(Excessive) Spontaneous Efforts May be Dangerous

Ehab G Daoud MD, FACP, FCCP
Associate professor of Medicine
JABSOM, HI, USA

1

To breath or not to breath (spontaneously) That is the question

2

Equation of motion

Equation of Motion

ventilation pressure (to deliver tidal volume) = **elastic pressure** (to inflate lungs and chest wall) + **resistive pressure** (to make air flow through the airways)

$$P_{mus} + P_{vent} = P_{elastic} + P_{resistive}$$

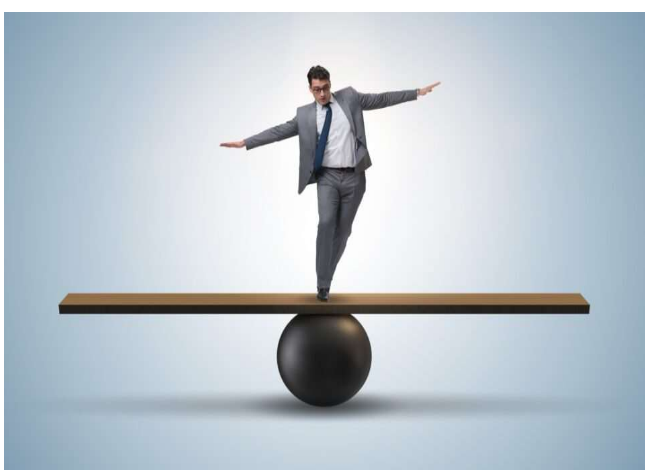
$$P_{mus} + P_{vent} = E \times V + R \times \dot{V}$$

3

Benefits

Spontaneous breathing

- Reduced dependent lung collapse
- Reduce diaphragmatic disuse atrophy
- Reduce the use of sedatives and NM blockers (Delerium and muscle weakness)
- Hemodynamic advantages
- Improved gas exchange ?
- Decreased VILI ?
- Early mobility



Passive breathing

- Reduce Asynchronies
- Reduce PSILI
- Decreased VILI ?
- Lower oxygen consumption
- Easier to adjust the ventilator, monitoring of static conditions
- Improved oxygenation ?

4

AME Publishing Company — ATM Annals of Translational Medicine

Spontaneous breathing: a double-edged sword to handle with care

Key physiologic findings on spontaneous breathing	First author, year
Pro—supporting spontaneous breathing	
Active diaphragmatic contraction, reduced diaphragmatic atrophy	Pellegrini 2017, Vassilakopoulos 2004, Yonis 2015
Improved ventilation/perfusion matching	Putensen 1999
Improvement of dorsal ventilation	Wrigge 2003, Langer 2016, Mauri 2015
Improvement of gas-exchange	Putensen 2001
Reduction of sedative drugs and their side effects	Hansen-Flaschen 1991
Hemodynamic improvement (increase in venous return)	Putensen 2001
Potentially reduction of pneumonia (better secretions clearance) in extubated patients	Mauri 2017
Cons—against spontaneous breathing	
Diaphragmatic atrophy	Dot 2017, Levine 2008
High risk of patient-ventilator asynchrony	Colombo 2011, Thille 2006, Spahija 2010, Tassaux 2005
Risk of uncontrolled, high, potentially injurious tidal volume	Yoshida 2017, Marini 2011
Risk of regional increase of transpulmonary pressure in the presence of safe average values that generates "occult pendelluft"	Yoshida 2013, Yoshida 2012
Higher dose of sedative and muscle relaxant to avoid spontaneous effort; collateral effects of high sedation drug dosage (stress disorders, delirium etc.)	Hansen-Flaschen 1991
Hemodynamic instability (increase filling of the right heart and dysfunction of left heart)	Eckstein 1958
Interstitial and alveolar edema	Perlman 2011, Kallet 1999

Mauri T, et al. Spontaneous breathing: a double-edged sword to handle with care. Ann Transl Med. 2017 Jul;5(14):292.

5

Spontaneous breathing

Diaphragm Muscle Tone

Controlled mechanical ventilation (i.e., no spontaneous breathing) induces diaphragmatic muscle dysfunction and atrophy. This is a serious problem, especially for subsequent weaning; it is detectable in patients within as little as 18 hours, and can be ameliorated by preservation of spontaneous effort

Cardiovascular Effects

Increase preload might improve Cardiac output and Hemodynamics

Pulmonary Function

Spontaneous breathing increases aeration in dependent lung, as well as increasing lung perfusion. Thus intrapulmonary shunt is reduced and V/Q matching and oxygenation increased

Yoshida T, et al. Fifty Years of Research in ARDS. Spontaneous Breathing during Mechanical Ventilation. Risks, Mechanisms, and Management. Am J Respir Crit Care Med. 2017 Apr 15;195(8):985-992.

6

Spontaneous breathing

APRV

Spontaneous breathing, accounting for 10–30% of V˙ E during APRV, leads to improved ventilation-perfusion matching, decreased intrapulmonary shunt, and decreased dead space, through improvement of transpulmonary pressure in the juxtadiaphragmatic lung regions, with alveolar recruitment, and without raising peak Furthermore, regular spontaneous breathing maintains diaphragmatic muscle condition.

Putensen and colleagues18 have documented the benefits of spontaneous breathing during APRV, which has increased the respiratory-system compliance, PaO_2, cardiac index, and oxygen delivery, compared to patients who were paralyzed during mechanical ventilation.

Outcome

Reduced length of intensive care unit stay

In severe ARDS, avoidance of spontaneous effort reduces injury and improves outcome. By contrast, in milder disease, the presence of spontaneous effort has little impact on outcome, but may prevent worsening of lung injury, improve pulmonary function and in some patients, reduce duration of mechanical ventilation

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

7

Patient-Self Inflicted Lung Injury during mechanical ventilation (P-SILI)

(A) Swings in transpulmonary pressure (lung stress) causing the inflation of big volumes in an aerated compartment markedly reduced by the disease-induced aeration loss

(B) Abnormal increases in transvascular pressure, favoring negative-pressure pulmonary edema

(C) Intra-tidal shift of gas between different lung zones, generated by different transmission of muscular force (pendelluft)

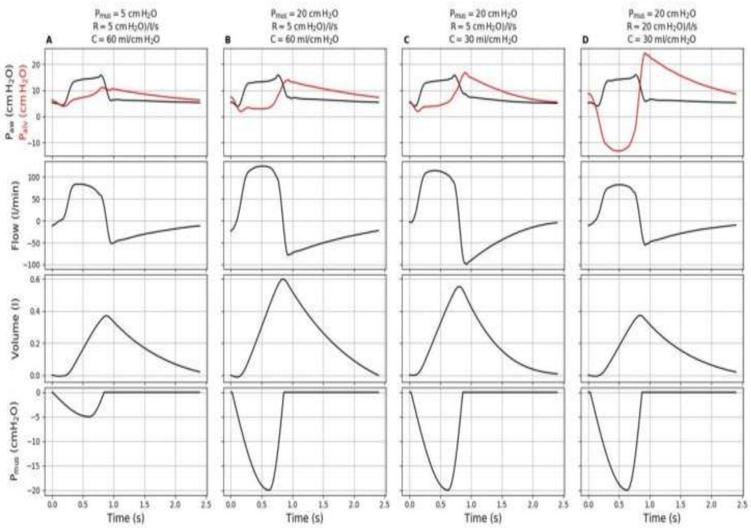
(D) Diaphragm injury.

(E) Patient-Ventilator Asynchrony

Patient self-inflicted lung injury: implications for acute hypoxemic respiratory failure and ARDS patients on non-invasive support. Minerva Anestesiologica 2019 September;85(9):1014-23

8

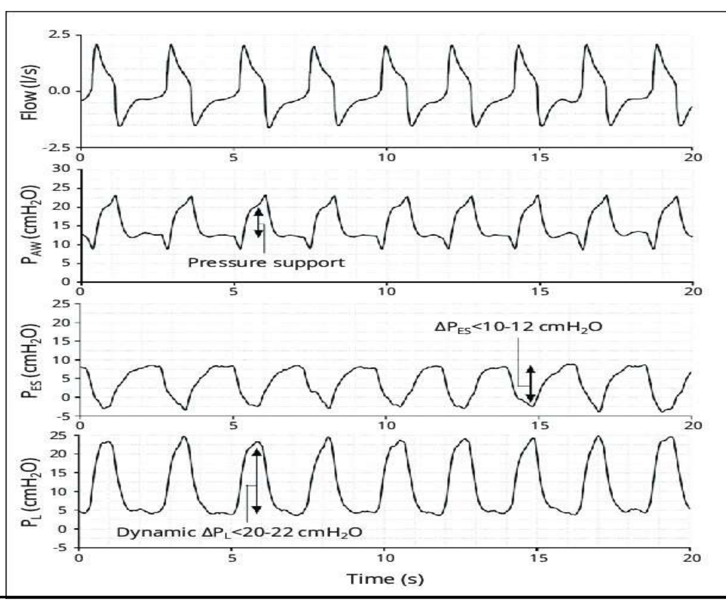
Patient-Self Induced Lung Injury during mechanical ventilation



Alveolar Pressures

9

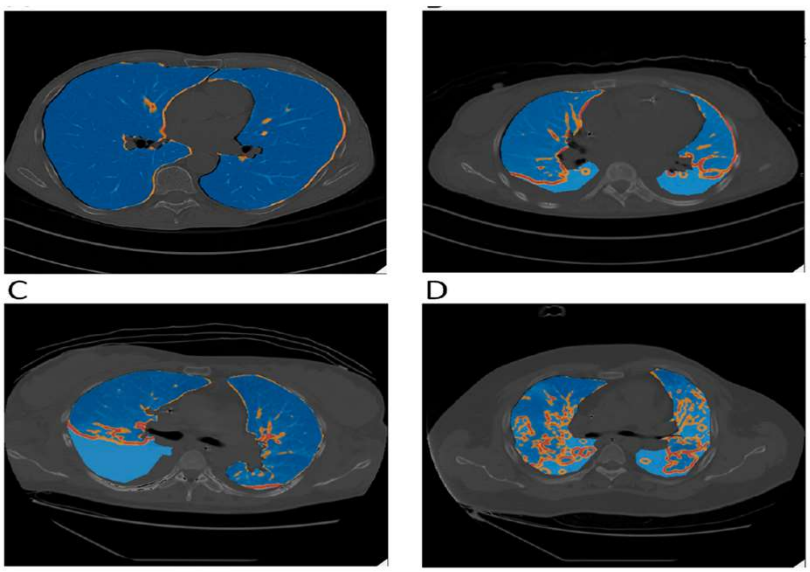
Patient-Self Induced Lung Injury during mechanical ventilation



Dynamic Inspiratory Transpulmonary pressure

10

Patient-Self Induced Lung Injury



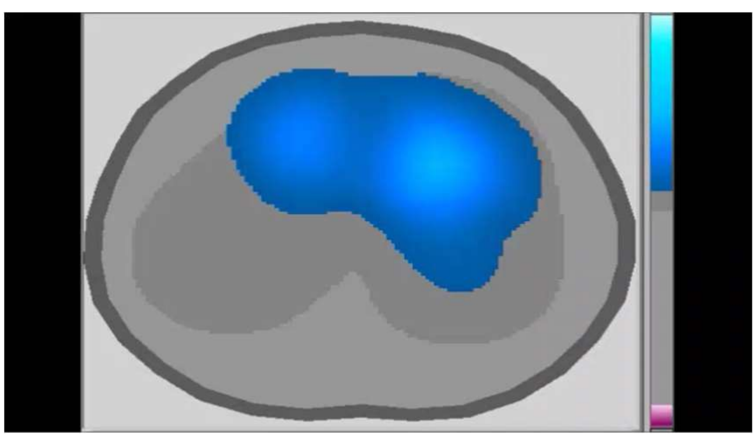
Stress raisers
Light blue < 1.6
Orange 1.61-3.00
Red >3

Cressoni et al. Am J Respir Crit Care Med 2014, 189:149-58

11

Patient-Self Induced Lung Injury

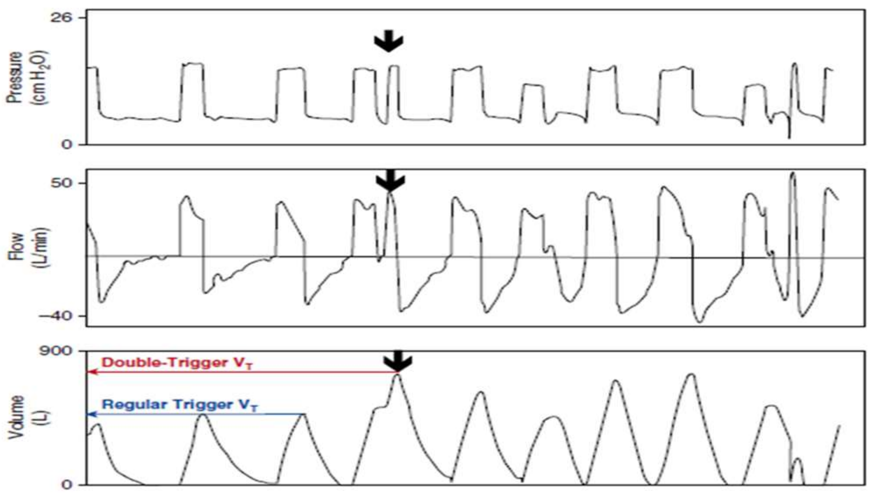
Large vertical pressure gradient of Ppl "swings" from nondependent (less negative) to dependent (more negative) regions



Su PL, et al. Spontaneous Breathing and Pendelluft in Patients with Acute Lung Injury: A Narrative Review. J Clin Med. 2022 Dec 15;11(24):7449.

12

Patient-Self Induced Lung Injury
Patient-Ventilator Asynchronies

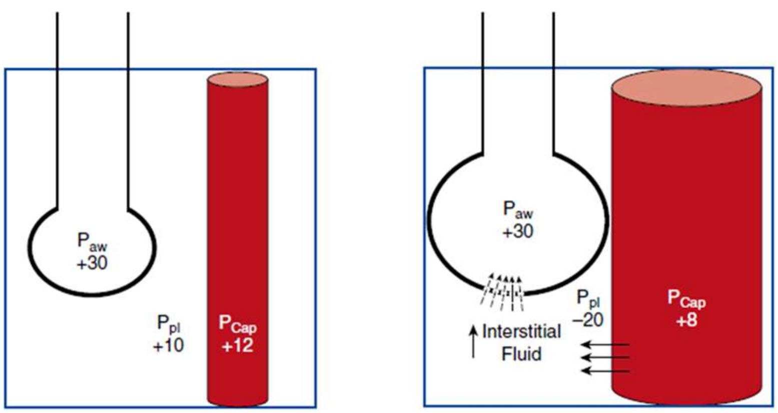


Increased
Tidal volume
(Strain)

Yoshida et al. Am J Respir Crit Care Med. 2017, 195(8):985–992

13

Patient-Self Induced Lung Injury
Trans-vascular pressure



Passive   Active

Increased
Lung perfusion
and edema

14

Patient-Self Induced Lung Injury
Vicious Cycle

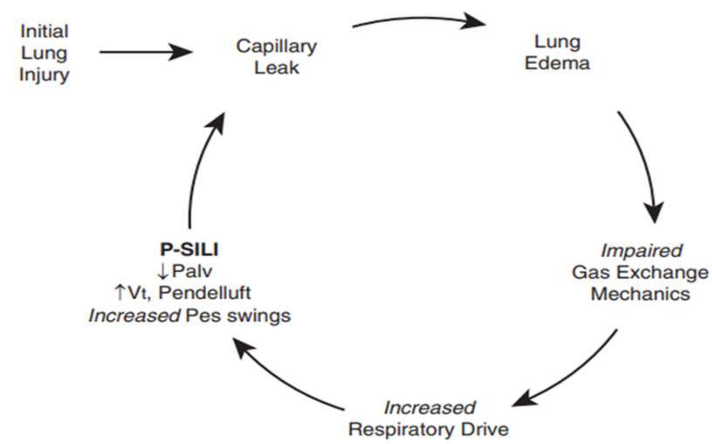


Figure 2. Illustration of the vicious cycle of injury present in patients with acute respiratory failure. Palv = alveolar pressure; Pes = esophageal pressure swings; P-SILI = patient self-inflicted lung injury.

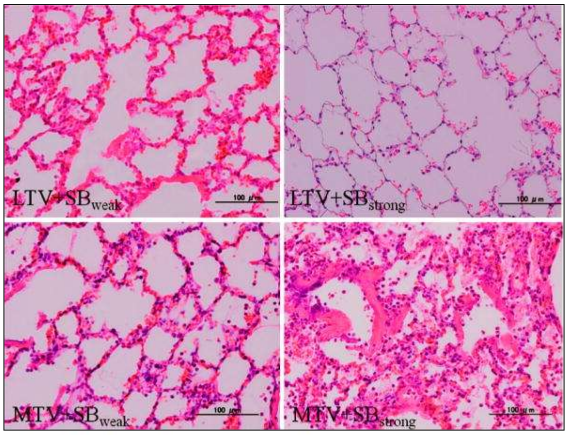
Brochard et al. *Am J Respir Crit Care Med* Vol 195, Iss 4, pp 438–442

15

16

Weak Spontaneous breaths

Strong Spontaneous breaths



Low Tidal Volume

Medium Tidal Volume

Conclusions: Even when plateau pressure is limited to <30 cm H2O, combined with increased respiratory rate and tidal volume, high transpulmonary pressure generated by strong spontaneous breathing effort can worsen lung injury. When spontaneous breathing is preserved during mechanical ventilation, transpulmonary pressure and tidal volume should be strictly controlled to prevent further lung injury.

Yoshida, T et al Spontaneous breathing during lung-protective ventilation in an experimental acute lung injury model: High transpulmonary pressure associated with strong spontaneous breathing effort may worsen lung injury. Critical Care Medicine. 40(5):1578-1585, May 2012.

17

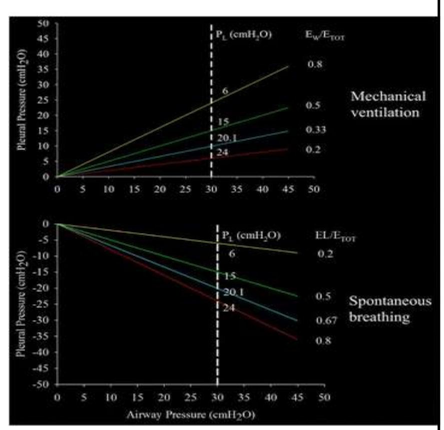
Intensive Care Med (2017) 43:256–258
DOI 10.1007/s00134-016-4483-4

EDITORIAL

CrossMark

Ventilation-induced lung injury exists in spontaneously breathing patients with acute respiratory failure: We are not sure

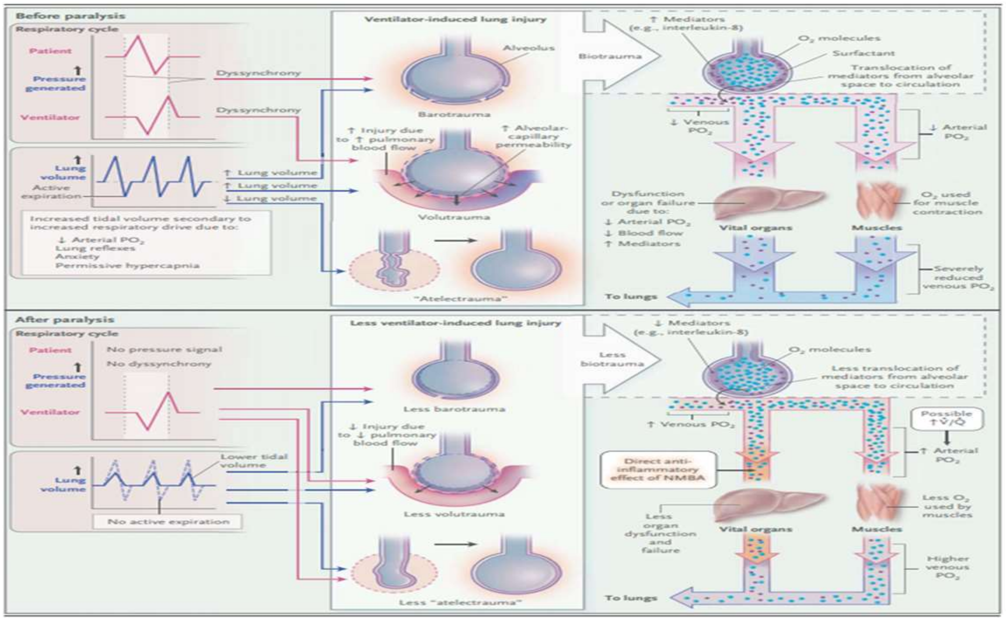
Luciano Gattinoni*



Gattinoni L. Ventilation-induced lung injury exists in spontaneously breathing patients with acute respiratory failure: We are not sure. Intensive Care Med. 2017 Feb;43(2):256-258.

18

Neuromuscular Blockers



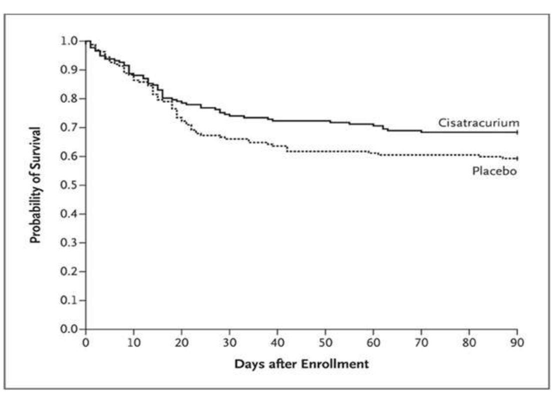
Slutsky AS. Neuromuscular blocking agents in ARDS. N Engl J Med. 2010 Sep 16;363(12):1176-80.

19

Neuromuscular Blockers in Early Acute Respiratory Distress Syndrome ACURASYS Study

CONCLUSIONS

In patients with severe ARDS, early administration of a neuromuscular blocking agent improved the adjusted 90-day survival and increased the time off the ventilator without increasing muscle weakness. (Funded by Assistance Publique–Hôpitaux de



ventilator free days

	Cisatracurium (n=177)	Placebo (n=162)	P
From day 1 to day 28	10.6±9.7	8.5±9.4	0.04
From day 1 to day 90	53.1±35.8	44.6±37.5	0.03

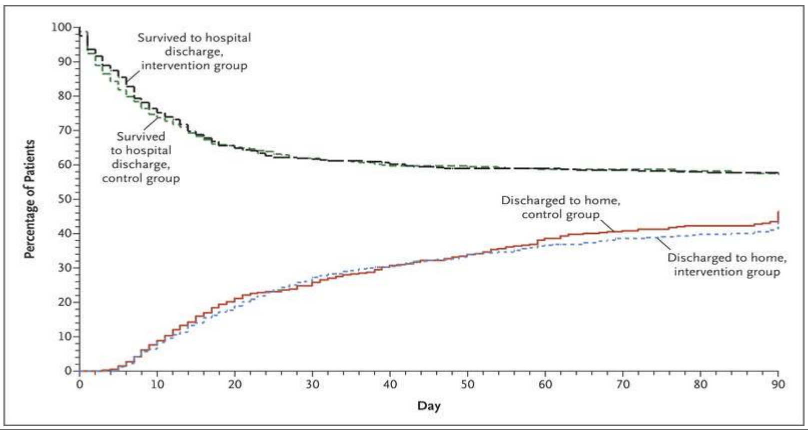
Papazian L, et al. N Engl J Med 2010; 363:1107-1116

20

Neuromuscular Blockers in Early Acute Respiratory Distress Syndrome Rose Trial

CONCLUSIONS

Among patients with moderate-to-severe ARDS who were treated with a strategy involving a high PEEP, there was no significant difference in mortality at 90 days between patients who received an early and continuous cisatracurium infusion and those who were treated with a usual-care approach with lighter sedation targets.



Papazian L, et al. N Engl J Med 2010; 363:1107-1116

21

Neuromuscular Blockers

Recommendations for acute respiratory distress syndrome in major guidelines

	JRS/JSICM/JSRCM-GL2021	SSCG 2021	SRLF-GL 2019	FICM/ICS- GL 2018	ATS/ESICM/SCCM-GL2017	SSAI-ARDS-GL2016	KSCCM/KATRD-ARDS-GL2016
Lower SpO_2 (PaO_2) target	D for excess control	-				–	
HFNC	B						
NPPV	B					–	
Lung protective ventilation							
Low tidal volume	A	A	A	A	A	A	A
Low plateau pressure	B	A Severe	A		A	A	–
High level PEEP	B	A: Moderate–severe	A	B: P/F ≤ 200	C: Moderate–severe	B	B
Recruitment maneuver	D	B: Moderate–severe traditional	E: routine use		C	B	B
Prone position	B: Long hours	A: Moderate–severe, ≥ 12 h	A: P/F < 150, ≥ 16 h	A: P/F < 150, ≥ 12 h	A: ≥ 12 h	B	A
High-frequency oscillatory ventilation (HFOV)	D		E	E	E	E	E
Limited muscle relaxants use	B: Moderate–severe	B: Moderate–severe, intermittent use	A: P/F < 150, ≤ 48 h	B: P/F ≤ 150, ≤ 48 h		B	B
Weening protocolization	B						
Early tracheotomy	B						D

Fujishima, S. Guideline-based management of acute respiratory failure and acute respiratory distress syndrome. *j intensive care* **11**, 10 (2023).

22

Neuromuscular Blockers in Acute Respiratory Distress Syndrome

ESICM guidelines on acute respiratory distress syndrome: definition, phenotyping and respiratory support strategies

We **recommend against** the *routine* use of continuous infusions of NMBA to reduce mortality in patients with moderate-to-severe ARDS not due to COVID-19.

Strong recommendation, moderate level of evidence.

We are **unable to make a recommendation** for or against the *routine* use of continuous infusions of NMBA to reduce mortality in patients with moderate-to-severe ARDS due to COVID-19.

No recommendation; no evidence.

Grasselli G, *et al.* ESICM guidelines on acute respiratory distress syndrome: definition, phenotyping and respiratory support strategies. *Intensive Care Med* **49**, 727–759 (2023)

23

Neuromuscular Blockers in Acute Respiratory failure & Septic Shock

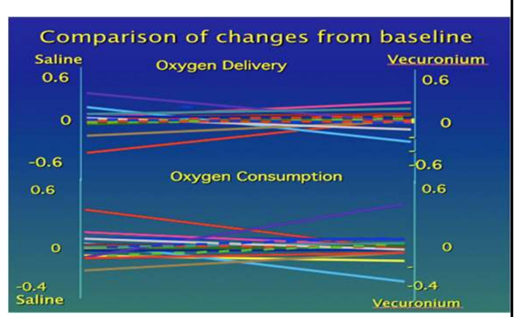
Oxygen delivery, oxygen consumption, and gastric intramucosal pH are not improved by a computer-controlled, closed-loop, vecuronium infusion in severe sepsis and septic shock

Conclusions

In these patients, vecuronium infusion achieved the targeted level of paralysis and improved respiratory compliance but did not alter intramucosal pH, VO_2, DO_2, or oxygen extraction ratios. With deep sedation, neuromuscular blockade in severe sepsis/septic shock does not significantly influence oxygen flux and should be abandoned as a routine method of improving tissue oxygenation in these patients. (Crit Care Med 1997; 25:72-77)

Differences: Saline vs Vecuronium (One tailed t- test)

Mean Airway Press	0.312	ns
Static Compliance	0.036	p≤0.05
O2 Content	0.098	ns
DO2	0.334	ns
VO2	0.350	ns
pHi	0.365	ns

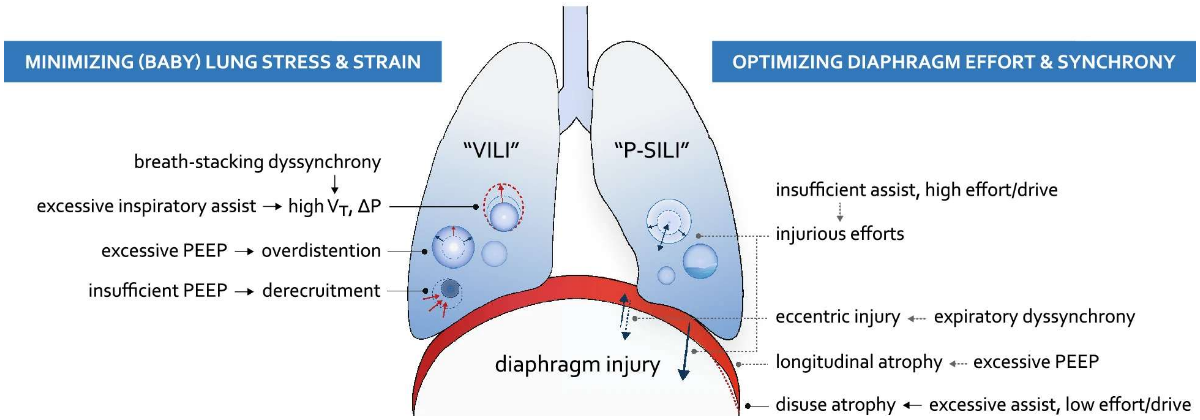


Freebairn RC, et al. Oxygen delivery, oxygen consumption, and gastric intramucosal pH are not improved by a computer-controlled, closed-loop, vecuronium infusion in severe sepsis and septic shock. Crit Care Med. 1997 Jan;25(1):72-7.

24

NARRATIVE REVIEW

Clinical strategies for implementing lung and diaphragm-protective ventilation: avoiding insufficient and excessive effort



Goligher, E., et al. Clinical strategies for implementing lung and diaphragm-protective ventilation: avoiding insufficient and excessive effort. Intensive Care Med 46, 2314–2326 (2020).

25

So what is the answer Spontaneously Breath or Not

Don't know But:

Balance
Personalized Ventilation

26