PRONE POSITION & ESOPHAGEAL BALLOON

Ehab Daoud MD, FACP, FCCP
Associate Professor of Medicine, JABSOM, University of Hawaii
Medical director of respiratory program, Kapiolani Community College

HSRC 2019
Objectives

- **Prone Position**
  - Why/Benefits
  - Why not/Contraindications
  - How/Logistics

- **Esophageal Balloon Manometry**
  - Why/Benefits
  - Why not/Contraindications
  - How/Logistics
Our Lungs

Ventilation
- Intrapleural pressure: more negative
- Greater transmural pressure difference
- Alveoli larger, less compliant
- Less ventilation

Source: Michael G. Levitzky: Pulmonary Physiology, 9e
Copyright © McGraw-Hill Education. All rights reserved.

Perfusion
- Lower intravascular pressures
- Less recruitment, distention
- Higher resistance
- Less blood flow

Intrapleural pressure: less negative
- Smaller transmural pressure difference
- Alveoli smaller, more compliant
- More ventilation

Greater vascular pressures
- More recruitment, distention
- Lower resistance
- Greater blood flow
How do we Breath

Source: Michael G. Levitzky: Pulmonary Physiology, 9e
Copyright © McGraw-Hill Education. All rights reserved.
Prone position
History

• 1974 Bryan et al suggested that anaesthetized and paralyzed patients in the prone position exhibit a better expansion of the dependent (dorsal) lung regions with consistent improvement in oxygenation, indicating prone’s potential beneficial impact on lung mechanics.

• 1976 Piehl et al reported dramatic effects on oxygenation improvement by prone position in five patients with ARDS

• 1977 Douglas et al. reported similar findings in six ARDS patients, confirming that prone positioning could effectively improve oxygenation in this patient group.
Early Prone studies
Short time 7-8 hrs/day

Sud et al. ICM 2010: 36:585-599

Abroug et al. Critical care 2011, 15:R6

Severe hypoxemia

RRR = 16%

RR = 0.84 (95% CI, 0.74 - 0.96)  P = 0.01
Newer Studies
Early initiation, 20 hrs/day

A Multicenter Trial of Prolonged Prone Ventilation in Severe Acute Respiratory Distress Syndrome

Number of patients at risk:
Supine group  40  31  28  28  28  28
Prone group   55  47  46  44  44  44

Conclusion: Prone ventilation is feasible and safe, and may reduce mortality in patients with severe ARDS when it is initiated early and applied for most of the day.

Newer Studies


P/F < 200

P/F = 100-200

P/F < 100

Entire population

Moderate hypoxemia

Severe hypoxemia

Survival Proportion

Patient positioning

- Prone
- Supine

Log-rank P = .31

Log-rank P = .79

Log-rank P = .21

Prone position = 18 h/day

Mortality:

32.8% vs. 31%

22.5% vs. 25.5%

46% vs. 38%
Newer Studies

PROSEVA

The NEW ENGLAND JOURNAL of MEDICINE

Prone Positioning in Severe Acute Respiratory Distress Syndrome

CONCLUSIONS

In patients with severe ARDS, early application of prolonged prone-positioning sessions significantly decreased 28-day and 90-day mortality. (Funded by the Programme Hospitalier de Recherche Clinique National 2006 and 2010 of the French Ministry of Health; PROSEVA ClinicalTrials.gov number, NCT00527813.)

Guerin et al. NEJM 368;23, 2159-2168
Prone position underutilized ≈ 13%
More use in Europe compared to North America
Main reason for not using PP: Hypoxemia not considered severe
Complications rare and similar to supine position
**Epidemiology, Patterns of Care, and Mortality for Patients With Acute Respiratory Distress Syndrome in Intensive Care Units in 50 Countries**

Table 4. Use of Adjunctive and Other Optimization Measures in Invasively Ventilated Patients With Acute Respiratory Distress Syndrome

<table>
<thead>
<tr>
<th>Measure</th>
<th>Patients of No. (%) [95% CI]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All (n = 2377)</td>
</tr>
<tr>
<td>Neuromuscular blockade</td>
<td>516 (21.7)</td>
</tr>
<tr>
<td>[20.1-23.4]</td>
<td>[4.8-9.4]</td>
</tr>
<tr>
<td>Recruitment maneuvers</td>
<td>496 (20.9)</td>
</tr>
<tr>
<td>[19.2-22.6]</td>
<td>[9.0-14.8]</td>
</tr>
<tr>
<td>Prone positioning</td>
<td>187 (7.9)</td>
</tr>
<tr>
<td>[6.8-9.0]</td>
<td>[0.3-2.3]</td>
</tr>
<tr>
<td>ECMO</td>
<td>76 (3.2)</td>
</tr>
<tr>
<td>[2.5-4.0]</td>
<td>[0.05-1.2]</td>
</tr>
<tr>
<td>Inhaled vasodilators</td>
<td>182 (7.7)</td>
</tr>
<tr>
<td>[6.6-8.8]</td>
<td>[0.20-5.4]</td>
</tr>
<tr>
<td>HFOV</td>
<td>28 (1.2)</td>
</tr>
<tr>
<td>[0.8-1.7]</td>
<td>[0.1-1.7]</td>
</tr>
<tr>
<td>None of the above</td>
<td>1431 (60.2)</td>
</tr>
<tr>
<td>[58.2-62.2]</td>
<td>[75.9-83.2]</td>
</tr>
<tr>
<td>Esophageal pressure catheter</td>
<td>19 (0.8)</td>
</tr>
<tr>
<td>[0.04-1.4]</td>
<td>[0.04-1.4]</td>
</tr>
<tr>
<td>Tracheostomy</td>
<td>309 (13.0)</td>
</tr>
<tr>
<td>[11.6-14.4]</td>
<td>[7.1-12.6]</td>
</tr>
<tr>
<td>High-dose corticosteroids</td>
<td>425 (17.9)</td>
</tr>
<tr>
<td>[16.4-19.5]</td>
<td>[9.5-15.5]</td>
</tr>
<tr>
<td>Pulmonary artery catheter</td>
<td>107 (4.5)</td>
</tr>
<tr>
<td>[3.7-5.4]</td>
<td>[0.8-3.4]</td>
</tr>
</tbody>
</table>

**Conclusions and Relevance.** Among ICUs in 50 countries, the period prevalence of ARDS was 10.4% of ICU admissions. This syndrome appeared to be underrecognized and undertreated and associated with a high mortality rate. These findings indicate the potential for improvement in the management of patients with ARDS.
Prone Position
Mechanisms

- Alteration of distribution of ventilation
- Redistribution of blood flow
- Improved matching of Ventilation & Perfusion (V/Q)
- Improved homogeneity of lung units
- Decreased alveolar Stress and Strain
- Recruitment maneuver
- Decrease VILI
- Relief of Left lower lung compression by the heart
- Relief dorsal lung compression by abdominal organs
- Enhanced secretion clearance
- Improved RV output and Pulmonary pressures
In PP there is a more homogeneous distribution of Ptp and alveolar distension.
Ventilation/Perfusion (V/Q)

More homogeneous alveoli and more homogeneous Trans-Pulmonary pressures
Ventilation/Perfusion (V/Q)
Stress and Strain

Fig. 4. Distribution of stress and strain and matching of ventilation and perfusion in the supine and prone postures. Considering the lung as a triangular-shaped spring (left), the combined effects of gravity and the greater tissue mass suspended from a larger dorsal chest wall produce more equal distribution of stress and strain in the lung, resulting in more uniform end-expiratory lung volume and alveolar size. On the right, each dot represents a single piece of lung. In the supine posture, there is close matching of ventilation and perfusion in the ventral lung but markedly poor matching in the dorsal lung, resulting in widespread distribution of ventilation-perfusion (middle and right). In the supine posture, ventilation and perfusion are more closely matched throughout, resulting in a tighter distribution of ventilation-perfusion ratios.
Effect of Abdominal pressure and abdominal contents on the lung
Heart weight and position
### Table 5. Incidence of Complications During the 28 Days After Randomization

<table>
<thead>
<tr>
<th></th>
<th>Supine Position</th>
<th></th>
<th>Prone Position</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Patient-Days</td>
<td>No. of Occurrences</td>
<td>Incidence per 100 Days (95% CI)</td>
<td>Patient-Days</td>
</tr>
<tr>
<td>Unplanned extubation</td>
<td>5188</td>
<td>47</td>
<td>0.91 (0.65-1.16)</td>
<td>5756</td>
</tr>
<tr>
<td>Selective intubation*</td>
<td>5188</td>
<td>0</td>
<td>0</td>
<td>5755</td>
</tr>
<tr>
<td>ETT obstruction†</td>
<td>5188</td>
<td>12</td>
<td>0.23 (0.10-0.36)</td>
<td>5755</td>
</tr>
<tr>
<td>Hemoptysis</td>
<td>5188</td>
<td>34</td>
<td>0.66 (0.45-0.88)</td>
<td>5755</td>
</tr>
<tr>
<td>SpO₂ &lt;85%</td>
<td>5188</td>
<td>207</td>
<td>3.09 (3.45-4.53)</td>
<td>5755</td>
</tr>
<tr>
<td>Cardiac arrest</td>
<td>5188</td>
<td>88</td>
<td>1.70 (1.34-2.05)</td>
<td>5754</td>
</tr>
<tr>
<td>Heart rate &lt;90/min</td>
<td>5188</td>
<td>72</td>
<td>1.39 (1.07-1.71)</td>
<td>5755</td>
</tr>
<tr>
<td>SAP &lt;60 mm Hg</td>
<td>5188</td>
<td>148</td>
<td>2.85 (2.30-3.31)</td>
<td>5754</td>
</tr>
<tr>
<td>Pressure sores‡</td>
<td>5188</td>
<td>157</td>
<td>3.03 (2.55-3.50)</td>
<td>5756</td>
</tr>
<tr>
<td>Atelectasis</td>
<td>5188</td>
<td>2a</td>
<td>0.54 (0.34-0.74)</td>
<td>5756</td>
</tr>
<tr>
<td>Intracranial hypertension</td>
<td>5188</td>
<td>3</td>
<td>0.06 (0.00-0.12)</td>
<td>5756</td>
</tr>
<tr>
<td>Pneumothorax</td>
<td>5188</td>
<td>2a</td>
<td>0.54 (0.34-0.74)</td>
<td>5756</td>
</tr>
</tbody>
</table>

Abbreviations: CI, confidence interval; ETT, endotracheal tube; SAP, systolic arterial pressure; 95% SpO₂, transcutaneous oxygen saturation of arterial blood.
*P=.01.
†P=.002.
‡P=.005 between supine and prone position groups.
Contraindications

PRONE POSITION

Relative contraindications for the prone position:

- Elevated ICP
- Intestinal ischemia
- Obesity
- Recent Abdominal Surgery

Absolute contraindications for the prone position:

- Spinal cord instability,
- Unstable facial fractures
- Anterior burns, open abdomen
- Increased abdominal pressures
- Unstable pelvic fractures.
Esophageal Balloon Manometry
History

• 1949, Buytendijk first showed that it was possible to use esophageal pressure as a surrogate for pleural pressure.

• In 1952, Dornhorst and Leathart showed that changes in pleural and esophageal pressures were similar and useful to understand respiratory mechanics.

• In 1955, Cherniack and colleagues confirmed that changes in pleural pressure were similar to changes in esophageal pressure, although the absolute values of pressures in the pleural space were often more negative than in the esophagus.
Esophageal Balloon Benefits

- Measuring Trans-Pulmonary pressure to set Inspiratory pressure and PEEP
- Assess WOB during spontaneous breathing
- Aid in diagnosing Patient-Ventilator dys-synchrony
- Aid in assessing recruitability during recruitment maneuver
- Measuring Chest wall and lung elastance separately
- Aid in weaning off mechanical ventilation
- Transmural vascular pressure (i.e. the difference between intravascular and extramural pressure reflected by $P_{es}$)

Despite all those benefits, this tool remains confined to research. Used in less than 1% of ARDS patients.
The Application of Esophageal Pressure Measurement in Patients with Respiratory Failure

- A physiologically based ventilator strategy should take the trans-pulmonary pressure into account
- Despite all those benefits, this tool remains confined to research
- Used in less than 1% of ARDS patients
Mechanical Ventilation Guided by Esophageal Pressure in Acute Lung Injury

### Table 4. Clinical Outcomes

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Esophageal-Pressure–Guided (N = 30)</th>
<th>Conventional Treatment (N = 31)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>28-Day mortality — no. (%)</td>
<td>5 (17)</td>
<td>12 (39)</td>
<td>0.055</td>
</tr>
<tr>
<td>180-Day mortality — no. (%)</td>
<td>8 (27)</td>
<td>14 (45)</td>
<td>0.13</td>
</tr>
<tr>
<td>Length of ICU stay — days</td>
<td></td>
<td></td>
<td>0.16</td>
</tr>
<tr>
<td>Median</td>
<td>15.5</td>
<td>13.0</td>
<td></td>
</tr>
<tr>
<td>Interquartile range</td>
<td>10.8–28.5</td>
<td>7.0–22.0</td>
<td></td>
</tr>
<tr>
<td>No. of ICU-free days at 28 days</td>
<td></td>
<td></td>
<td>0.96</td>
</tr>
<tr>
<td>Median</td>
<td>5.0</td>
<td>4.0</td>
<td></td>
</tr>
<tr>
<td>Interquartile range</td>
<td>0.0–14.0</td>
<td>0.0–16.0</td>
<td></td>
</tr>
<tr>
<td>No. of ventilator-free days at 28 days</td>
<td></td>
<td></td>
<td>0.50</td>
</tr>
<tr>
<td>Median</td>
<td>11.5</td>
<td>7.0</td>
<td></td>
</tr>
<tr>
<td>Interquartile range</td>
<td>0.0–20.3</td>
<td>0.0–17.0</td>
<td></td>
</tr>
<tr>
<td>No. of days of ventilation among survivors</td>
<td></td>
<td></td>
<td>0.71</td>
</tr>
<tr>
<td>Median</td>
<td>12.0</td>
<td>16.0</td>
<td></td>
</tr>
<tr>
<td>Interquartile range</td>
<td>7.0–27.5</td>
<td>7.0–20.0</td>
<td></td>
</tr>
</tbody>
</table>

### Conclusions

As compared with the current standard of care, a ventilator strategy using esophageal pressures to estimate the transpulmonary pressure significantly improves oxygenation and compliance. Multicenter clinical trials are needed to determine whether this approach should be widely adopted. (ClinicalTrials.gov number, NCT00127491.)
Trans-Pulmonary Pressure

\[ P_{tp} = P_{alv} - P_{pl} \]

Is the distending pressure of the alveoli

Too high during inhalation → boom rupture (stress)

Too low during exhalation → fssss collapse (strain)
Trans-Pulmonary Measurement

- Goal is to keep Inspiratory PL < 15-20 cmH2O, to avoid lung stress (over distension, i.e. volutrauma and barotrauma) i.e. Stress
- Goal to keep Expiratory PL > 0 (0-5) cmH2O to avoid lung strain (repeated opening and closing of alveoli, i.e. atelectatotrauma) i.e. Strain

Transpulmonary Measurement
Compliance
Respiratory System, Chest Wall, Lung

Pressure-Volume Curve for Lungs, Chest Wall, and Combined Lung/Chest Wall

- Slope = compliance
- Transmural (in – out)
  - For lung
    - alveolar – pleural
  - For chest wall
    - pleural – atm
  - For unit
    - alveolar – atm
- Lung pressures referred to atm press (zero)
  - Chest wall likes to expand
  - Lung likes to collapse
It is NOT enough to look for the Plateau pressure (1 side of the coin)
Patient – Ventilator Asynchrony
Weaning from mechanical ventilation

- Esophageal Balloon is needed to calculate both: Work Of Breathing (WOB) and Pressure-Time Product (PTP).

- Multiple studies have shown the significance of monitoring the WOB & PTP during weaning trials. The higher the variables, the higher the likelihood of failing the trial.

Am J Respir Crit Care Med 1997;155:906–915
Understanding the real Filling pressure of the Heart

Mean Pes is the more convenient technique to estimate extramural pressure and therefore the transmural filling pressures, that is, the intravascular minus the surrounding extravascular pressure

CVP-Pes
PAWP-Pes
LVEDP-Pes
New: Use in APRV
THANK YOU
Be Happy, Be Thankful and Appreciate what you have

MAHALO