Mechanical Ventilation 2018

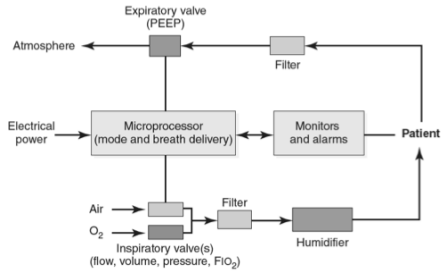
Dean Hess

Disclosures

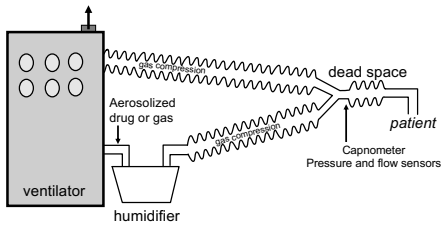
- Philips Respironics
- Ventec Life Systems
- Daedalus Enterprises
- Jones and Bartlett
- McGraw-Hill
- UpToDate
- American Board of Internal Medicine

Objectives

- Compare noninvasive and invasive ventilation.
- Describe common ventilator modes.
- Discuss the principles of lung-protective ventilation.
- Discuss the approach to ventilator liberation.



Hess, Respiratory Care Principles and Practice, 2016



Breath Delivery

- Trigger: initiates inspiration
  - Ventilator (time) or patient (pressure or flow)
- Control: what the ventilator controls during the inspiratory phase
  - Volume (flow) or pressure
- Cycle: initiates exhalation
  - Time, flow, volume, or pressure
- Baseline: PEEP

Ventilator Breath Types

- Mandatory: either triggered or cycled by the ventilator (back-up rate)
  - Volume-control
  - Pressure-control
- Spontaneous: triggered and cycled by the patient (no back-up rate)
  - Continuous positive airway pressure
  - Pressure support ventilation

Volume Control / Pressure Control

- Volume control
  - Fixed tidal volume and fixed inspiratory time (flow)
  - Pressure varies with lung mechanics
- Pressure Control
  - Fixed inspiratory pressure and inspiratory time
  - Volume varies with lung mechanics and patient effort

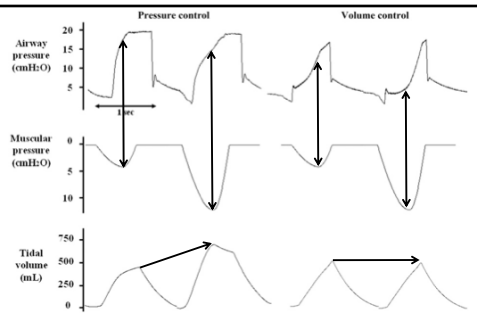
Volume Control / Pressure Control

Volume control settings
- Tidal volume
- Flow
- Rate
- FIO_2
- PEEP

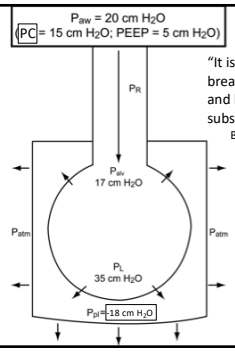
Inspiratory Time

Pressure control settings
- PC (above PEEP)
- Inspiratory time
- Rate
- FIO_2
- PEEP

Respiratory rate is the principal determinant of expiratory time and I:E.



Rittayamai, Chest 2015;148:340



"It is important to ascertain whether the spontaneously breathing patient in fact has a high respiratory drive and has adopted a ventilatory pattern which will lead to subsequent lung injury. **This is not a trivial matter.**"

Brochard, Slutsky, Pesenti. Am J Respir Crit Care Med Am J 2017;l195:438

"Patient-self inflicted lung injury (P-SILI)"
- More likely with PCV.

Alveolar stretch (P_L) = P_{alv} - P_{pl}

Volume Control Versus Pressure Control

Volume Control
- Advantage:
  - Tidal volume constant
- Disadvantages:
  - Increased alveolar pressure if disease worsens
  - Asynchrony is increased with effort

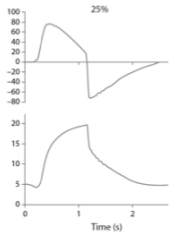
Monitor pressure

Pressure Control
- Advantages:
  - Plateau pressure cannot be greater than set pressure
  - Better synchrony?
- Disadvantage:
  - Alveolar over-distention with increased effort

Monitor volume

Pressure Support Ventilation

- Spontaneous breath type: much patient control over breathing pattern.
  - Patient triggered (flow or pressure)
  - Pressure limited
  - Flow cycled (fraction of peak flow)
  - No set rate
  - Apnea triggers alarm/backup ventilation



Breath delivery is similar for pressure support and pressure control: difference is that rate and inspiratory time are set with pressure control.

Modes (Pattern of Breath Delivery)

- Continuous mandatory ventilation (CMV)
  - Assist/control (rate set; patient can trigger): VC, PC
- Continuous spontaneous ventilation
  - Pressure support (no rate set; patient must trigger)
- Synchronized intermittent mandatory ventilation: VC or PC ± PS
  - Available evidence does not support

Noninvasive Ventilation

Noninvasive Ventilation and Survival in Acute Care Settings: A Comprehensive Systematic Review and Meta-Analysis of Randomized Controlled Trials

Crit Care Med 2015;43:880

Luca Cabrini, MD; Giovanni Landoni, MD; Alessandro Oriani, MD; Valentina P. Plumari, MD; Leda Nobile, MD; Massimiliano Greco, MD; Laura Pasin, MD; Luigi Beretta, MD; Alberto Zangrillo, MD

TABLE 2. Effects of Noninvasive Ventilation on Hospital Mortality With Subanalyses Performed in Different Settings

Purpose of Treatment and Disease	Events/ Cases	Events/ Controls	Relative Risk (95% CI)	*p* for Effect	Number Needed to Treat	*p* for Heterogeneity, I²Patients)	No Crossover* *p* (No. of	Crossover* *p* (No. of Patients)
Treatment	181/1,619	292/1,558	0.64 [0.54–0.75]	< 0.001	13	0.53, 0%	< 0.001 (1,611)	0.007 (1,566)
Chronic obstructive pulmonary disease	35/520	68/525	0.56 [0.38–0.82]	0.003	16	0.74, 0%	0.06 (254)	0.01 (791)
Acute pulmonary edema	48/501	70/446	0.64 [0.45–0.90]	0.01	16	0.67, 0 %	0.003 (651)	0.66 (296)
Treatment of postoperative ARF	10/149	23/148	0.51 [0.28–0.92]	0.02	11	0.45, 0%	0.02 (297)	–
Prevention of postextubation ARF	25/201	43/204	0.63 [0.40–0.99]	0.04	12	0.62, 0%	0.30 (137)*	0.10 (268)

The Evidence Is In: Noninvasive Ventilation Saves Lives*

Official ERS/ATS clinical practice guidelines: noninvasive ventilation for acute respiratory failure

Bram Rochwerg[1], Laurent Brochard[2,3], Mark W. Elliott[4], Dean Hess[5], Nicholas S. Hill[6], Stefano Nava[7] and Paolo Navalesi[8] (members of the steering committee); Massimo Antonelli[9], Jan Brozek[1], Giorgio Conti[9], Miquel Ferrer[10], Kalpalatha Guntupalli[11], Samir Jaber[12], Sean Keenan[13,14], Jordi Mancebo[15], Sangeeta Mehta[16] and Suhail Raoof[17,18] (members of the task force)

Eur Respir J 2017;50:1602426

NIV Should Be Used For:

- COPD exacerbation.
- Acute cardiogenic pulmonary edema.
- Post-operative acute respiratory failure.
- Chest trauma with acute respiratory failure.
- Prevent post-extubation respiratory failure in high-risk patients.

Eur Respir J 2017;50:1602426

ARDS Network Study

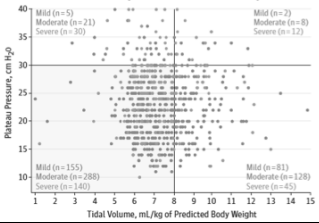
- 861 patients with ARDS
  - Control: 12 mL/kg ideal body weight
  - 6 mL/kg ideal body weight
    - Pplat ≤ 30 cm H_2O
    - Tidal volume decreased to 4 mL/kg for Pplat ≤ 30 cm H_2O
    - Tidal volume increased to 8 mL/kg for asynchrony or acidosis provided ≤ 30 cm H_2O
    - Volume-controlled continuous mandatory ventilation
- 25% mortality reduction for smaller tidal volume
- Number-needed-to-treat: 12 patients

N Engl J Med 2000;342:1301

Epidemiology, Patterns of Care, and Mortality for Patients With Acute Respiratory Distress Syndrome in Intensive Care Units in 50 Countries

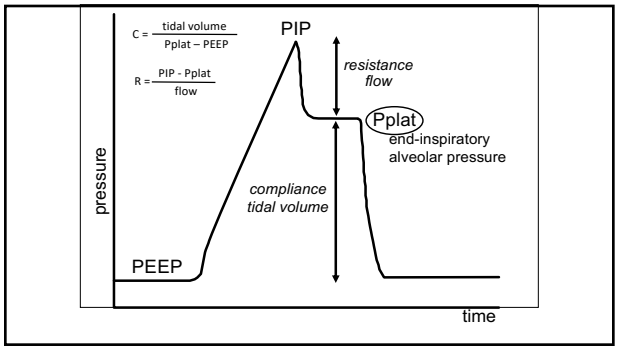
JAMA 2016;315:788

Giacomo Bellani, MD, PhD; John G. Laffey, MD, MA; Tài Pham, MD; Eddy Fan, MD, PhD; Laurent Brochard, MD, HDR; Andres Esteban, MD, PhD;

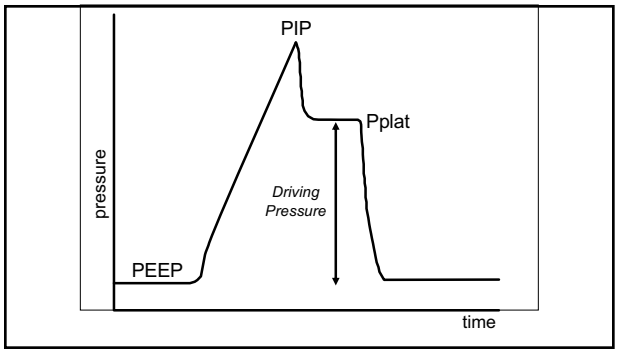


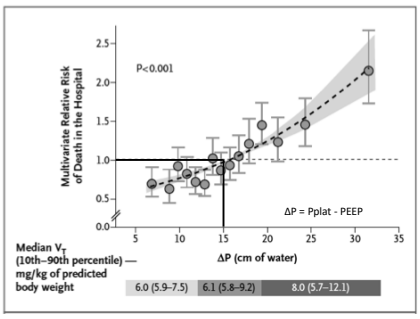
Fewer than two-thirds of patients with ARDS received a tidal volume ≤8 mL/kg PBW.

Plateau pressure was measured in only 40%.



PIP versus Plateau





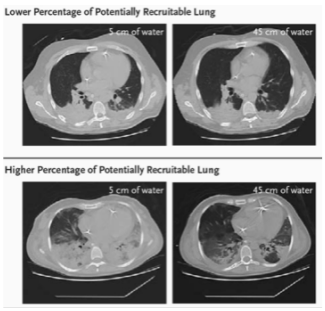
Amato, N Engl J Med 2015;372:747

Lung-Protective Ventilation With Low Tidal Volumes and the Occurrence of Pulmonary Complications in Patients Without Acute Respiratory Distress Syndrome: A Systematic Review and Individual Patient Data Analysis

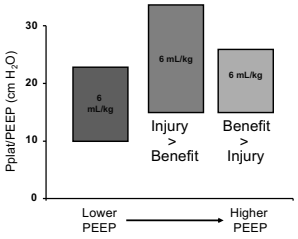
Ary Serpa Neto, MD, MSc, PhD[1,2,3]; Fabienne D. Simonis, MD[1]; Carmen S. V. Barbas, MD, PhD[3]; Michelle Biehl, MD[4]; Rogier M. Determann, MD, PhD[5]; Jonathan Elmer, MD[5]; Gilberto Friedman, MD, PhD[6]; Ognjen Gajic, MD[4]; Joshua N. Goldstein, MD, PhD[7];

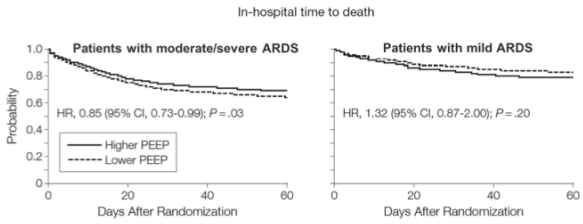
Variables	Less Than or Equal to 7 mL/kg PBW	Greater Than 7 and Less Than 10 mL/kg PBW	Greater Than or Equal to 10 mL/kg PBW	Adjusted OR (Low vs High) (95% CI)[a]	p
Pulmonary complications	166 (23)	211 (29)	220 (31)	0.72 (0.52–0.98)	0.042
Acute respiratory distress syndrome	86 (12)	121 (16)	163 (23)	0.48 (0.32–0.71)	< 0.01
Pneumonia	122 (17)	158 (21)	106 (15)	1.47 (0.89–2.21)	0.093
In-hospital mortality	245 (34)	279 (37)	270 (38)	0.82 (0.65–1.02)	0.081

Crit Care Med 2015;43:2155



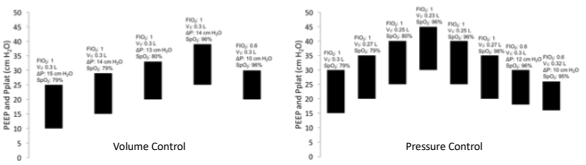
Gattinoni, N Engl J Med 2006;354:1775





JAMA 2010;303:865

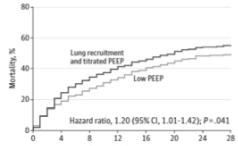
Stepwise Recruitment Maneuver With Decremental PEEP Titration



Target:
- Pplat < 28 cm H_2O (provided normal chest wall)
- Lowest driving pressure (highest compliance)
- SpO_2 88% – 95%
- Hemodynamic stability

Effect of Lung Recruitment and Titrated Positive End-Expiratory Pressure (PEEP) vs Low PEEP on Mortality in Patients With Acute Respiratory Distress Syndrome

A Randomized Clinical Trial



CONCLUSIONS AND RELEVANCE In patients with moderate to severe ARDS, a strategy with lung recruitment and titrated PEEP compared with low PEEP increased 28-day all-cause mortality. These findings do not support the routine use of lung recruitment maneuver and PEEP titration in these patients.

September, 2017

Selecting the 'right' positive end-expiratory pressure level

Luciano Gattinoni[a,b], Eleonora Carlesso[b], and Massimo Cressoni[b]

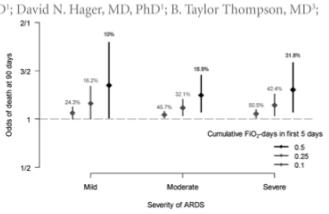
- Best PEEP does not exist.
- Better PEEP as a reasonable compromise among oxygenation, hemodynamic status, and intra-tidal opening and closing.
  - 15 - 20 cm H2O in severe ARDS; P/F < 100
  - 10 - 15 cm H2O in moderate ARDS; P/F 100 – 200
  - 5 - 10 cm H2O in mild ARDS; P/F > 200

Curr Opin Crit Care 2015,21:50

Oxygen Exposure Resulting in Arterial Oxygen Tensions Above the Protocol Goal Was Associated With Worse Clinical Outcomes in Acute Respiratory Distress Syndrome

Neil R. Aggarwal, MD[1,2]; Roy G. Brower, MD[1]; David N. Hager, MD, PhD[1]; B. Taylor Thompson, MD[3];

FIO_2 days (excess oxygen): FIO_2 – 0.5, for a PaO_2 greater than 80 mm Hg and a corresponding FIO_2 greater than 0.5.



Crit Care Med 2017 Epub

Effect of Conservative vs Conventional Oxygen Therapy on Mortality Among Patients in an Intensive Care Unit
The Oxygen-ICU Randomized Clinical Trial

JAMA. 2016;316(15):1583-1589

Massimo Girardis, MD; Stefano Busani, MD; Elisa Damiani, MD; Abele Donati, MD; Laura Rinaldi, MD; Andrea Marudi, MD;

PaO_2 ≤ 150 mm Hg or SpO_2 97% - 100%

PaO_2 70 -100 mm Hg or SpO_2 94% - 98%

	Oxygen Therapy, No. (%)			
	Conservative (n = 216)	Conventional (n = 218)	Absolute Risk Reduction (95% CI)	*P* Value
Primary outcome				
ICU mortality	25 (11.6)	44 (20.2)	0.086 (0.017-0.150)	.01
Secondary outcomes				
Shock	8 (3.7)	23 (10.6)	0.068 (0.020-0.120)	.006
Liver failure	4 (1.9)	14 (6.4)	0.046 (0.008-0.088)	.02
Bacteremia	11 (5.1)	22 (10.1)	0.050 (0.000-0.090)	.049

An Official American Thoracic Society/European Society of Intensive Care Medicine/Society of Critical Care Medicine Clinical Practice Guideline: Mechanical Ventilation in Adult Patients with Acute Respiratory Distress Syndrome

Eddy Fan, Lorenzo Del Sorbo, Ewan C. Goligher, Carol L. Hodgson, Laveena Munshi, Allan J. Walkey, Neill K. J. Adhikari, Marcelo B. P. Amato, Richard Branson, Roy G. Brower, Niall D. Ferguson, Ognjen Gajic, Luciano Gattinoni, Dean Hess, Jordi Mancebo, Maureen O. Meade, Daniel F. McAuley, Antonio Pesenti, V. Marco Ranieri, Gordon D. Rubenfeld, Eileen Rubin, Maureen Seckel, Arthur S. Slutsky, Daniel Talmor, B. Taylor Thompson, Hannah Wunsch, Elizabeth Uleryk, Jan Brozek, and Laurent J. Brochard; on behalf of the American Thoracic Society, European Society of Intensive Care Medicine, and Society of Critical Care Medicine

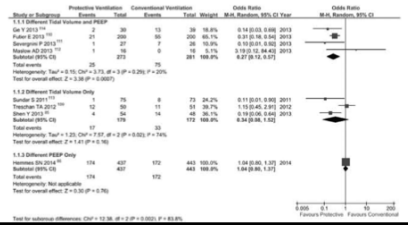
Strong Guideline For:
- Tidal volumes 4 to 8 mL/kg PBW and Pplat <30 cm H_2O.

Conditional Guidelines For:
- Higher PEEP in patients with moderate or severe ARDS.
- Recruitment maneuvers in patients with moderate or severe ARDS.

Am J Respir Crit Care Med 2017;195:1253

Intraoperative Protective Mechanical Ventilation for Prevention of Postoperative Pulmonary Complications
A Comprehensive Review of the Role of Tidal Volume, Positive End-expiratory Pressure, and Lung Recruitment Maneuvers

Anesthesiology 2015;123:692



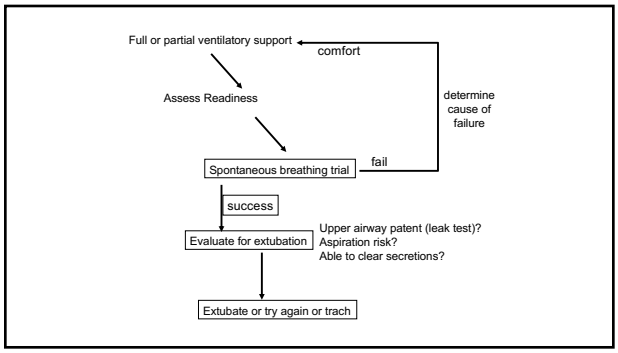
Online version at http://www.minervamedica.it
Minerva Anestesiologica 2017 October;83(10):1075-88
DOI: 10.23736/S0375-9393.17.11970-X

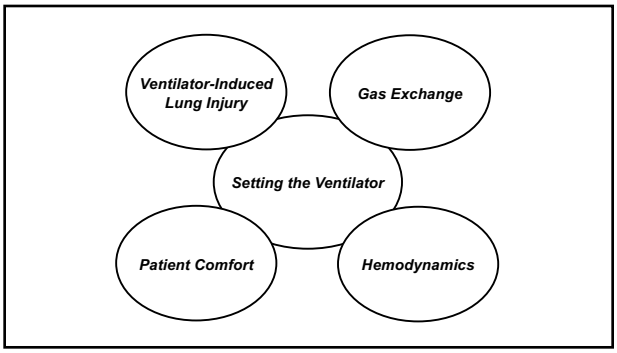
REVIEW

Intraoperative mechanical ventilation: state of the art

Lorenzo BALL, Federico COSTANTINO, Giulia OREFICE, Karthikka CHANDRAPATHAM, Paolo PELOSI *

- Mechanical ventilation during general anesthesia is potentially harmful for the lungs, and ventilation settings are associated with postoperative pulmonary complications, directly affecting the clinical outcome.
- A protective ventilatory strategy, comprising low tidal volume and moderate-low PEEP levels to achieve the lowest possible driving pressure, should be part of clinical practice.





Discussion Topics

- When is a Pplat > 30 cm H_2O safe?
- What is the difference between PEEP and auto-PEEP?
- What can be done to decrease the risk of re-intubation?