Optimizing mechanical ventilation for COVID-19
Before thinking ECMO

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To watch the lecture

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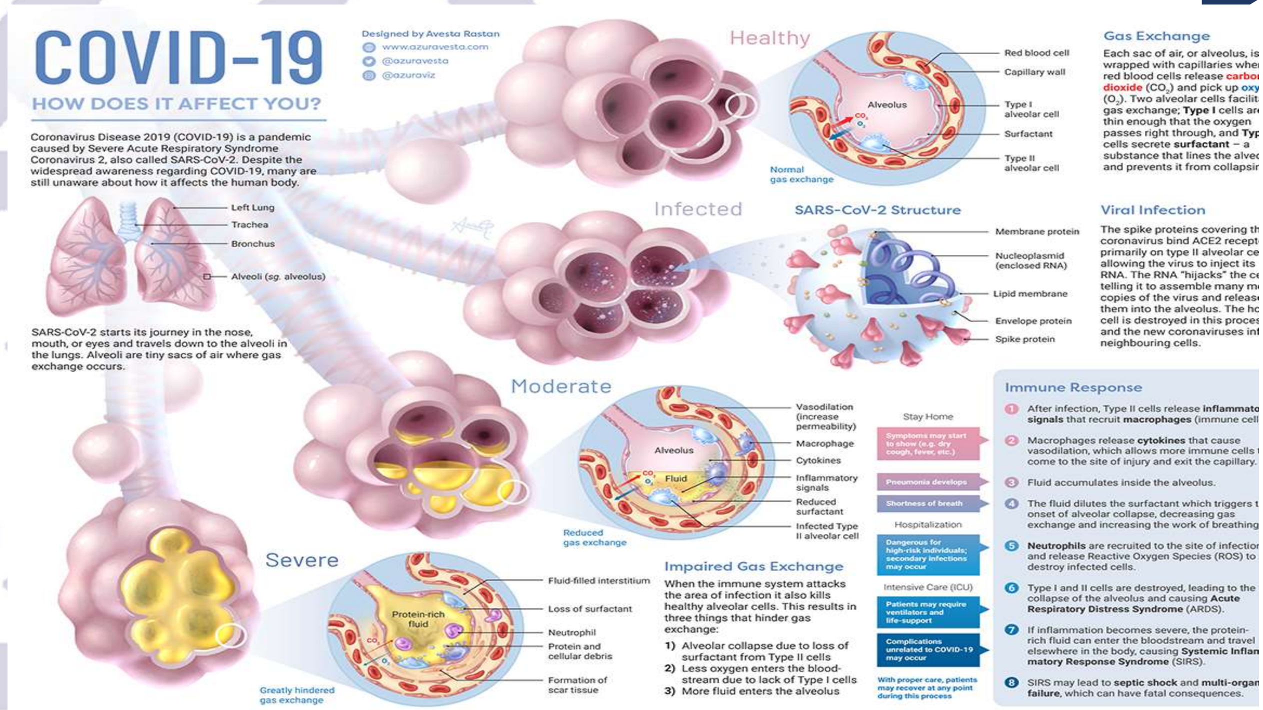
Objectives

- Review of Pathology
- Invasive mechanical ventilation for COVID-19
- Optimizing ventilatory support
- ECMO

COVID-19 Pathology

- Diffuse Alveolar Damage (DAD)
- Pulmonary vascular damage with macro/micro thrombosis



Shanmugam C, Mohammed AR, Ravuri S, et al. COVID-2019 - A comprehensive pathology insight. *Pathol Res Pract*. 2020;216(10):153222

COVID-19 ARDS similar to the non COVID-19 ARDS ?????

- Different phenotypes: L & H ?

- Higher respiratory compliance ?

- Similar ARDS ?

Gattinoni L, Chiumello D, Caironi P, Busana M, Romitti F, Brazzi L et al. (2020) COVID-19 pneumonia: different respiratory treatments for different phenotypes? Intensive Care Med 46:1099–1102

Haudebourg AF, Perier F, Tuffet S, de Prost N, Razazi K, Mekontso Dessap A, Carteaux G. Respiratory Mechanics of COVID-19- versus Non-COVID-19-associated Acute Respiratory Distress Syndrome. Am J Respir Crit Care Med. 2020 Jul 15;202(2):287-290.

When to initiate Mechanical Ventilation

Early in course ?

After failing HFNC/NIPPV

Clinically

O_2 saturation

As always, we should only intubate when necessary, but we must not leave it too late. Therefore, critical care needs highly trained, experienced clinicians involved in bedside care. It is also why we need more research.

When to initiate Mechanical Ventilation

Timing of invasive mechanic ventilation in critically ill patients with coronavirus disease 2019

Conclusion: Early initial intubation after NIV/HFNC might have a beneficial effect in reducing mortality for critically ill patients meeting IMV indication. Considering APACHE II and PSI scores might help physicians in decision making about timing of intubation for curbing subsequent mortality.

Zhang Q, Shen J, Chen L, et al. Timing of invasive mechanic ventilation in critically ill patients with coronavirus disease 2019. J Trauma Acute Care Surg. 2020 Dec;89(6):1092-1098.

Timing of Intubation and Mortality Among Critically Ill Coronavirus Disease 2019 Patients: A Single-Center Cohort Study

Conclusions: In this cohort of critically ill patients with coronavirus disease 2019, neither time from ICU admission to intubation nor high-flow nasal cannula use were associated with increased mortality. This study provides evidence that coronavirus disease 2019 respiratory failure can be managed similarly to hypoxic respiratory failure of other etiologies. (*Crit Care Med* 2020; XX:00–00)

Hernandez-Romieu AC, Adelman MW, Hockstein MA, et al. Timing of Intubation and Mortality Among Critically Ill Coronavirus Disease 2019 Patients: A Single-Center Cohort Study. *Crit Care Med*. 2020;48(11):e1045-e1053.

Invasive mechanical ventilation for COVID-19 Strategies

- Same strategy as non COVID-19 given the lack of understanding of how the pathology really differ
- Every mechanical ventilation strategy should be ***INDIVIDUALIZED*** to the patient not one-size-fit all strategy
- Avoid VILI, appropriate PEEP, lowest driving pressure, tidal volume
- Be patient: tolerate some hypoxia and hypercapnia and acidimia

Optimizing Mechanical Ventilation

Ventilatory strategies

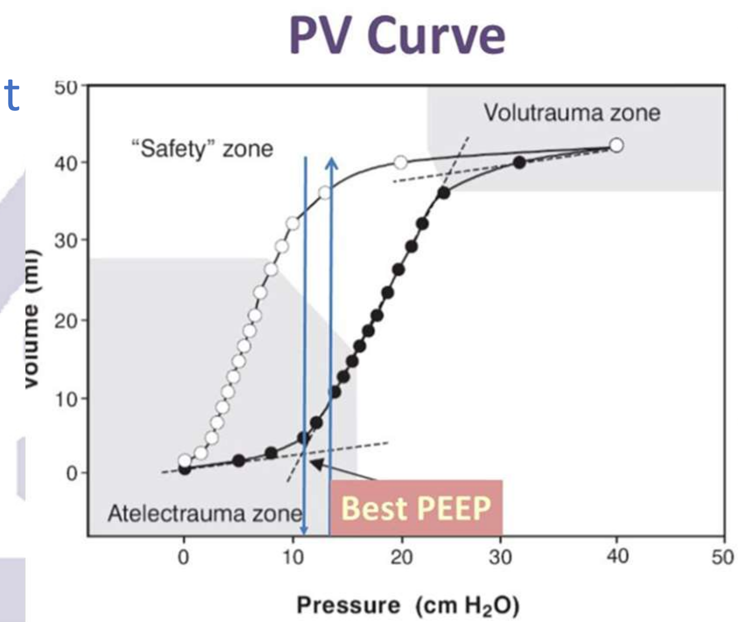
- Optimal PEEP
  - -Pressure-Volume curve
  - -Trans-Pulmonary pressure
  - -Electrical Impedance Tomography (EIT)
- APRV

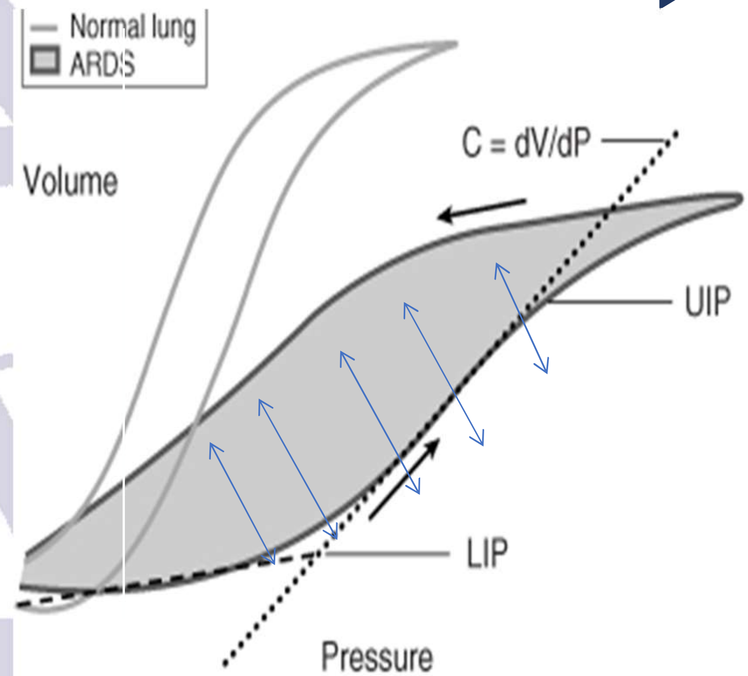
Non Ventilatory strategies

- Prone Position
- Inhaled Pulmonary Vasodilators
- Steroids

Pressure-Volume curve (Best Compliance)

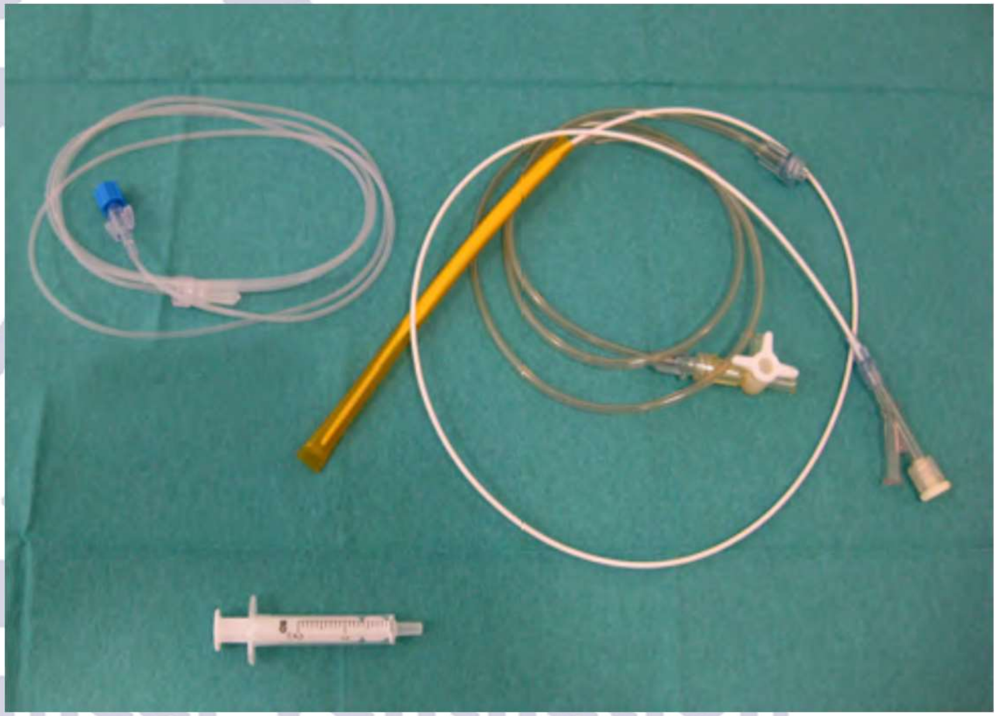
- Lower Inflection point (LIP)
- Point of Maximal Curvature (PMC)
- Hysteresis





Esophageal Balloon Manometry

- Measuring Trans-Pulmonary pressure to set Inspiratory pressure and PEEP
- Assess WOB during spontaneous breathing
- Aid in diagnosing Patient-Ventilator dys-synchrony
- Aid in assessing recruitability during recruitment maneuver
- Measuring Chest wall and lung elastance separately
- Aid in weaning off mechanical ventilation
- Transmural vascular pressure (i.e. the difference between intravascular and extramural pressure reflected by *Pes*)



Esophageal Balloon Manometry

CONCISE CLINICAL REVIEW

The Application of Esophageal Pressure Measurement in Patients with Respiratory Failure

- A physiologically based ventilator strategy should take the trans-pulmonary pressure into account

- Despite all those benefits, this tool remains confined to research

- Used in less than 1% of ARDS patients

Akoumianaki E, Maggiore SM, Valenza F, et al. The application of esophageal pressure measurement in patients with respiratory failure. Am J Respir Crit Care Med. 2014 Mar 1;189(5):520-31.

Esophageal Balloon Manometry Beneficial ?

The NEW ENGLAND JOURNAL of MEDICINE

ESTABLISHED IN 1812 NOVEMBER 13, 2008 VOL. 359 NO. 20

Mechanical Ventilation Guided by Esophageal Pressure in Acute Lung Injury

CONCLUSIONS

As compared with the current standard of care, a ventilator strategy using esophageal pressures to estimate the transpulmonary pressure significantly improves oxygenation and compliance. Multicenter clinical trials are needed to determine whether this approach should be widely adopted. (ClinicalTrials.gov number, NCT00127491.)

Effect of Titrating Positive End-Expiratory Pressure (PEEP) With an Esophageal Pressure–Guided Strategy vs an Empirical High PEEP-FIO_2 Strategy on Death and Days Free From Mechanical Ventilation Among Patients With Acute Respiratory Distress Syndrome

A Randomized Clinical Trial

Conclusions and Relevance Among patients with moderate to severe ARDS, P_{ES}-guided PEEP, compared with empirical high PEEP-FIO_2, resulted in no significant difference in death and days free from mechanical ventilation. These findings do not support P_{ES}-guided PEEP titration in ARDS.

Talmor D, Sarge T, Malhotra A, et al. Mechanical ventilation guided by esophageal pressure in acute lung injury. N Engl J Med. 2008 Nov 13;359(20):2095-104

Beitler JR, Sarge T, Banner-Goodspeed VM, et al. Effect of Titrating Positive End-Expiratory Pressure (PEEP) With an Esophageal Pressure-Guided Strategy vs an Empirical High PEEP-Fio2 Strategy on Death and Days Free From Mechanical Ventilation Among Patients With Acute Respiratory Distress Syndrome: A Randomized Clinical Trial. JAMA. 2019 Mar 5;321(9):846-857.

Trans-Pulmonary Pressure (PTP)
PTP = Palv – Ppl.

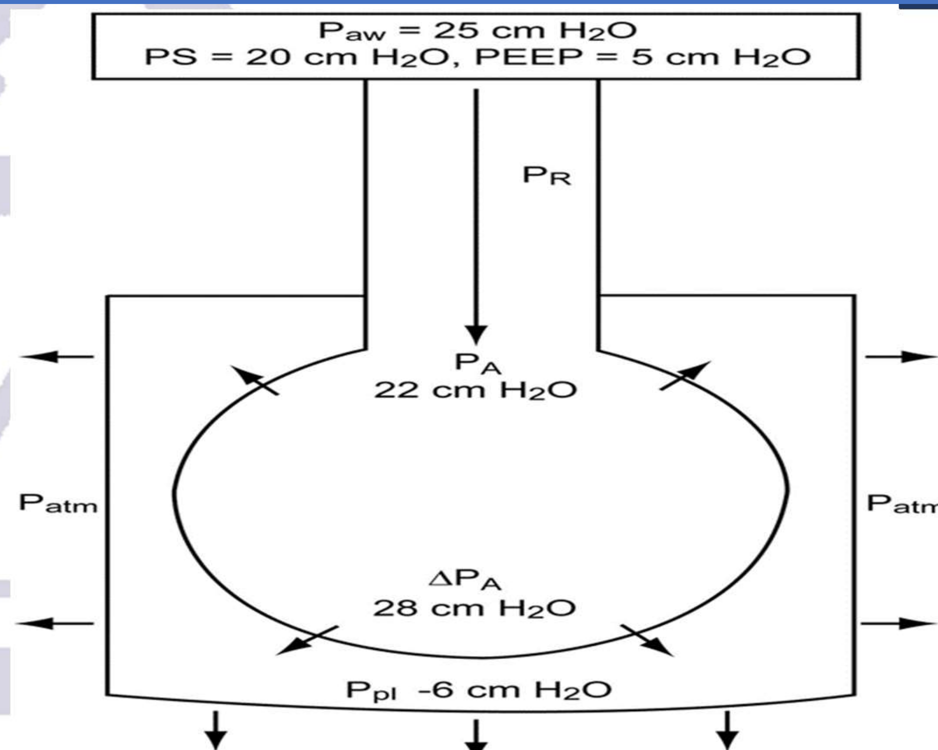
- Is the distending pressure of the alveoli

End Inspiratory PTP

Too high during inhalation: rupture (stress)

End Expiratory PTP

- Too low during exhalation : collapse (strain)

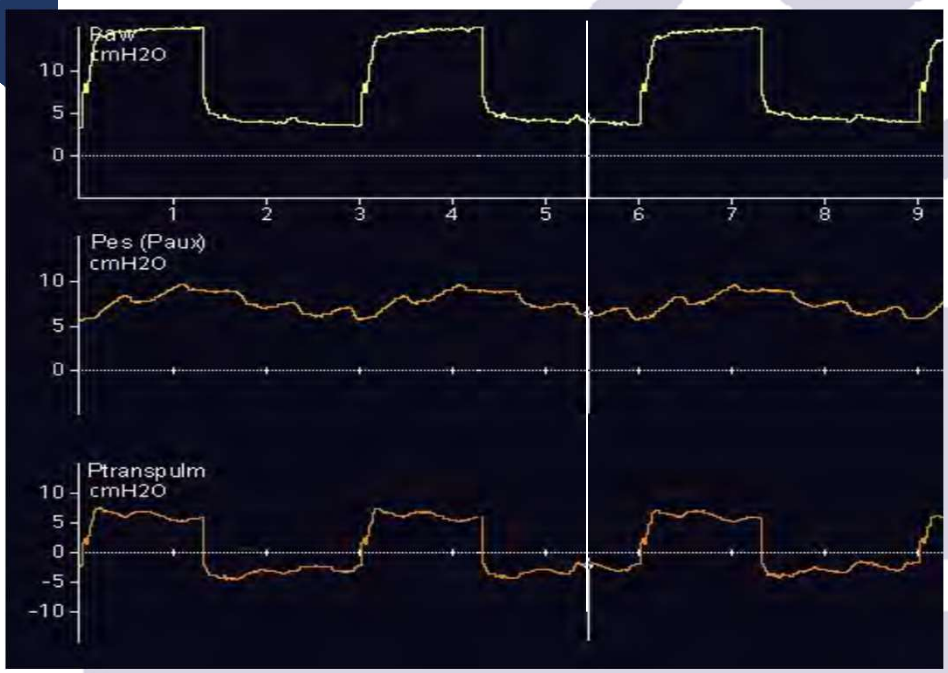


Trans-Pulmonary Measurement

Goal is to keep Inspiratory PL < 15-20 cmH_2O, to avoid lung stress (over distension, i.e. volu-trauma and barotrauma) i.e. Stress

Goal to keep Expiratory PL > 0 (0-5) cmH_2O to avoid lung strain (repeated opening and closing of alveoli, i.e. atelectrauma) i.e. Strain

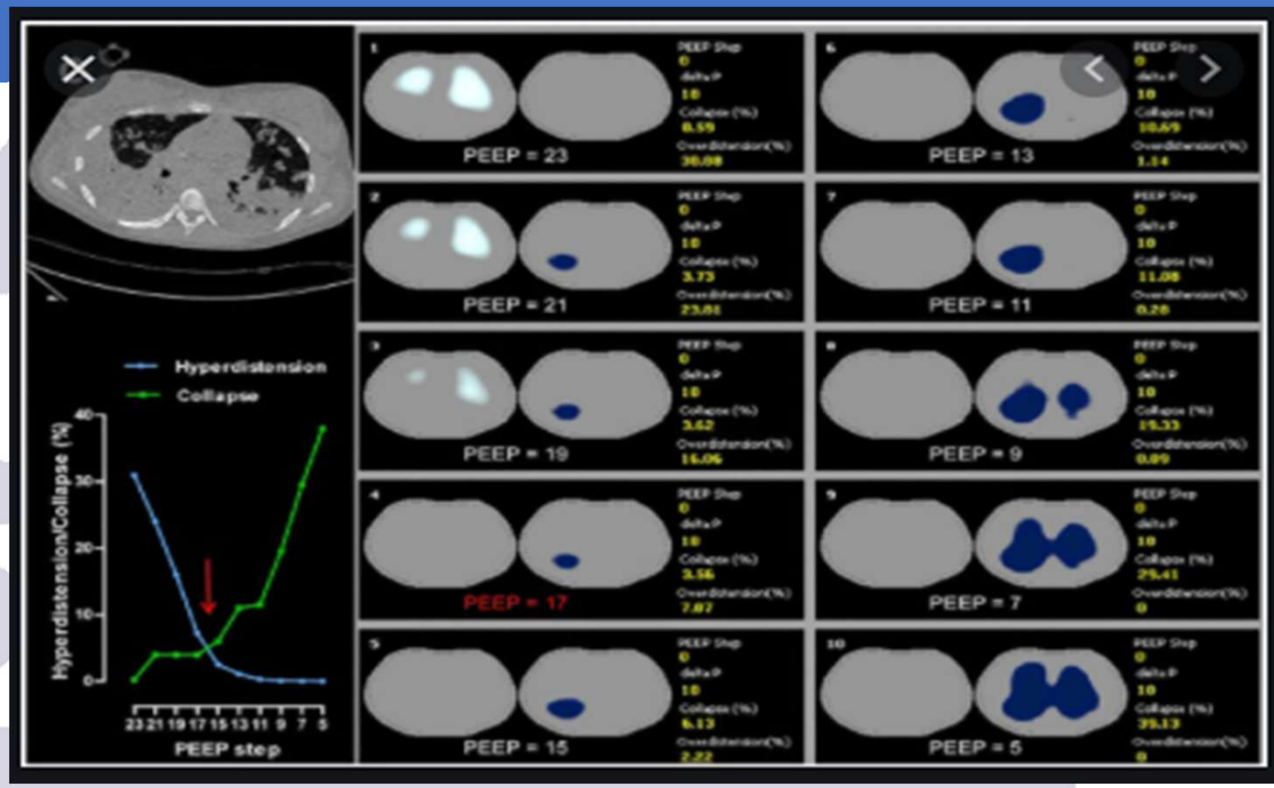
Trans-Pulmonary Measurement



EG Daoud, KH Yamasaki, K Nakamoto, D Wheatley. Esophageal pressure balloon and transpulmonary pressure monitoring in airway pressure release ventilation: a different approach. Can J Respir Ther 2018;54(3):1–4.

Electrical Impedance Tomography

Noninvasive, bedside monitoring technique that provides semicontinuous, real-time information about the regional distribution of changes in the electrical resistivity of lung tissue due to variations in ventilation



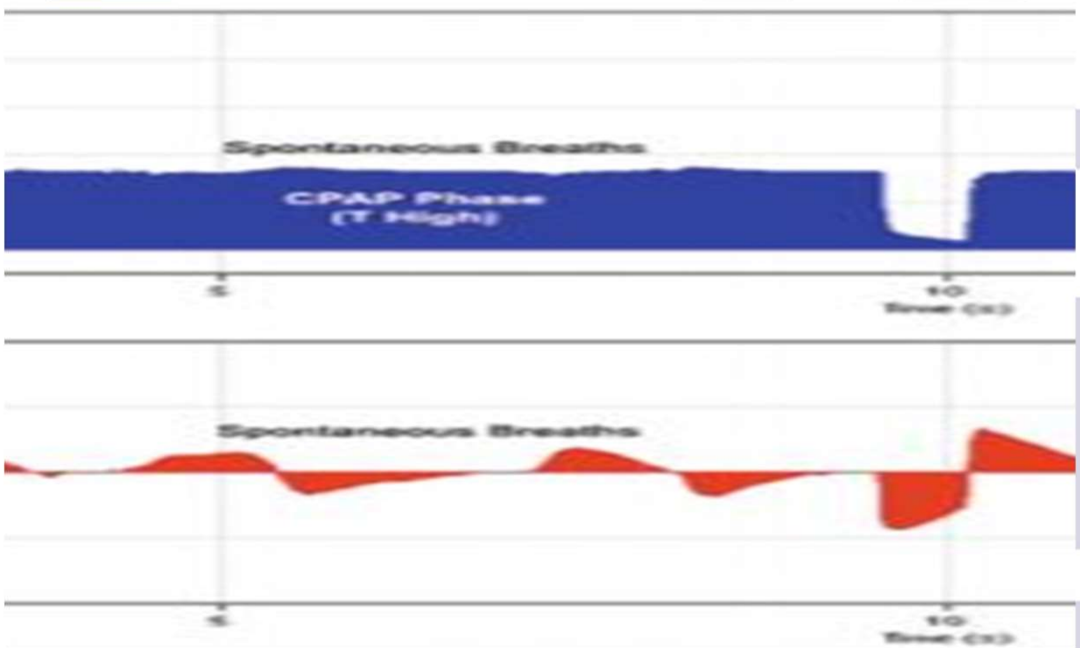
Lobo B, Hermosa C, Abella A, Gordo F. Electrical impedance tomography. Ann Transl Med. 2018;6(2):26.

APRV (Airway Pressure Release Ventilation)

- APRV was described more than 30 years ago (1987) by Stock and Downs as CPAP with intermittent release phase
- APRV is classified as pressure controlled intermittent mandatory ventilation, and is typically applied using inverse inspiratory I:E ratios
- There are both mandatory breaths (i.e. time-triggered and time-cycled), as well as spontaneous breaths (i.e. patient triggered and patient-cycled)
- Spontaneous breaths can occur both during and between mandatory breaths

Daoud EG, Farag HL, Chatburn RL. Airway pressure release ventilation: what do we know? Respir Care. 2012 Feb;57(2):282-92.

APRV setting

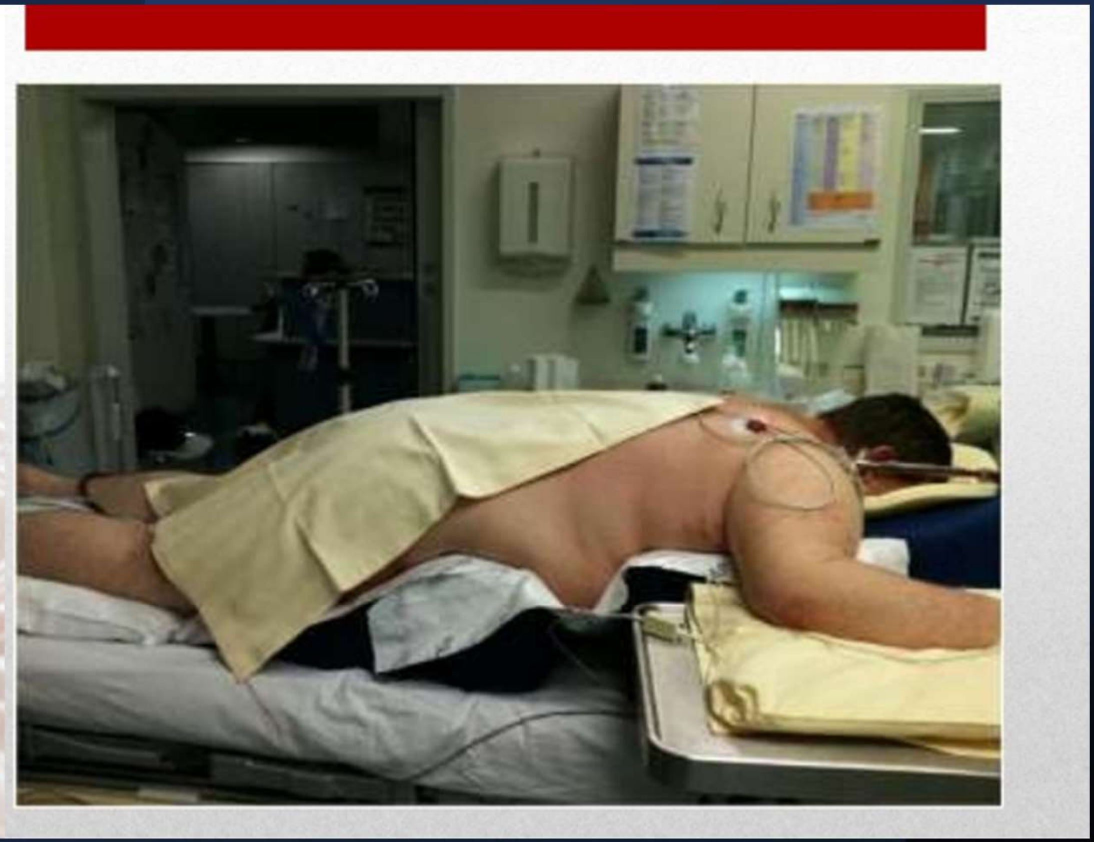


- P High: mandatory inspiratory pressure (Driving pressure)
- P Low: expiratory pressure (PEEP)
- T High: mandatory inspiratory time (I time)
- T Low: expiratory time
- Release rate: mandatory respiratory rate

APRV + Esophageal balloon

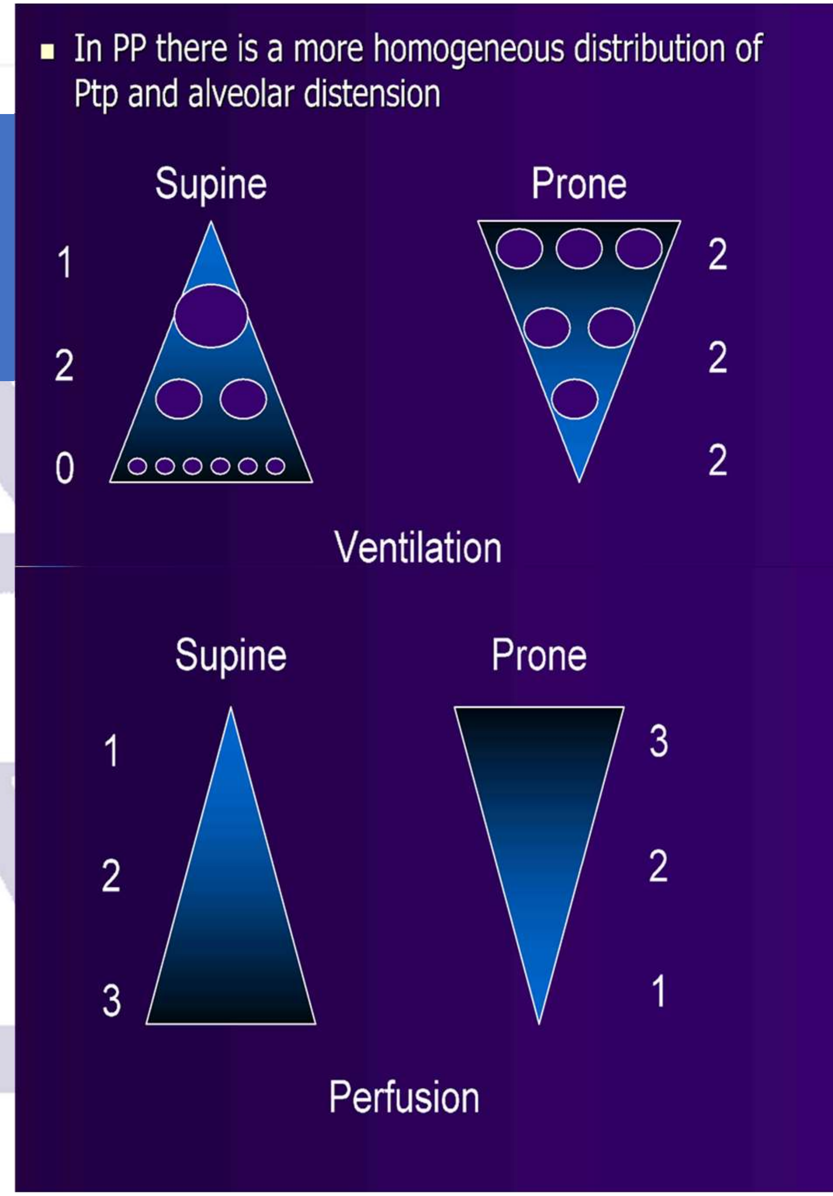
Daoud EG, Yamasaki KH, Nakamoto K, et al. Esophageal pressure balloon and transpulmonary pressure monitoring in airway pressure release ventilation: a different approach. Can J Respir Ther. 2018; 54(3):62-65.

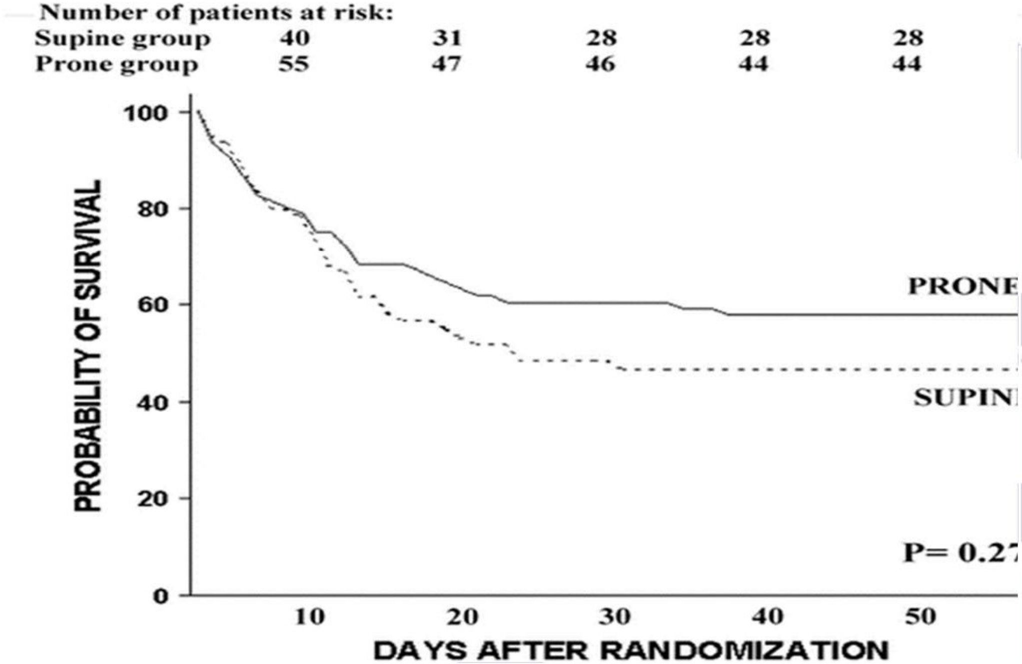
Prone Position

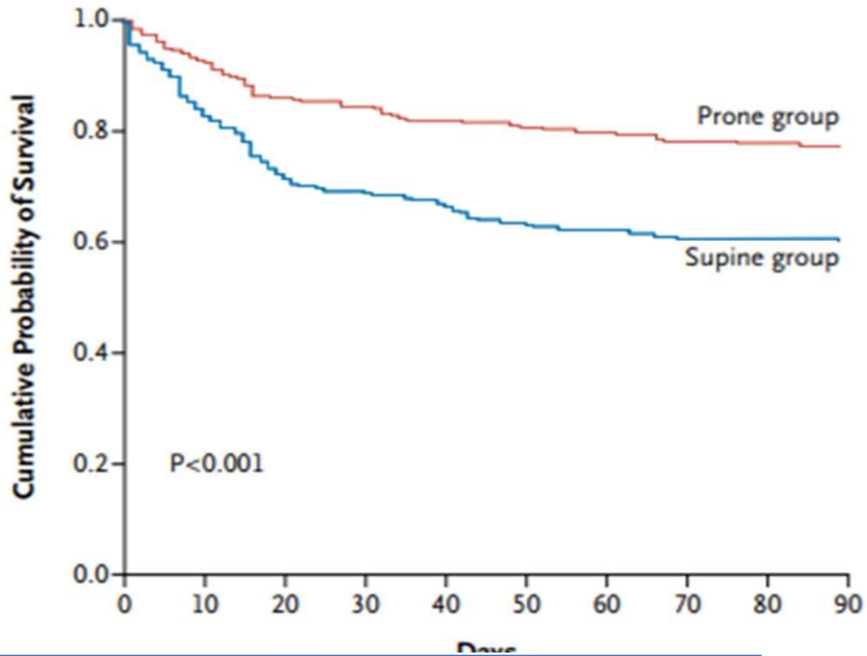


Prone Position Mechanisms

- Alteration of distribution of ventilation
- Redistribution of blood flow
- Improved matching of Ventilation & Perfusion (V/Q)
- Improved homogeneity of lung units
- Decreased alveolar Stress and Strain
- Recruitment maneuver
- Decrease VILI
- Relief of Left lower lung compression by the heart
- Relief dorsal lung compression by abdominal organs
- Enhanced secretion clearance
- Improved RV output and Pulmonary pressures







Improved mortality in ARDS

Munshi L, Del Sorbo L, Adhikari NKJ, Hodgson CL, Wunsch H, Meade MO, Uleryk E, Mancebo J, Pesenti A, Ranieri VM, Fan E. Prone Position for Acute Respiratory Distress Syndrome. A Systematic Review and Meta-Analysis. Ann Am Thorac Soc. 2017 Oct;14(Supplement_4):S280-S288.

Hu, S.L., He, H.L., Pan, C. *et al.* The effect of prone positioning on mortality in patients with acute respiratory distress syndrome: a meta-analysis of randomized controlled trials. *Crit Care* 18, R109 (2014)

Prone position in ARDS 2ry to COVID-19

- Improves oxygenation
- Possible improved mortality
- Improves oxygenation and might prevent invasive mechanical ventilation in non intubated patients
- 75-80% of patients with COVID-19

Role of Perfusion

Short communication

Prone position and APRV for severe hypoxemia in COVID-19 patients: The role of perfusion

Ryota Sato MD[1)], Natsumi T. Hamahata[1)], Ehab G. Daoud MD[1)2)3)]

DOI: 10.5281/zenodo.3984886
Cite: Sato R, Hamahata TN, Daoud EG. Prone position and APRV for severe hypoxemia in COVID-19 patients: The role of perfusion. Journal Mech Vent 2020; 1(1):19-21.

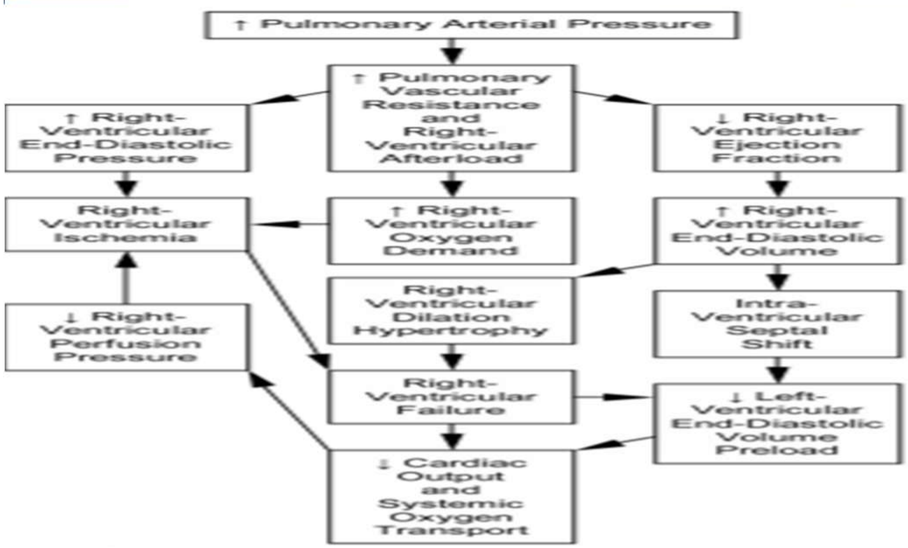
Abstract

There have been confusion and contradiction on how to best manage patients with acute respiratory failure secondary to Corona virus disease-2019 (COVID-19). Recent report suggested two different phenotypes of patho-physiology (type L and type H). Type L is characterized by low elastance and low ventilation-perfusion mismatch ratio (V/Q), while type H is more consistent with the classic acute respiratory distress syndrome (ARDS) characterized by high elastance, and increased right to left shunt. The role of perfusion deficits has been clearer with the discovery of micro and macro vascular thrombi in the lung vascular endothelium. Prone position has gained interest in research and guidelines as a maneuver capable of improving ventilation and perfusion. Airway pressure release ventilation (APRV) can theoretically improve hypoxemia due to ventilation/perfusion mismatch in patients with COVID-19 compared to other conventional strategies. From this perspective, we may have to consider perfusion as the major problem in the disease process more than just ventilation.
More studies are required to explore the role of perfusion and the different ventilatory strategies to best manage those patients.

Key Words: airway pressure release ventilation; APRV; prone position; COVID-19; SARS-CoV-2.

Sato R, Hamahata TN, Daoud EG. Prone position and APRV for severe hypoxemia in COVID-19 patients: The role of perfusion. J Mech Vent 2020; 1(1):19-21.

Inhaled Pulmonary Vasodilators



ig. 4. Pulmonary hypertension secondary to acute respiratory
istress syndrome can result in a vicious cycle of right-ventricular
ailure. Acutely elevated pulmonary arterial pressure increases pul-
nonary vascular resistance and right-ventricular afterload (the re-
istance the right ventricle pumps against), and results in a pro-
ressive inability of the right ventricle to sustain its flow output
decreased right-ventricular stroke volume and ejection fraction).
This eventually leads to elevated right-ventricular end-diastolic vol-
ume, right-ventricular dilation, ischemia, and failure. Right-ventric-
ılar hypertrophy and failure decreases left-ventricular preload (the
end-diastolic volume prior to left-ventricle contraction), displaces
he interventricular septum, decreases cardiac output, and reduces
ystemic oxygen transport. (Adapted from Reference 1.)

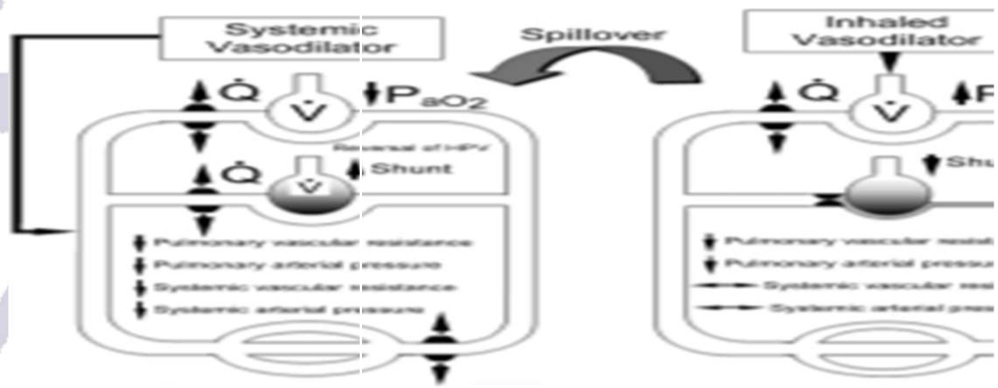
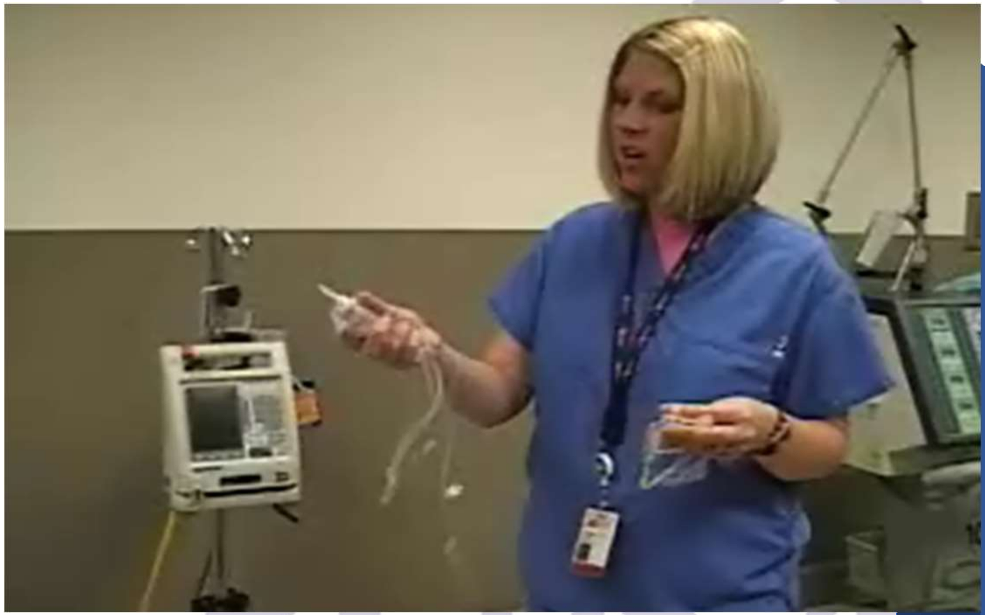


Fig. 1. Effects of systemic vasodilation (from intravenous,
taneous, or oral administration) versus selective pulmonar
dilation (from inhalation). Systemic vasodilation affects all v
beds, thereby decreasing mean arterial blood pressure an
ening oxygenation by increasing blood flow to poorly ve
alveoli, secondary to reversal of hypoxic pulmonary vasoc
tion. Inhaled vasodilators selectively dilate pulmonary vas
adjacent to alveoli that are well ventilated, thus reducing
nary arterial pressure while improving ventilation-perfusion
ing and oxygenation. However, spillover of long-acting
drug into poorly ventilated alveoli and into the systemic cir
can worsen shunt fraction and systemic blood pressure. Q
fusion. V̇ = ventilation. HPV = hypoxic pulmonary vasoc
tion. (Adapted from Reference 1.)



Inhaled Vasodilators

Inhaled Pulmonary Vasodilators: do they work ?

Makes sense but controversial

No: Critical Care Explorations: October 2020 - Volume 2 - Issue 10 - p e0259

No: BJA October 14, 2020

Yes (50%): *Journal of Intensive Care Medicine 2020 November 25*

ECMO

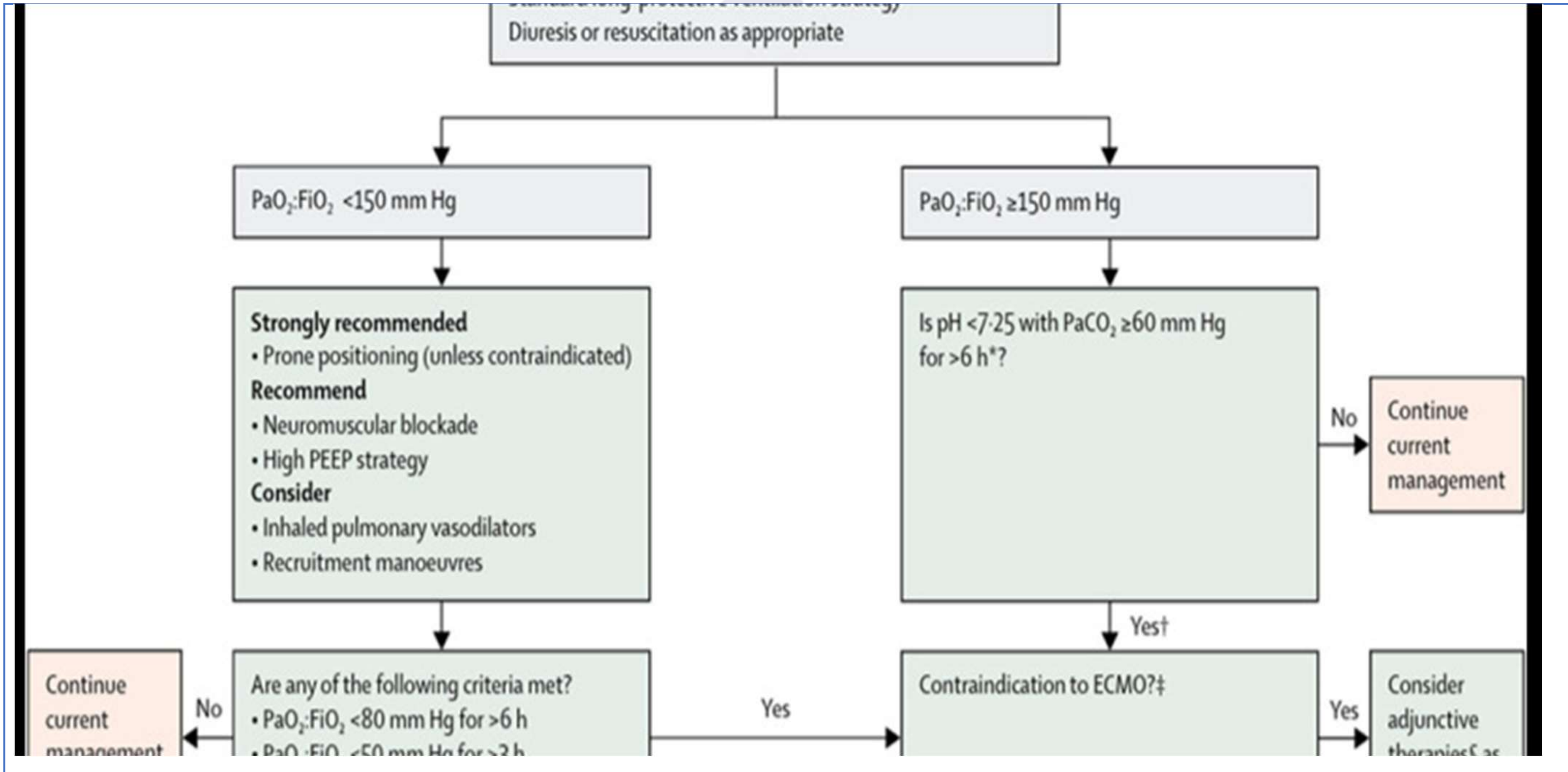
- WHEN to start? when everything fails: PEEP, Recruitment, Prone, NMB, Pulmonary Vasodilators
- WHO gets it: unclear
- Mortality: unclear but NO
- For how long? Unclear
- Cost: 73,000 USD, for 14 days
- Side effects
- Ethics

Table 1 Proposed indications and contraindications to ECMO for ARDS

Indications	Relative contraindications	Absolute contraindications
EOLIA entry criteria[a] $PaO_2/FiO_2 < 50$ mmHg for > 3 h $PaO_2/FiO_2 < 80$ mmHg for > 6 h pH < 7.25 with a $PaCO_2 \geq 60$ mmHg for > 6 h[b]	Invasive mechanical ventilation for more than 7–10 days Contraindication to anticoagulation Severe coagulopathy Advanceed age Salvage ECMO (referred to as "rescue" in EOLIA), i.e., employing ECMO when severe right heart failure, or other severe decompensation occurs	Moribund state with established multiple organ failure Prolonged cardiac arrest Severe anoxic brain injury Massive intracranial hemorrhage Severe chronic respiratory failure with no possibility of lung transplantation Metastatic malignancy or hematological disease with poor short-term prognosis Other advanced comorbidities with poor short-term prognosis

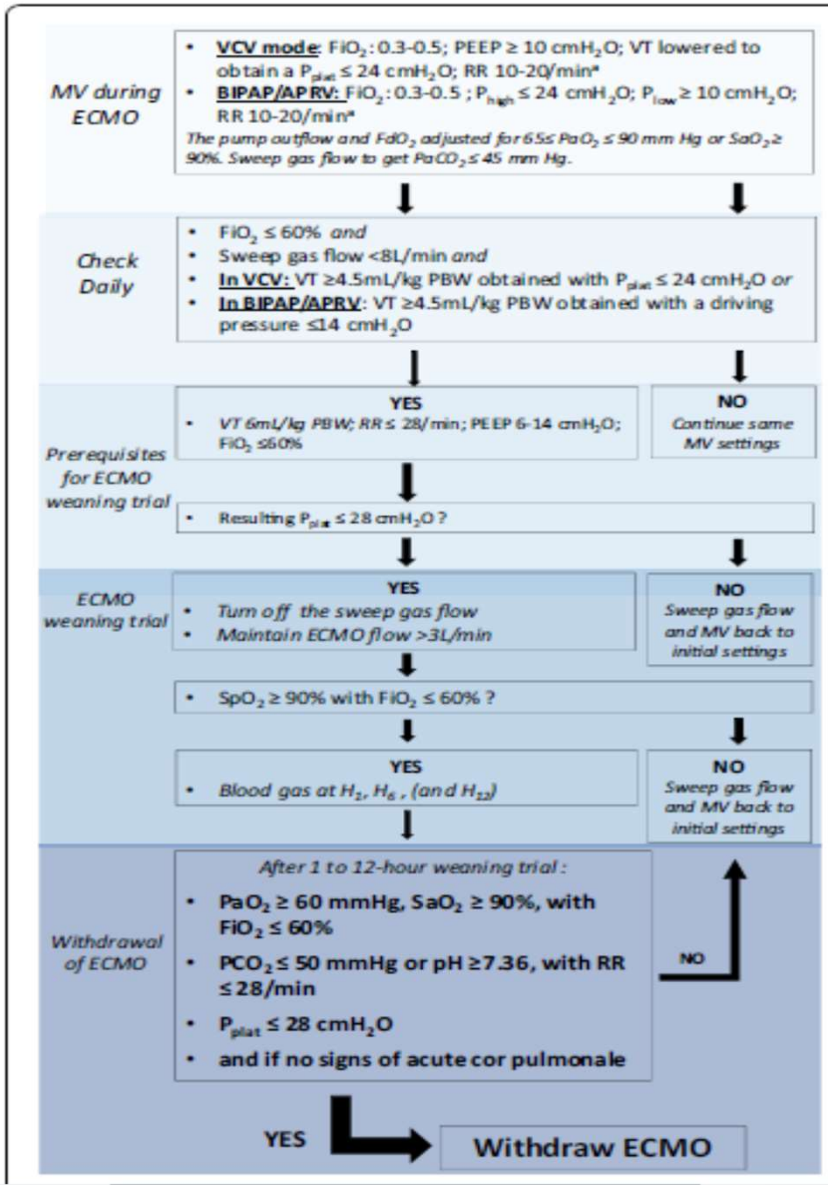
ECMO Indications & Contraindications

EOLIA. Combes A, Hajage D, Capellier G et al (2018) Extracorporeal membrane oxygenation for severe acute respiratory distress syndrome. N Engl J Med 378:1965–1975



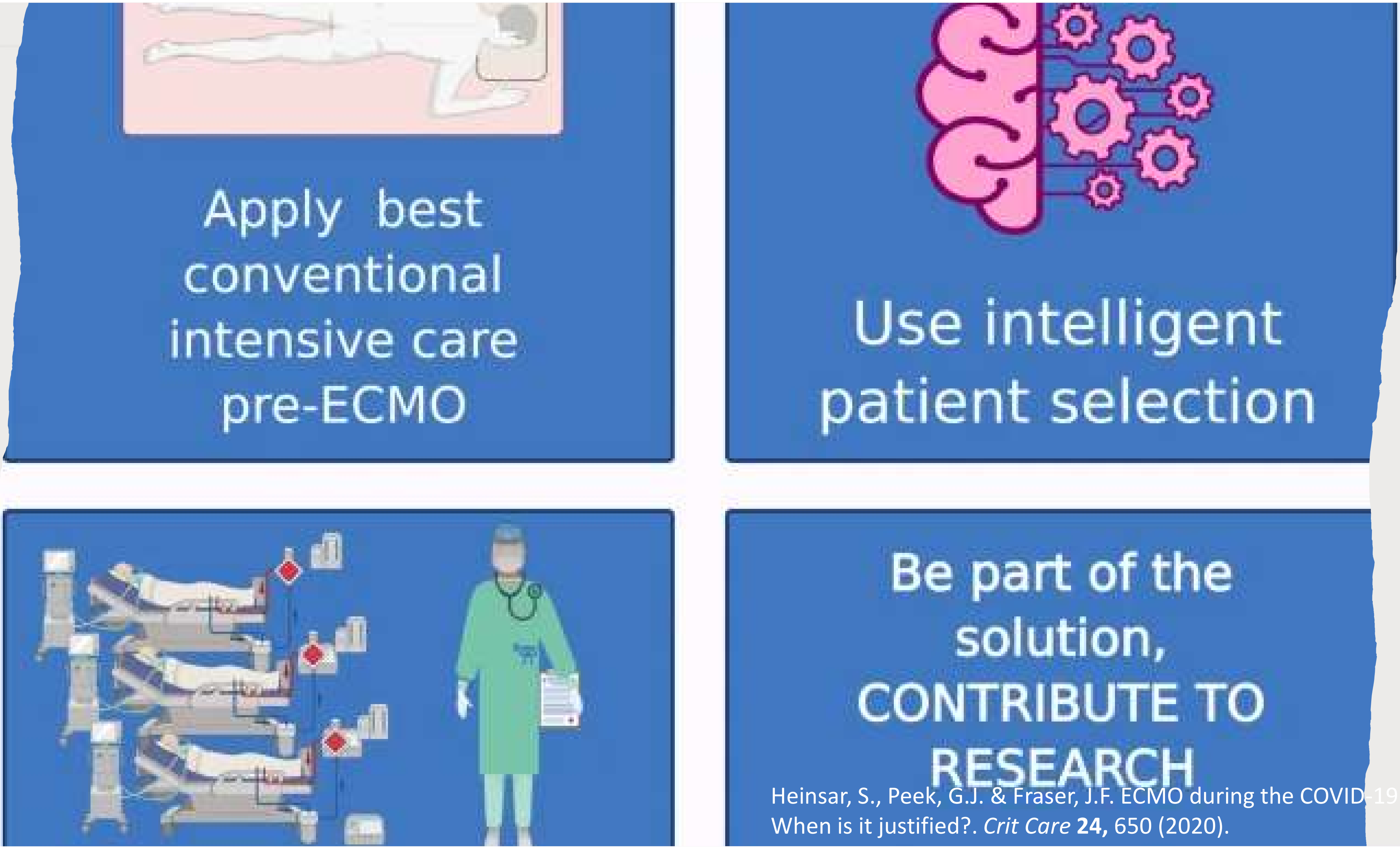
Initial ELSO Guidance Document: ECMO for COVID-19 Patients with Severe Cardiopulmonary Failure. ASAIO J. 2020 May;66(5):472-474.

Weaning ECMO



Mortality in COVID-19

- >90%: early case studies and small cohorts
- 50%: Li X, Guo Z, Li B, et al. Extracorporeal Membrane Oxygenation for Coronavirus Disease 2019 in Shanghai, China. ASAIO J. 2020 May;66(5):475-481.
- 42%: Zeng Y, Cai Z, Xianyu Y, et al. Prognosis when using extracorporeal membrane oxygenation (ECMO) for critically ill COVID-19 patients in China: a retrospective case series. *Crit Care*. 2020;24(1):148. Published 2020 Apr 15.
- 31%: Schmidt M, Hajage D, Lebreton G, D et al. Extracorporeal membrane oxygenation for severe acute respiratory distress syndrome associated with COVID-19: a retrospective cohort study. Lancet Respir Med.
- 37%: Barbaro RP, MacLaren G, Boonstra PS et al. (2020) Extracorporeal membrane oxygenation support in COVID-19: an international cohort study of the Extracorporeal Life Support Organization registry. Lancet S0140–6736(20):32008



Heinsar, S., Peek, G.J. & Fraser, J.F. ECMO during the COVID-19 panc
When is it justified?. *Crit Care* **24,** 650 (2020).

Thank You

Society of Mechanical Ventilation