Revista Mexicana de Anestesiología

CONFERENCIAS MAGISTRALES
Vol. 34. Supl. 1 Abril-Junio 2011
pp S293-S301

Perioperative ventilator management: Why it makes a difference

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OBJECTIVES

- Review significance of respiratory failure during the perioperative period
- Discuss mechanical ventilation strategies associated with improved outcomes in ICU patients with acute lung injury
- Review emerging data suggesting that mechanically ventilation strategies impact outcomes in patients with healthy lungs

PERIOPERATIVE PULMONARY COMPLICATIONS, WHY BE CONCERNED?

- Frequency appears to exceed cardiac complications
- High associated morbidity and mortality

Multifactorial risk index for predicting postoperative respiratory failure in men after major noncardiac surgery

Ahsan M. Arozullah, MD, MPH,* Jennifer Daley, MD,† William G. Henderson, PhD,‡ and Shukri F. Khuri, MD,§ for the National Veterans Administration Surgical Quality Improvement Program

- Prospective cohort study in 81,719 patients
- All male patients undergoing non-cardiac surgery
- Respiratory failure defined as mechanical ventilation for > 48 hours or re-intubation following post-operative extubation

Ann Surg 2000;232:242-53

POSTOPERATIVE RESPIRATORY FAILURE

- Common finding
  - 3.4% of patients (MI 0.07%)
    - Surgical procedure, emergent surgery, age, dependent functional status, COPD, ↑ BUN, ↓ albumin
- Associated with adverse outcomes
  - Mortality 27% (*versus* 1%)

Arozullah AM, et al. Ann Surg 2000; 232:242-53

Prediction of postoperative pulmonary complications in a population-based surgical cohort

Jaume Canet, MD, PhD,* Lluís Gallart, MD, PhD,† Carmen Gomar, MD, PhD,‡ Guillem Paluzie, MD,§ Jordi Vallès, MD,† Jordi Castillo, MD, PhD,† Sergi Sabaté, MD, PhD, II Valentín Mazo, MD,# Zahara Briones, M. Math,** Joaquín Sanchis, MD, PhD,†† on behalf of the ARISCAST Group‡‡

- 2,464 patients in 59 hospitals
- Failure = Respiratory infection, failure, bronchospasm, atelectasis, effusion, pneumothorax or aspiration pneumonitis
- 55% general; 45% neuraxial/regional

Anesthesiology 2010;113:1338-50

PREDICTING POSTOPERATIVE RESPIRATORY FAILURE IN A LARGE SURGICAL COHORT

- 5% failure with higher associated 30 day mortality (19.5% vs. 0.5%)
- Risk factors included:
  - Preoperative hypoxemia
  - Respiratory infection in prior month

- Age
- Anemia
- Thoracic or upper abdominal surgery
- Surgery > 2 hours
- Emergency surgery

Canat J, et al. Anesthesiology 2010;113:1338-50

PATIENT AND PROCEDURAL FACTORS MAY BE ASSOCIATED WITH PERIOPERATIVE RESPIRATORY FAILURE. DOES INTRAOPERATIVE CARE CONTRIBUTE?

VENTILATOR-INDUCED LUNG INJURY (VILI)

- Inspired oxygen concentration
  - Alveolar over distention
  - Collapse and reopening of alveoli

INFLATION PRESSURE AND LUNG INJURY

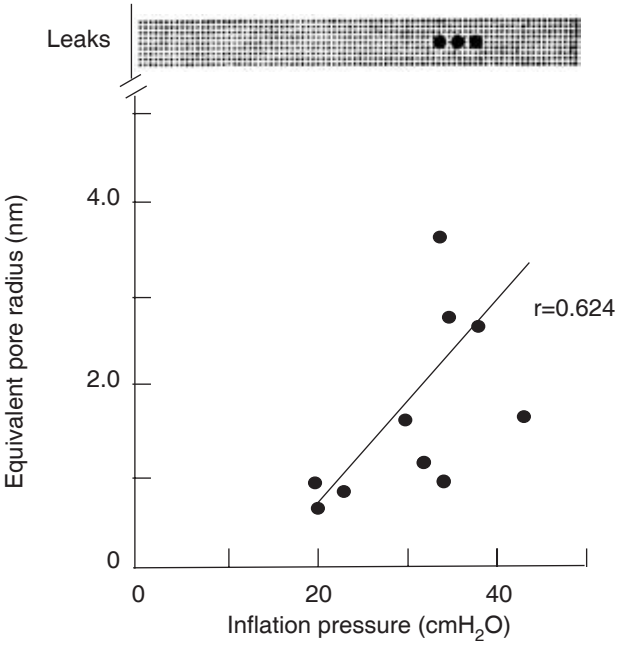
45 cm H_2O peak inspiratory pressure

Normal 5 Minutes 20 Minutes

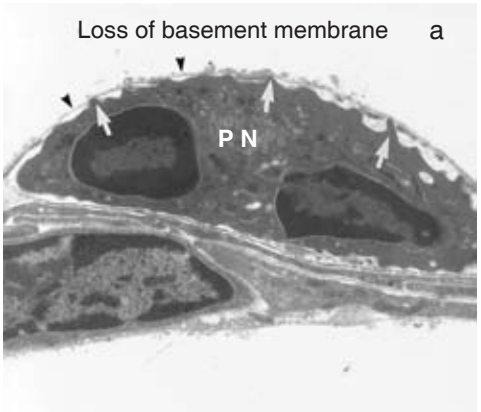
Dreyfuss, et al. AJRCCM 1985

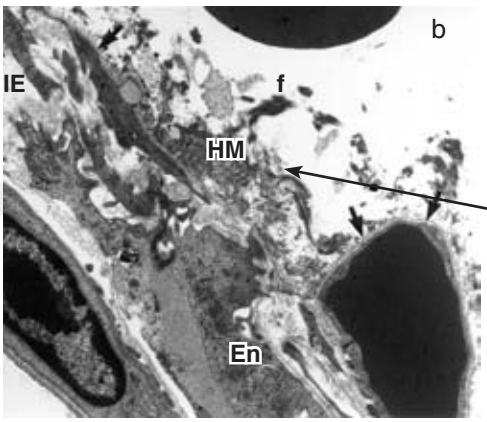
INFLATION PRESSURE *VS* EPITHELIAL PERMEABILITY

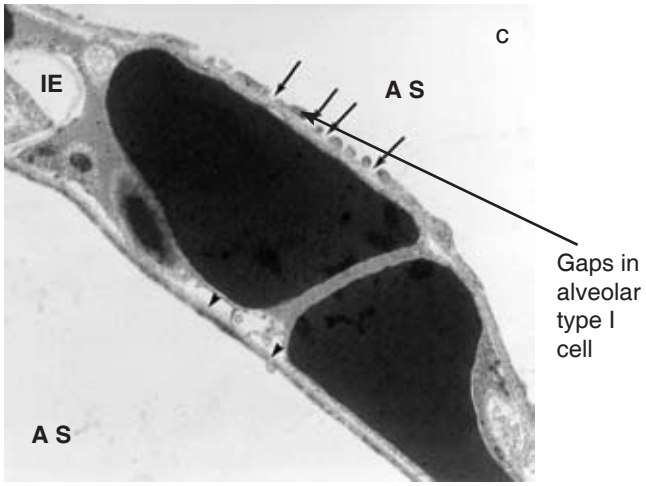
- Albumin freely diffusible at high pressures
- c/w large leaks *vs* hydrostatic edema



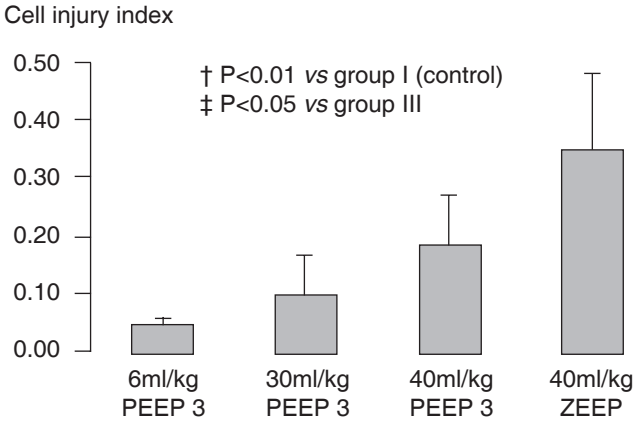
Egan J. Physiol. (Lond.) 1976;260:409-424







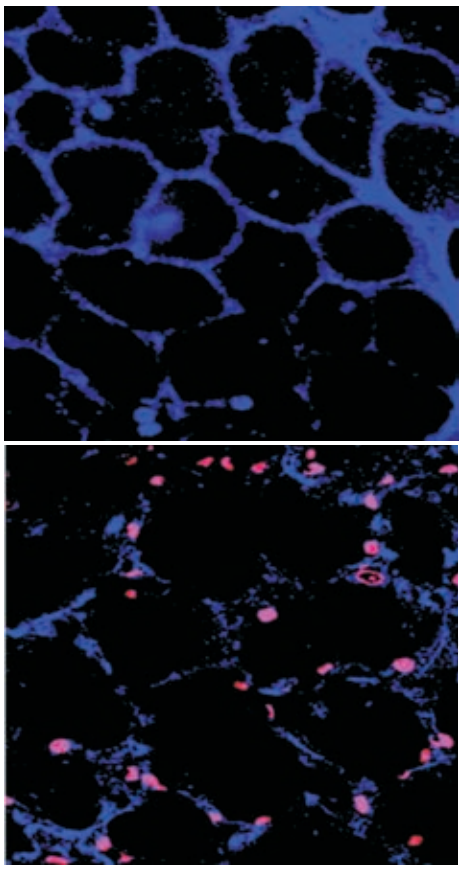
Dreyfuss Am J. Respir Crit Care Med 1998;157:294-323

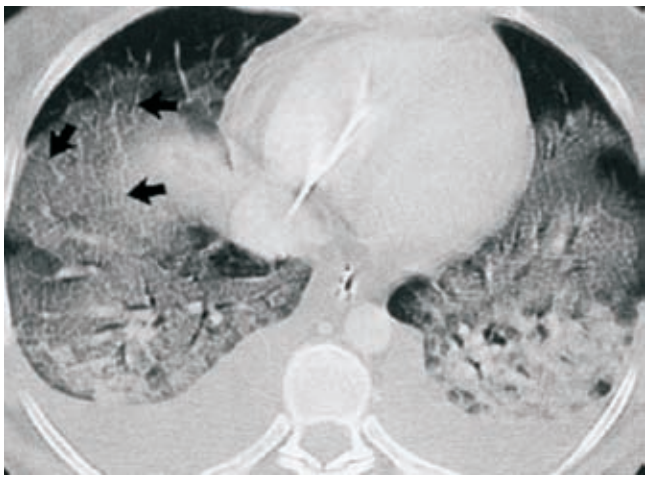


Gajic AJRCCM 2003;167:1057-1063

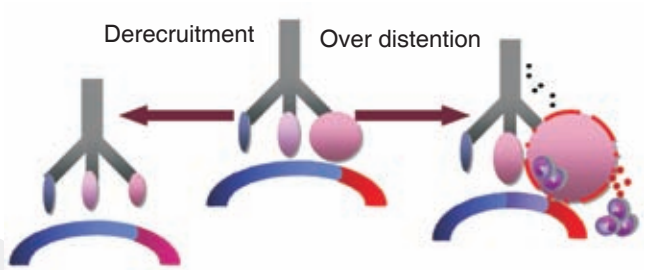
VENTILATOR-INDUCED CELL WOUNDING

- Red nuclei mark injured cells
- More cell injury with larger tidal volumes
- Less injury with PEEP at comparable tidal volumes





BALANCING VENTILATION PRIORITIES



Consequences:	Consequences:
Atelectasis	VQ mismatch
Hypoxemia	Barotrauma
Hypercapnia	Alveolar-capillary injury
Inflammation	Inflammation

- 18 Clinical centers comprised of 42 hospitals
- United States National Institutes of Health funded clinical network
- Goal: efficiently test promising agents, devices or management strategies to improve the care of patients with ARDS


The New England Journal of Medicine

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VOLUME 342 MAY 4, 2000 NUMBER 18

VENTILATION WITH LOWER TIDAL VOLUMES AS COMPARED WITH TRADITIONAL TIDAL VOLUMES FOR ACUTE LUNG INJURY AND THE ACUTE RESPIRATORY DISTRESS SYNDROME

THE ACUTE RESPIRATORY DISTRESS SYNDROME NETWORK*

ARDSNET TIDAL VOLUME STUDY

- Multicenter, randomized trial
- 12 *vs* 6 ml/kg ideal body weight
- 861 patients enrolled
- Primary outcomes:
  - Death before discharge home and breathing without assistance
  - Ventilator-free days

ARDSNET NEJM 2000;342:1301-8

PREDICTED BODY WEIGHT

Predicted body weight for men (IBW) = 50 +[2.3x (ht. in inches –60)]

Ht/in	64	65	66	67	68	69	70	71	72	73	74	75
Htcm	163	165	168	170	173	175	178	180	183	185	188	191
IBW	59.2	61.5	63.8	66.1	68.4	70.7	73	75.3	77.6	79.9	82.2	84.5
Vt	355	369	383	397	410	424	438	452	466	479	493	507

Predicted body weight for women (IBW) = 45.5+[2.3x(ht. in inches-60)]

Ht/in	61	62	63	64	65	66	67	68	69	70	71	72
Htcm	155	157	160	163	165	168	170	173	175	180	183	185
IBW	47.8	50	52.4	54.7	57	59.3	61.6	63.9	66.2	68.5	70.8	73.1
Vt	287	301	314	328	342	356	370	383	397	411	425	439

ARDSNET NEJM 2000;342:1301-8

ARDSNET VENTILATOR STRATEGY

- Assist control mode
- Set rate to maintain minute ventilation (not to exceed 35 breathes/min)
- Keep $P_{plateau} < 30$ cm H_2O
- Maintain SpO_2 88-95%

ARDSNET NEJM 2000;342:1301-8

ADDITIONAL MANAGEMENT PROTOCOLS

- Accept mild acidosis
  - pH < 7.30, increase respiratory rate to maximum of 35
  - If acidosis persisted despite respiratory rate = 35, consider $NaHCO_3$
  - For persistent/resistant acidosis, increase tidal volume to achieve pH > 7.15
- Daily spontaneous weaning trials

ARDSNET NEJM 2000;342:1301-8

HYPERCAPNIA

- Improved outcomes in ARDS patients
  ARDSNet NEJM 2000;342:1301-8
  Amato MB, et al. NEJM 1998;338:347-54
- May have direct lung-protective effects
  Laffey JG, et al. Intensive Care Med 2004;30:347-56
  Shibata K, et al. Am J Respir Cit Care Med 1998;158:1578-84
- Increased oxygenation, oxygen tensions and decreased capillary permeability
  Akca O, et al. Anaesthesia 2003;58:536-42
  Fleischman E, et al. Anesthesiology 2006:104:944-9
- May increase ICP, pulmonary artery pressures, catecholamines and decrease renal blood flow

ARDSNET FINDINGS

- Mortality 39.8% (12 mL/kg) *vs* 31.0% (6 mL/kg) (P = 0.007)
- 22% reduction in mortality with low tidal volume strategy
- Has become standard initial tidal volume management in much of the world for ARDS patients

ARDSNET NEJM 2000;342:1301-8

CYTOKINE, INFLAMMATION AND TIDAL VOLUMES

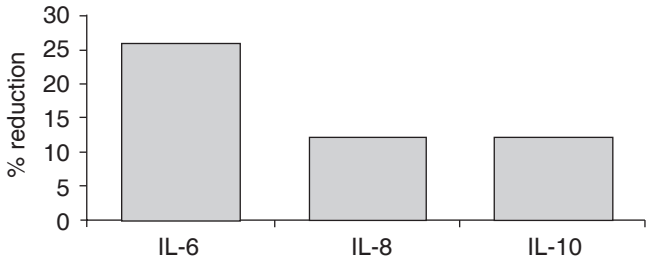


Figure 1. Percent reduction in 6 mL/kg group *vs* 12 mL/kg group during the first 3 study days. The 95% confidence intervals are 12-37% for interleukin *(IL)*-6, 1-23% for IL-8, and -4 to 25% for IL-10.
From: Parsons: Crit Care Med, Volume 33(1), January 2005.1-6

Parsons PE *et al.* Crit Care Med 2005;33:1-6

NINJA CONVENTION
Sold Out!!!

Very Demotivational.com

WHAT ABOUT PEEP?

- PEEP improves oxygenation in ARDS
- Increases functional residual capacity (FRC)
- Likely recruitment of alveoli
- But associated with potential for
  - Alveolar over distension
  - Hemodynamic compromise


The NEW ENGLAND JOURNAL of MEDICINE

JULY 22, 2004

Higher versus Lower Positive End-Expiratory Pressures in Patients with the Acute Respiratory Distress Syndrome

The National Heart, Lung, and Blood Institute ARDS Clinical Trials Network*

ARDSNET PEEP TRIAL

- Prospective, randomized, controlled trial
- Higher *vs* lower PEEP level in ARDS patients managed with a lower tidal volume strategy
- Similar outcome measures

ARDSNET NEJM 2004;351:327-36

ALLOWABLE PEEP AND FIO_2 COMBINATIONS

Allowable combinations of PEEP and FiO_2†

Lower-PEEP group

FiO_2	0.3	0.4	0.4	0.5	0.5	0.6	0.7	0.7	0.7	0.8	0.9	0.9	0.9	1.0
PEEP	5	5	8	8	10	10	10	12	14	14	14	16	18	18-24

Higher-PEEP group (before protocol changed to use higher levels of PEEP)

FiO_2	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.5	0.5	0.5-0.8	0.8	0.9	1.0
PEEP	5	8	10	12	14	14	16	16	18	20	22	22	22-24

Higher-PEEP group (after protocol changed to use higher levels of PEEP)

FiO_2	0.3	0.3	0.4	0.4	0.5	0.5	0.5-0.8	0.8	0.9	1.0
PEEP	12	14	14	16	16	18	20	22	22	22-24

ARDSNET NEJM 2004;351:327-36

ARDSNET PEEP TRIAL

- Stopped after 549 patients enrolled due to lack of efficacy
- Mean PEEP 8.3 *vs* 13.2 cm H2O
- Mortality 24.9% (low PEEP) *vs* 27.5% (high PEEP)

ARDSNET NEJM 2004;351:327-36

WHAT ABOUT HEALTHY LUNGS?

Feature Articles

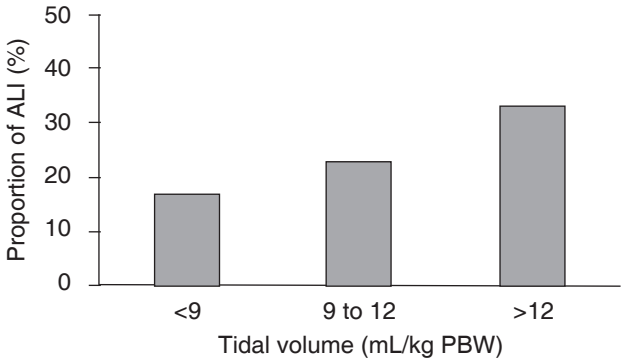
Ventilator-associated lung injury in patients without acute lung injury at the onset of mechanical ventilation*

Ognjen Gajic, MD; Saqib I. Dara, MD; Jose L. Mendez, MD; Adebola O. Adesanya, MD; Emir Festic, MD; Sean M. Caples, MD; Rimki Rana, MD; Jennifer L. St. Sauver, PhD; James F. Lymp, PhD; Bekele Afessa, MD; Rolf D. Hubmayr, MD

- 332 ICU patients without lung injury at onset of mechanical ventilation
- 80 developed acute lung injury within 5 days
- Risk factors included tidal volume, blood product transfusion, acidosis and restrictive lung disease

Crit Care Med 2004;32:1817-24

RISK OF LUNG INJURY *VS* TIDAL VOLUME



Gajic O, *et al*. Crit Care Med 2004;32:1817-24

Intensive Care Med (2005) 31:922-926
DOI 10.1007/s00134-005-2625-1

ORIGINAL

Ognjen Gajic
Fernando Frutos-Vivar
André Esteban
Rolf D. Hubmayr
Antonio Anzueto

Ventilator settings as a risk factor for acute respiratory distress syndrome in mechanically ventilated patients

- International mechanical ventilation study database
- 48 h of mechanical ventilation without ARDS at onset of mechanical ventilation
- 3,261 mechanically ventilated patients who did not have ARDS at onset
- 205 (6.2%) developed ARDS 48 h or more after onset of mechanical ventilation

- Risk factors for development of ARDS
  - Tidal Volume > 700 mL OR 2.67 (1.94-3.65)
  - Peak Pressure > 30 cm H_2O OR 1.57 (1.16-2.13)
  - PEEP > 5 cm H_2O OR 1.69 (1.20-2.34)

Intensive Care Med 2005;31:922-6

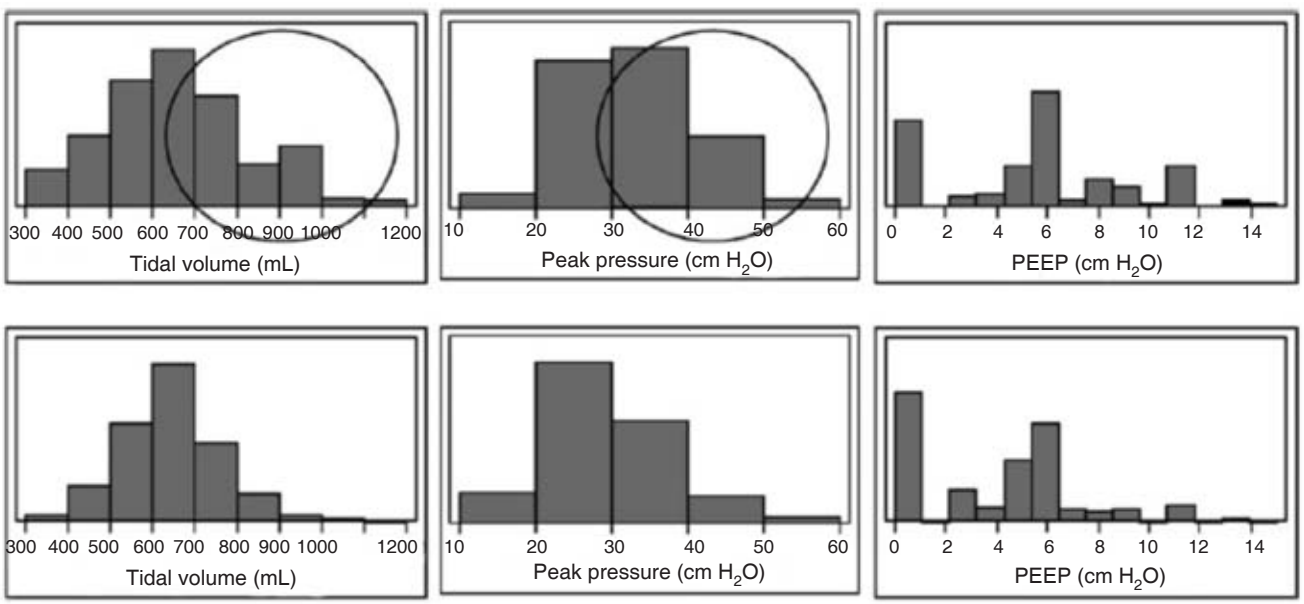


Figure 1. Distribution of day 1 tidal volume, peak airway pressure, and PEEP, and PEEP among mechanically ventilated patients who did (a) or did not (b) subsequently develop ARDS.

SURROGATE MARKER SUMMARY

- Initial human studies suggest little or no difference in inflammatory cytokines associated with conventional ventilation
- More recent data suggest an association between higher tidal volumes and/or no PEEP and inflammatory markers

ENOUGH CYTOKINES, WHAT OUTCOMES DATA EXIST FOR OR PATIENTS?

Anesthesiology 2006; 105: 14-8

Intraoperative Tidal Volume as a Risk Factor for Respiratory Failure after Pneumonectomy

Evans R. Fernández-Pérez, M.D.,* Mark T. Keegan, M.B.M.R.C.P.I.,† Daniel R. Brown, M.D., Ph.D.,† Rolf D. Hubmayr, M.D.,‡ Oprijen Gajic, M.D., M.Sc.§

- Elective pneumonectomy 1999-2003 (170 pts)
- 18% respiratory failure
  - Mortality: 23% *vs* 4%
- Risk factors by regression analysis:
  - Intraoperative tidal volume (8.3 *vs* 6.7 mL/kg)
  - Fluid administration (2.2 *vs* 1.3 liters)

INTRAOPERATIVE TIDAL VOLUME AND RESPIRATORY FAILURE

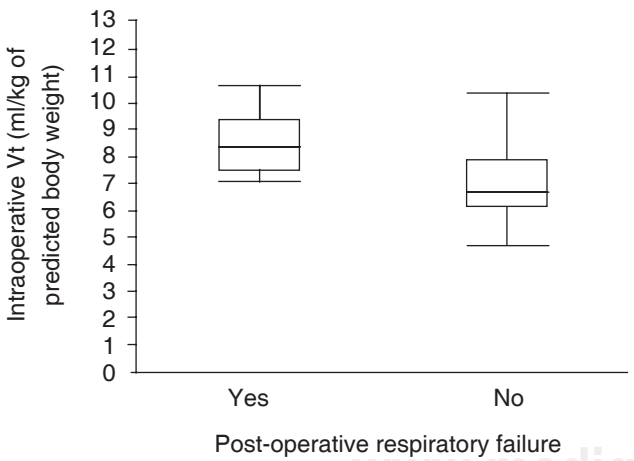


Figure 1. Median *(borizontal line)*, 25th and 75th percentiles *(box)*, and range *(wbiskers)* of intraoperative tidal volume (V_T) in patients who did and did not develop postpneumonectomy respiratory failure

Fernandez-Perez ER *et al*. Anesthesiology 2006;105:14-8

INTRAOPERATIVE VENTILATOR SETTINGS AND ACUTE LUNG INJURY:A PROSPECTIVE STUDY

- Prospective study of 4,420 patients undergoing surgery > 3 h; followed for 5 days
- 238 (5.4%) developed postoperative respiratory failure
- 113 (2.5%) developed postoperative ALI

Fernandez-Perez E, Thorax 2009

INTRAOPERATIVE VENTILATOR SETTINGS AND ACUTE LUNG INJURY: A PROSPECTIVE STUDY

- Intraoperative mean first hour peak inspiratory pressure (OR 1.07, 95% CI 1.02-1.15) but not mean first hour tidal volume, PEEP, or FIO_2 were associated with ALI-related postoperative respiratory failure

Fernandez-Perez E, Thorax 2009

TRANSPULMONARY PRESSURE, PEEP, RECRUITMENT AND LUNG INJURY

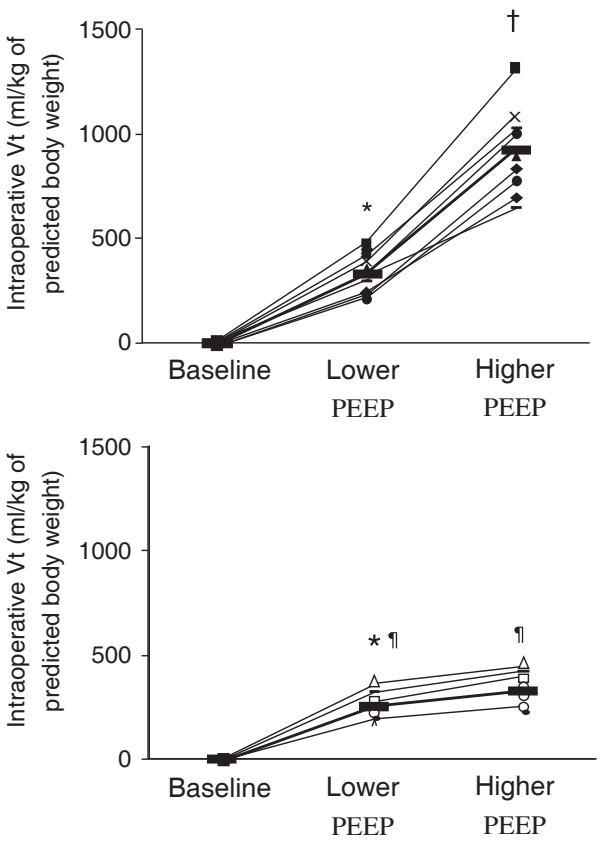
- Should I use a recruitment maneuver and, if so, how?
- If plateau pressure is low, should I care about the tidal volume?
- What is transpulmonary pressure and is it important?

AC MODE, RR 30, VT 360, FIO_2 1.0

- PEEP 10, SaO_2 81%, P_{Plat} 25 — 15
- PEEP 15, SaO_2 80%, P_{Plat} 29 — 14
- PEEP 20, SaO_2 81%, P_{Plat} 34 — 14
- PEEP 25, SaO_{22} 97%, P_{Plat} 39 — 14
- PEEP 20, VT 280, RR 35, P_{Plat} 31, SaO_2 91% on FIO_2 0.6 — 11
- $PaCO_2$ 68, pH 7.21

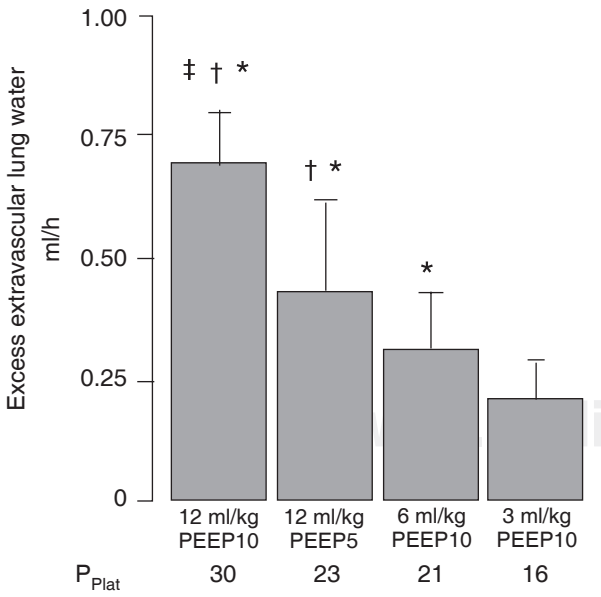
RECRUITERS *VS* NON-RECRUITERS

- 19 ARDS pts, 9 vs. 16 cm H_2O PEEP
- Recruiters had alveolar recruitment, improved oxygenation and decreased elastance



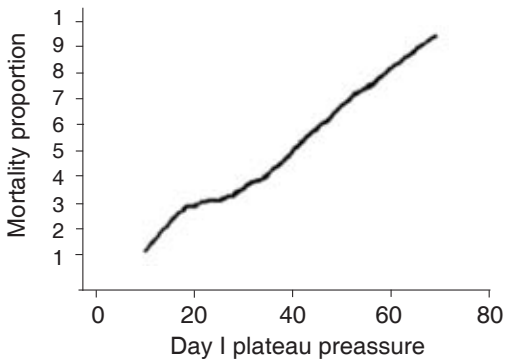
Grasso S, et al. AJRCCM 2005

LOWER TIDAL VOLUMES AND PLATEAU PRESSURES ARE PROTECTIVE

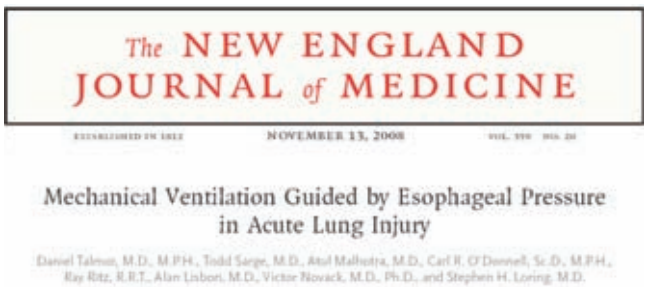


Frank JA, et al AJRCCM 2002

DAY 1 PLATEAU PRESSURE AND MORTALITY IN ARDSNET STUDY



Hager DN, et al. AJRCCM 2005


The NEW ENGLAND JOURNAL of MEDICINE

NOVEMBER 13, 2008

Mechanical Ventilation Guided by Esophageal Pressure in Acute Lung Injury

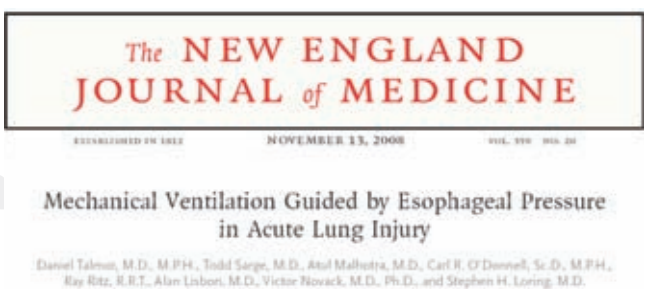
- Esophageal-pressure guided ventilation *vs* ARDS protocol; 61 patients studied, stopped at interim analysis

Esophageal-pressure-guided group

FiO_2	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.8	0.9	0.9	1.0
P_{LexP}	0	0	2	2	4	4	6	6	8	8	10	10

Control group

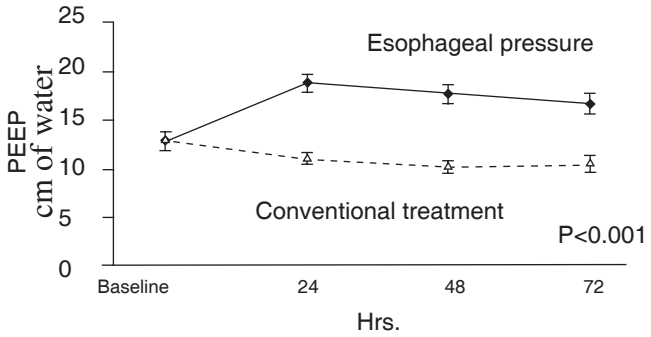
FiO_2	0.3	0.4	0.4	0.5	0.5	0.6	0.7	0.7	0.7	0.8	0.9	0.9	0.9	1.0
PEEP	5	5	8	8	10	10	10	12	14	14	14	16	18	20-24

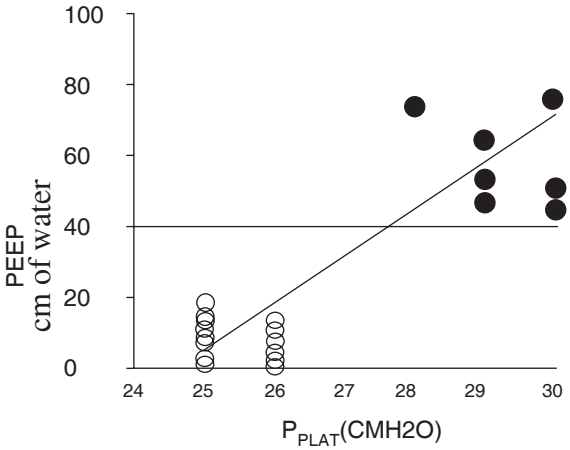

The NEW ENGLAND JOURNAL of MEDICINE

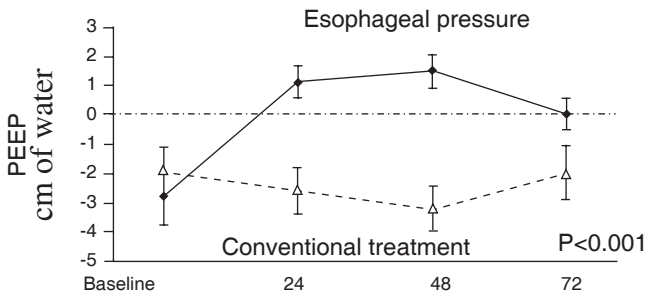
NOVEMBER 13, 2008

Mechanical Ventilation Guided by Esophageal Pressure in Acute Lung Injury

- Improved oxygenation (p = 0.002) and pulmonary compliance (p = 0.01) with esophageal guidance
- 28-Day mortality P = 0.055 (5 esophageal *vs* 12 ARDS)







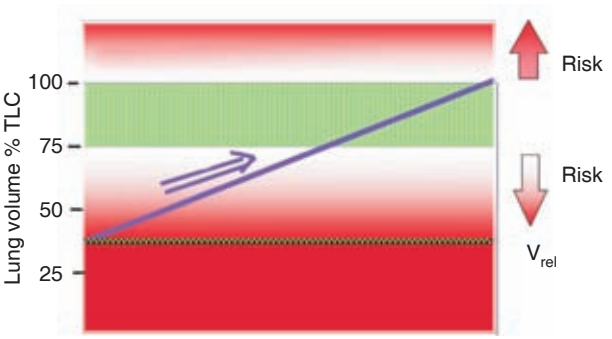
Terragni PP, et al. AJRCCM 2007

Table 3. Changes in PEEP at the initiation of ventilation according to the protocol.*

Treatment group	Change in PEEP				
	-1 to -6 cm of water	0 to 5 cm of water	6 to 10 cm of water	11 to 15 cm of water	16 to 20 cm of water
	No. of patients				
Esophageal-pressure-guided group	3	9	12	4	2
Control group	12	18	1	0	0

NEJM 2008:359:2095-104

GOALS OF VENTILATOR MANAGEMENT



SHOULD P_{PLAT} TARGET BE < 30?

- 30 ARDS pts receiving low 6 mL/kg IBW
- CT evaluation for hyperinflation
- Solid circles indicate hyperinflation
- Cytokines lower and ventilator-free days greater in protected group

CONCLUSIONS

- Respiratory failure is a common and serious complication during the perioperative period
- Recent data in patients with acute lung injury indicate ventilator strategy has a profound impact on patient outcome
- Intraoperative ventilator strategy may have an impact on patient outcome, even in the absence of lung injury