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


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

Este artículo puede ser consultado en versión completa en http://www.medigraphic.com/rma

www.medigraphic.org.mx
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 H₂O peak inspiratory pressure

<table>
<thead>
<tr>
<th></th>
<th>Normal</th>
<th>5 Minutes</th>
<th>20 Minutes</th>
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<tr>
<td>Leaks</td>
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<td>2.0</td>
<td>0</td>
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</table>

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

INFLATION PRESSURE VS EPITHELIAL PERMEABILITY

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

Dreyfuss, et al. AJRCCM 1985
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:
- Atelectasis
- Hypoxemia
- Hypercapnia
- Inflammation

Consequences:
- VQ mismatch
- Barotrauma
- Alveolar-capillary injury
- Inflammation

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

Gajic AJRCCM 2003;167:1057-1063
18 Clinical centers comprised of 42 hospitals
18 United States National Institutes of Health funded clinical network
18 Goal: efficiently test promising agents, devices or management strategies to improve the care of patients with ARDS

**ARDSNET VENTILATOR STRATEGY**

- Assist control mode
- Set rate to maintain minute ventilation (not to exceed 35 breathes/min)
- Keep $P_{plateau} < 30$ cm H$_2$O
- 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
  - May have direct lung-protective effects
  - Increased oxygenation, oxygen tensions and decreased capillary permeability
  - 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

**PREDICTED BODY WEIGHT**

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

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<tr>
<th>Ht/in</th>
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**Predicted body weight for women (IBW) = 45.5 + [2.3x(h. in inches – 60)]**

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**VOLUME 342 NUMBER 19**

**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**

**The New England Journal of Medicine**

**Copyright, 2000, by the Massachusetts Medical Society**

**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

**HYPERCAPNIA**

- **PREDICTED BODY WEIGHT**

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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.


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 FiO2 COMBINATIONS

Allowable combinations of PEEP and FiO2:

Lower-PEEP group

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<thead>
<tr>
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<th>0.3</th>
<th>0.4</th>
<th>0.5</th>
<th>0.6</th>
<th>0.7</th>
<th>0.8</th>
<th>0.9</th>
<th>1.0</th>
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<td>5</td>
<td>8</td>
<td>8</td>
<td>10</td>
<td>10</td>
<td>12</td>
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Higher-PEEP group (before protocol changed to use higher levels of PEEP)

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<thead>
<tr>
<th>FiO2</th>
<th>0.3</th>
<th>0.3</th>
<th>0.3</th>
<th>0.3</th>
<th>0.4</th>
<th>0.4</th>
<th>0.5</th>
<th>0.5-0.8</th>
<th>0.8</th>
<th>0.9</th>
<th>1.0</th>
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<td>10</td>
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<td>16</td>
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<td>22-24</td>
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Higher-PEEP group (after protocol changed to use higher levels of PEEP)

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<th>0.3</th>
<th>0.4</th>
<th>0.4</th>
<th>0.5</th>
<th>0.5-0.8</th>
<th>0.8</th>
<th>0.9</th>
<th>1.0</th>
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<td>PEEP</td>
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<td>14</td>
<td>16</td>
<td>16</td>
<td>18</td>
<td>20</td>
<td>22-24</td>
<td>22</td>
<td>22</td>
<td>22-24</td>
</tr>
</tbody>
</table>

ARDSNET NEJM 2004;351:327-36

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

ARDSNET NEJM 2004;351:327-36

WHAT ABOUT HEALTHY LUNG?
• 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**


- 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$_2$O OR 1.57 (1.16-2.13)
  - PEEP > 5 cm H$_2$O OR 1.69 (1.20-2.34)


**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?

• 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)

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 FIO₂ 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, FIO₂ 1.0

• PEEP 10, SaO₂ 81%, Pplat 25
• PEEP 15, SaO₂ 80%, Pplat 29
• PEEP 20, SaO₂ 81%, Pplat 34
• PEEP 25, SaO₂ 97%, Pplat 39
• PEEP 20, VT 280, RR 35, Pplat 31, SaO₂ 91% on FIO₂ 0.6
• PaCO₂ 68, pH 7.21

RECRUITERS VS NON-RECRUITERS

• 19 ARDS pts, 9 vs. 16 cm H₂O PEEP
• Recruiters had alveolar recruitment, improved oxygenation and decreased elastance
Esophageal-pressure-guided ventilation vs ARDS protocol; 61 patients studied, stopped at interim analysis

- 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)

**DAY 1 PLATEAU PRESSURE AND MORTALITY IN ARDSNET STUDY**

- Lower tidal volumes and plateau pressures are protective
- Postoperative ventilator management: Why it makes a difference

Grasso S, et al. AJRCCM 2005

Frank JA, et al AJRCCM 2002

Hager DN, et al. AJRCCM 2005
Table 3. Changes in PEEP at the initiation of ventilation according to the protocol.*

<table>
<thead>
<tr>
<th>Treatment group</th>
<th>Change in PEEP</th>
<th>No. of patients</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-1 to -6 cm of water</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>0 to 5 cm of water</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>6 to 10 cm of water</td>
<td>12</td>
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<td></td>
<td>11 to 15 cm of water</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>16 to 20 cm of water</td>
<td>2</td>
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</tbody>
</table>

Esophageal-pressure-guided group 3 9 12 4 2
Control group 12 18 1 0 0

NEJM 2008:359:2095-104

**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

**GOALS OF VENTILATOR MANAGEMENT**

- 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

**CONCLUSIONS**

Terragni PP, et al. AJRCCM 2007