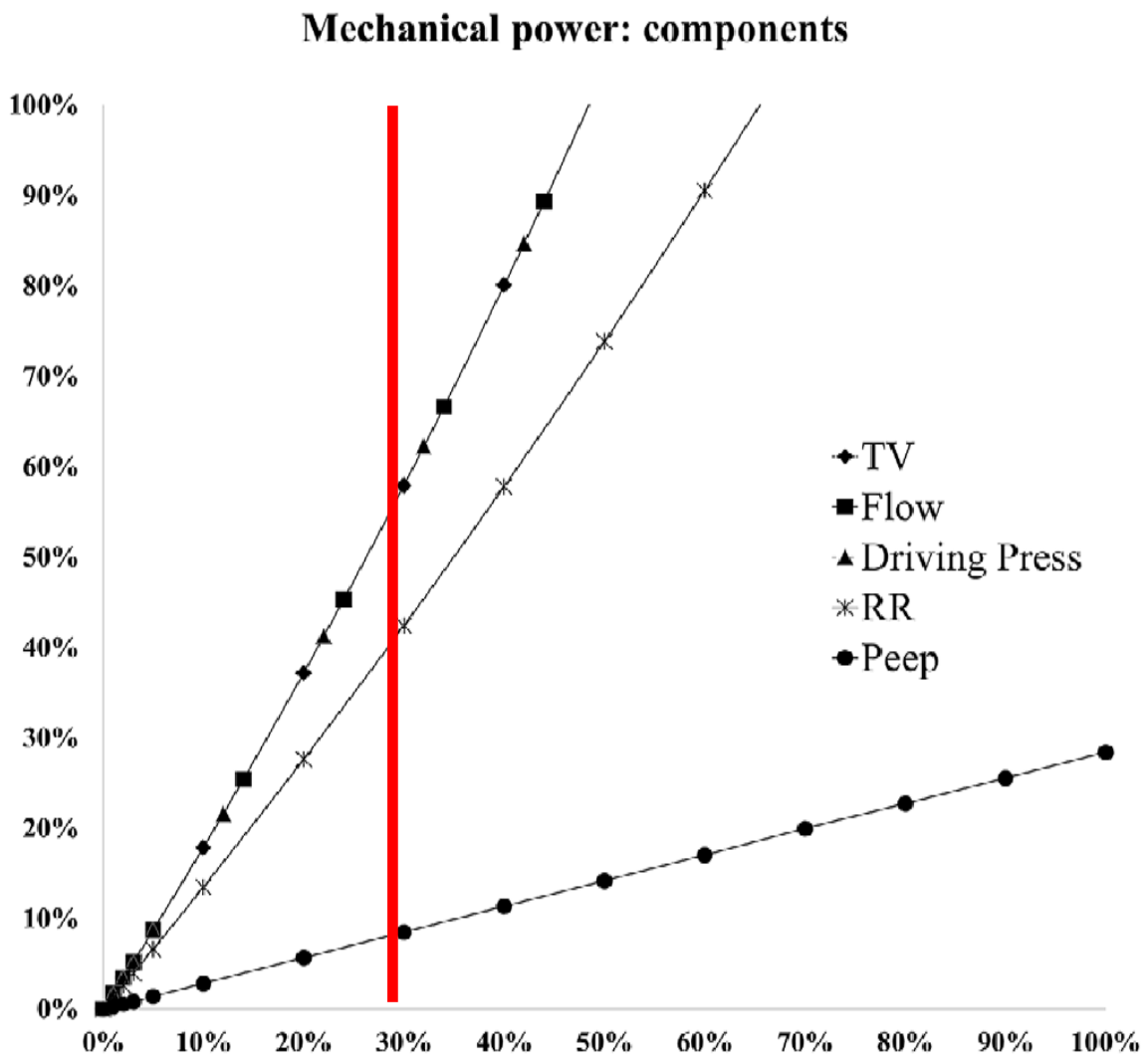
Mechanical power normalized to predicted body weight as a predictor of mortality in patients with acute respiratory distress syndrome

Zhongheng Zhang[1*], Bin Zheng[2], Nan Liu[3,4], Huiqing Ge[5] and Yucai Hong[1]

5159 critically ill patients with acute onset of ARDS

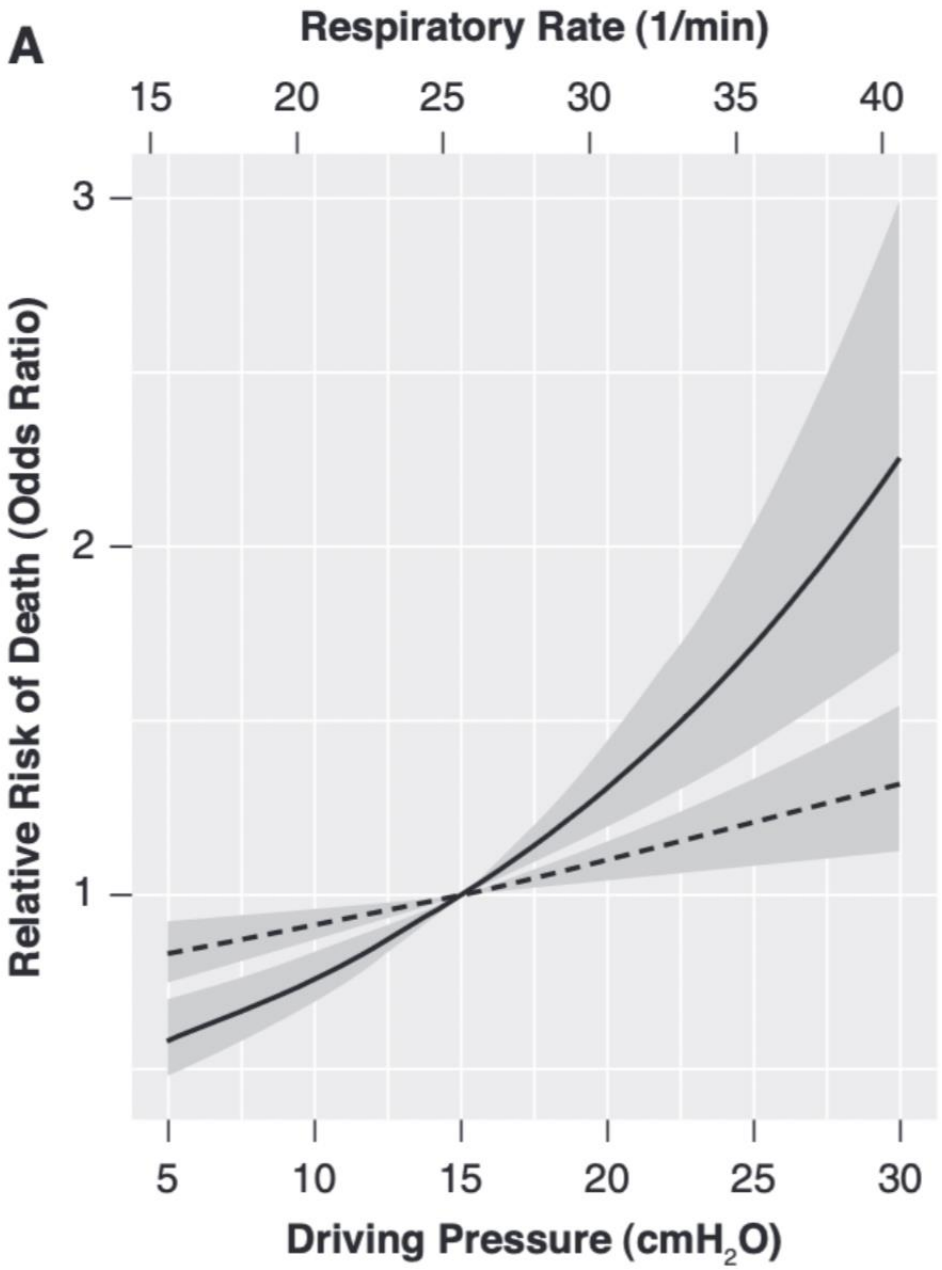


Intensive Care Med (2019) 45:856–864
https://doi.org/10.1007/s00134-019-05627-9



% variations of MP versus % variations of MP components

- The association between MP and mortality is debated!



Driving Pressure Respiratory Rate

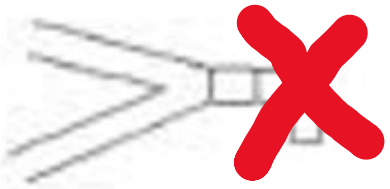
- Only DP and RR were independent predictors of mortality
- The contribution of DP weighted four times more than the contribution of RR

[(4 x DP) + RR]

Costa et al. Am J Respir Crit Care Med

Could we manage it?

- Temp control
- Tracheostomy
- External dead space (filters ,tubes etc)



Mechanical Deadspace: artificial airways including ventilator circuits

Intensive Care Med (2012) 38:1573–1582
DOI 10.1007/s00134-012-2682-1

SPECIAL ARTICLE

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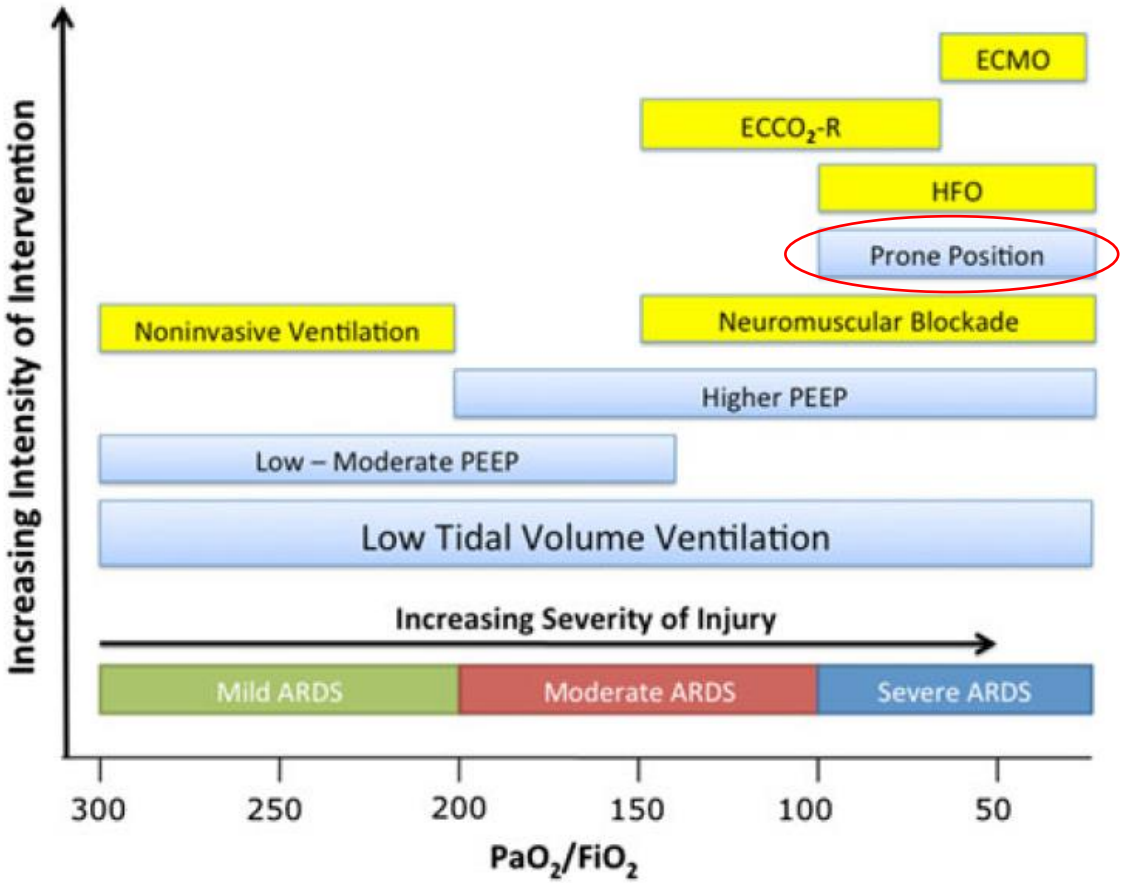
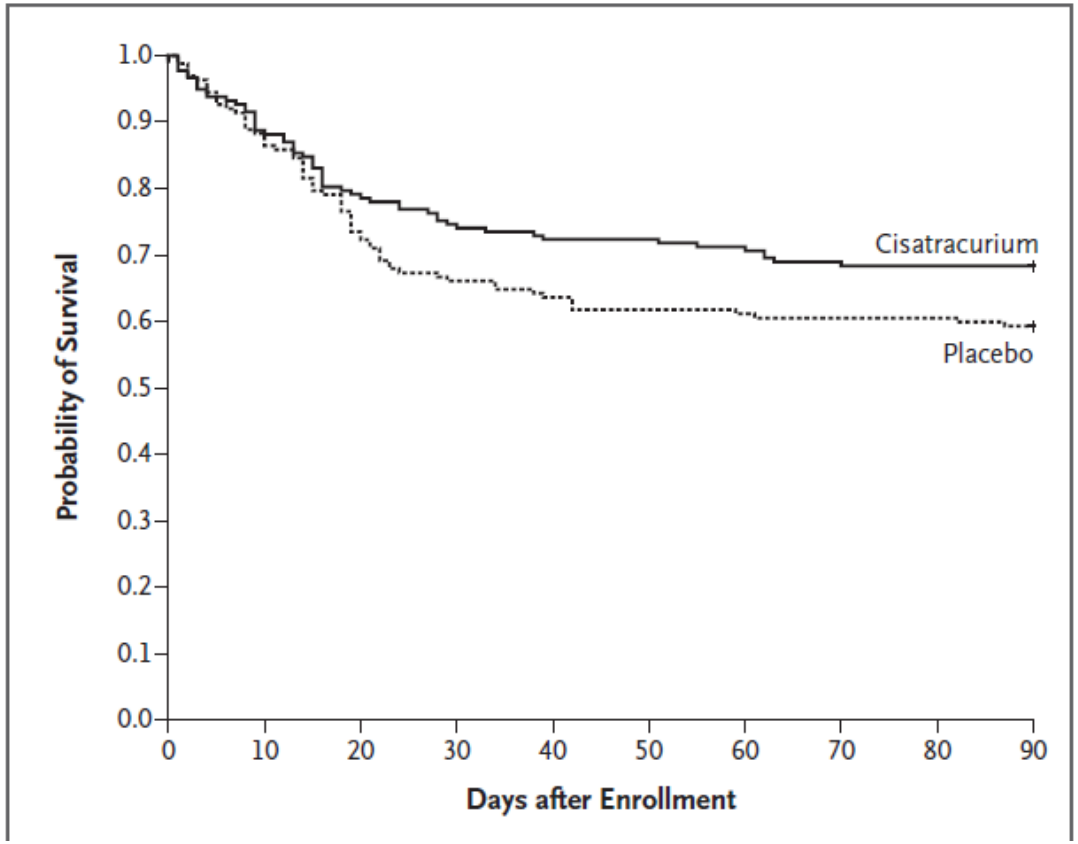


Neuromuscular Blockers in Early Acute Respiratory Distress Syndrome

Laurent Papazian, M.D., Ph.D., Jean-Marie Forel, M.D., Arnaud Gacouin, M.D., Christine Penot-Ragon, Pharm.D., Gilles Perrin, M.D., Anderson Loundou, Ph.D., Samir Jaber, M.D., Ph.D., Jean-Michel Arnal, M.D., Didier Perez, M.D., Jean-Marie Seghboyan, M.D., Jean-Michel Constantin, M.D., Ph.D., Pierre Courant, M.D., Jean-Yves Lefrant, M.D., Ph.D., Claude Guérin, M.D., Ph.D., Gwenaël Prat, M.D., Sophie Morange, M.D., and Antoine Roch, M.D., Ph.D., for the ACURASYS Study Investigators*



N Engl J Med 2010;363:1107-16.
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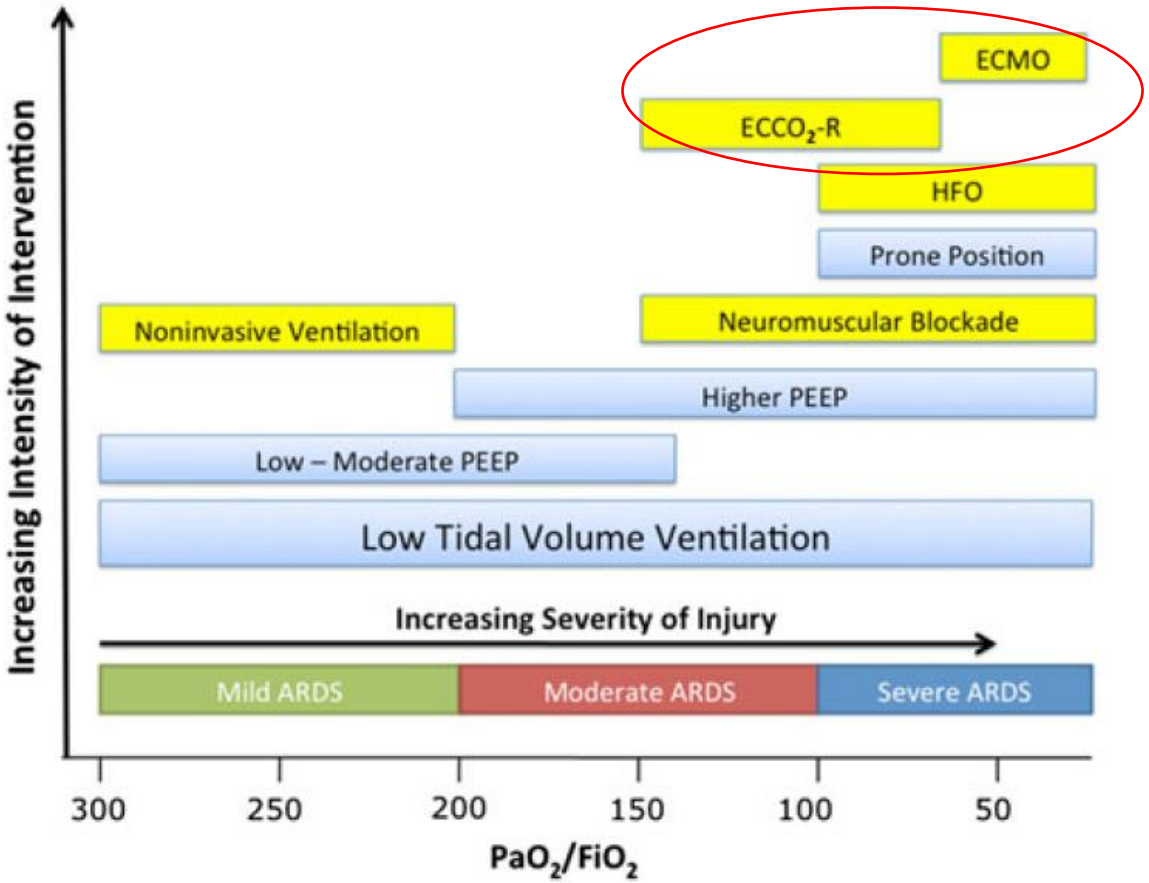
V. Marco Ranieri

The Berlin definition of ARDS: an expanded rationale, justification, and supplementary material



Reverse-Thrust Ventilation in Hypercapnic Patients with Acute Respiratory Distress Syndrome

Acute Physiological Effects

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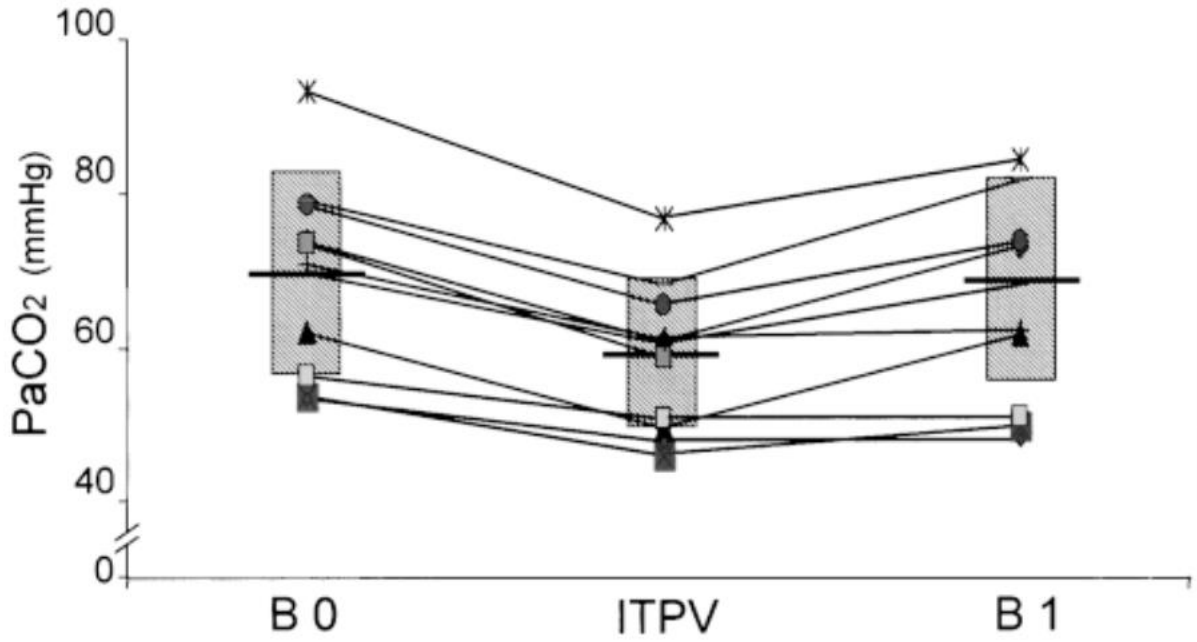

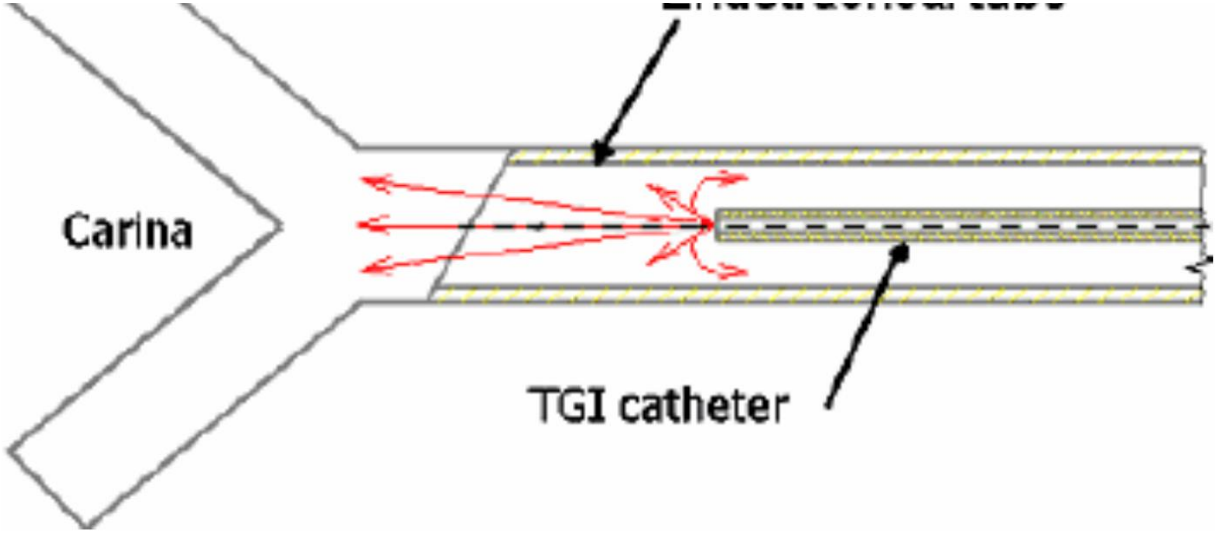

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CONCLUSIONS

- Carbon Dioxide elimination is the true target of ventilation
- Impairment of CO_2 elimination is easily measured by Vd/Vt
- Vd/Vt is a global index of pulmonary function, with important prognostic value
- We ventilate our patients to eliminate CO_2
- BAD CO_2 ELIMINATION = VILI

Non sta succedendo nel mio ospedale ma è una storia che ho già visto, sentito, vissuto.
Lei una signora di 84 anni, viene portata in Pronto Soccorso perché non respira bene,
Viene intubata e portata in Rianimazione con poche speranze.
Il marito, 88 anni, di cui molti passati al suo fianco, può starle accanto solo pochi minuti al giorno.
Non hanno figli ed il povero signore ha "forse" il conforto di poche parole che i curanti gli rivolgono in una manciata di minuti, una vota al giorno. e a cui lui risponde " speriamo".
Mentre mi raccontano questa storia penso: se fossimo capaci per un momento di guardare quello che il nostro signore vede con i suoi occhi, non potrebbe accadere un miracolo? (Henry David Thoureau)