Pulmonary Complications: Lung Protective Ventilation for Surgical Patients

William E. Hurford, MD, FCCM
Professor and Chair
Department of Anesthesiology
University of Cincinnati
Is there a role for protective lung ventilation strategies in surgical patients without ARDS?
Some patterns of mechanical ventilation can produce lung injury

Intraoperative patients may be at risk for respiratory failure

Limiting tidal volume has reduced the incidence and severity of ARDS

A similar approach to intraoperative mechanical ventilation may limit postoperative respiratory complications.
VALI

Ventilator Associated Lung Injury
Dreyfuss et al., *AJRCCM* 157:294, 1998
Fu Z et al., J Appl Phys 73:123, 1992
What’s Wrong with a Little Atelectasis?

Radford EP. Handbook of Physiology, Section 3, Volume 1 1964:429-449
Figure 1: Atelectotrauma
The interface between collapsed and consolidated lung (A) and over-distended lung units (B) is heterogeneous and unstable. Depending on ambient conditions this region is prone to cyclic recruitment and derecruitment and localised asymmetrical stretch of lung units (C) immediately apposed to regions of collapsed lung.
Atelectasis during Induction of General Anesthesia in Obese Patients

Coussa M et al., Anesth Analg 2004;98:1491

With 0 cm H2O PEEP

Before induction

After intubation
Atelectasis during Induction of General Anesthesia in Obese Patients

Coussa M et al., *Anesth Analg* 2004;98:1491
NIH NHLBI ARDS Network

Prospective, Randomized, Multi-Center Trial of 12 ml/kg Vs 6 ml/kg Tidal Volume Positive Pressure Ventilation for Treatment of Acute Lung Injury and Acute Respiratory Distress Syndrome

*NEJM*, 342:1301-8, 2000
28 day survival

Proportion Surviving

Days after study entry

Proportion Surviving

NEJM, 342:1301-8, 2000
Proportion alive and off ventilator

**NEJM**, 342:1301-8, 2000
Median organ failure free days

* = 6 ml/kg
= 12 ml/kg

NEJM, 342:1301-8, 2000
Tidal volume reduction in patients with ALI when plateau pressures are not high

Hager DN et al. AJRCCM 172:1241, 2005

- Re-analysis of ARDSnet data
- Mortality was associated with $P_{\text{plat}}$ at all levels
- Patients benefited from TV reduction at all levels of $P_{\text{plat}}$
Barotrauma and Respiratory Failure

Van der Werff YD et al., Chest 111:1278, 1997

• Respiratory failure following pneumonectomy (29/197 pts, 15%) associated with use of high ventilating pressures [> 40 cm H₂O]

• 3.0 increase in relative risk of respiratory failure in pts exposed to high pressures (23%)
Effects of Ventilatory Settings on Pulmonary and Systemic Inflammatory Responses during Major Surgery
Wrigge H et al., Anesth Analg 2004:98:775

- 64 patients (normal lungs) randomized:
  - TV 12 – 15 ml/kg; ZEEP
  - TV 6 ml/kg; 10 cm H$_2$O PEEP
- PaO$_2$ and plasma cytokines not different over 3 hours of study
- Maximal airway pressures < 28 cm H$_2$O
Intraoperative TV and Respiratory Failure after Pneumonectomy

Fernández-Pérez ER et al., *Anesthesiology* 105:14, 2006

- Retrospective review of Mayo Clinic patients from 1999-2003
- 18% (30/170) pneumonectomy patients developed post-op respiratory failure
- Respiratory failure associated with larger tidal volume (odds ratio 1.56 for each ml/kg increase in tidal volume)
Intraoperative TV and Respiratory Failure after Pneumonectomy

Fernández-Pérez ER et al., *Anesthesiology* 105:14, 2006
56 adults with abdominal surgery > 2 hrs randomized to:
- 9 ml/kg PBW; no PEEP
- 7 ml/kg PBW; PEEP 10 + recruitment maneuvers

Improved PFTs and PaO$_2$
Improved modified Clinical Pulmonary Infection Score (mCPIS)
No change in hospital stay

Protective MV during abdominal surgery improves postop pulmonary function
Paolo S et al. *Anesthesiology* 118:1307-21, 2013
Intraop low TV ventilation in abdominal surgery

• 400 adults at risk of pulmonary complications randomized to:
  – 10 – 12 ml/kg PBW no PEEP
  – 6 – 8 ml/kg PBW; PEEP 6 – 8 + recruitment maneuvers q30 min

• Fewer complications:
  – 10.5% vs 27.5%

• Less mechanical ventilation
  – 5% vs 17%

• Shorter hospital stay (2.5 days)
High vs low PEEP in abdominal surgery

• In 30 centers, 900 adults at risk of pulmonary complications received 8 ml/kg PBW TV and randomized to:
  – 12 cm H$_2$O PEEP + recruitment maneuvers
  – ≤ 2 cm H$_2$O PEEP no recruitment maneuvers

• No difference in pulmonary complications (40%)

• More intraop hypotension in high PEEP group
Temporal trends for intraoperative ventilation
Wanderer JP et al. BMC Anesthesiol 2015; 15:40

- EMR data of 295k patients between 2005-13 extracted
- Vanderbilt, Mayo, Colorado, Partners (Harvard), Jefferson
- Slow change over time
- 41% of anesthetics in 2013 used TV > 8 ml/kg
Short patients receive protective ventilation less frequently
Han S et al. *Crit Care* 15:R262, 2011

- Reviewed 421 patients with sepsis-related ALI in 7 academic centers participating in a Consortium to Evaluate Lung Edema Genetics between 2002 and 2008
- Only 53% of patients received LPV (PBV ≤ 8 ml/kg PBW)
- Women less likely to receive LPV (46 vs 59%)
- Once adjusted for shorter stature, height, not gender, was associated with likelihood of receiving appropriate ventilator settings
Improving Adherence to Intraoperative Lung Protective Ventilation

**Figure 2:** Rate of Failure to Use Intraoperative Lung-Protective Ventilation (P Chart)

- **Timeout**
- **Timeout + 1 hr**
- **Timeout + 2 hr**

- **P**
- **Pbar**
- **UCL(p)**
- **LCL(p)**
- **Grand Mean**

- 42.9%
- 40.0%
- 46.2%
- 37.6%
Summary

• Secondary injury (barotrauma) appears important even in patients without ARDS
• Protective ventilation may be useful in “at risk” groups
• Intraoperative use of low tidal volumes is growing
Recommendations

- Measure height to calculate predicted body weight
- In usual situations, set TV to 6 to 8 ml/kg predicted body weight (450 to 550 ml TV for 70 kg pt)
- 5 cm PEEP should be used routinely
- Routine use of higher PEEP not supported