Indications for Mechanical Ventilation

After agreeing to speak…

• I find it very difficult to teach mechanical ventilation; maybe you have a better way.

• Just remember that the course is for internal medicine board review, not pulmonary board review and the participants can get a little irritable (as reflected in their comments about the lectures) if it is too complicated.

• The lectures are also on a Friday evening after they have been sitting in a lecture hall for several days so they may be a little less receptive then they might be earlier in the week.

Outline

• Indications for mechanical ventilation

• Modes of ventilation (including NIPPV)

• Ventilator as diagnostic tool

• Evidence based mechanical ventilation
  – Use in ARDS
  – “Weaning”
  – Complications

Disclosures

• Apnex Medical
Indications for Mechanical Ventilation

- Hypoxemia
- Hypoventilation
- Work of Breathing
- Airway Protection

Principles of Mechanical Ventilation

- Minute Ventilation = Respiratory Rate x Tidal Volume
- Alveolar Ventilation = RR x (TV – dead space)

- pCO₂ inversely proportional to alveolar ventilation
  - to ↓ pCO₂  ↑ alveolar ventilation
  - to ↑ pCO₂  ↓ alveolar ventilation

Principles of Mechanical Oxygenation

- Alveolar gas equation:
  \[ \text{PAO}_2 = \text{FiO}_2(\text{Patm} – \text{PH}_2\text{O}) – \text{PaCO}_2/R \]

- \( \text{PaO}_2 \) proportional to airway pressure
  - ↑ airway pressure by ↑ PEEP

  - to ↑ \( \text{pO}_2 \)
  - ↑ \( \text{FiO}_2 \)
  - ↑ PEEP

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Common Ventilator Modes

- Assist/Control
  - Assists every spontaneous breath and controls minute ventilation
    - Volume cycled ventilation (VCV)
    - Pressure cycled (PCV)

- Pressure Support
  - Supports every spontaneous breath
  - ~BiPAP

Assist/Control

- No patient effort
  - Triggered by set RR
  - Cycles off once tidal volume is delivered or set pressure is achieved for a certain amount of time
**Assist/Control**

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**Advantages**
- Control of tidal volume and minute ventilation

**Disadvantages**
- Patient comfort

**Pressure Support Ventilation**

- Requires patient effort
  - Triggered by patient
  - Cycles off once flow decreases

**Advantages**
- Patient comfort
- "Weaning"

**Disadvantages**
- Minute ventilation not assured

**Non-invasive positive pressure ventilation**

**CPAP**
- PEEP

**BIPAP**
- Expiratory PAP = PEEP
- Inspiratory PAP = PEEP + PS

- Can improve oxygenation
- Hemodynamic effects:
  - ↓ Preload
  - ↓ Afterload

- Improve ventilation
- Decrease work of breathing
Non-invasive positive pressure ventilation

**Indications**
- Sleep apnea
- Heart failure
- Hypercapnic respiratory failure

**Contraindications**
- Copious Secretions
- Altered mental status
- Need for secure airway

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Ventilator as diagnostic tool

- The ventilator can be used to determine whether respiratory failure is a problem of lung parenchyma, the airways, or respiratory muscles
- Perform “inspiratory hold” to measure:
  - Compliance = \( \frac{\Delta P}{\Delta V} \)
  - Resistance = \( \frac{\Delta P}{\text{Flow}} \)

Plateau pressure ~ Compliance

\[
C = \text{Tidal Volume} \times \frac{\text{Plateau} - \text{PEEP}}{\text{Tidal Volume}}
\]

Normal: 50-100ml/cmH₂O

**Pressure**
- \( \text{PIP} \)
- \( \text{Plateau} \)
- \( \text{PEEP} \)

**Flow**

**Tidal Volume**

\[
\Delta P = C \times \text{Tidal Volume} + R \times \text{Flow}
\]

Normal: 5-10 cmH₂O/L/s
Intrinsic or “Auto” PEEP

- Pressure will build in the chest if there is not adequate expiratory time to empty each tidal volume

How to measure Auto PEEP

- Qualitatively

Intrinsic or “Auto” PEEP

- Usually only clinically relevant in those with obstructive lung disease (e.g. COPD)
- Can cause:
  - Ventilator dyssynchrony
  - Barotrauma
  - Hypotension

How to measure Auto PEEP

- Quantitatively
How to treat Auto PEEP

- Decrease minute ventilation
  - Decrease TV
  - Decrease RR
- Increase expiratory time
  - Increase inspiratory flow rate
- Increase extrinsic PEEP to facilitate synchrony

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Acute Respiratory Distress Syndrome

- ARDS is a type of acute diffuse lung injury associated with recognized risk factors, characterized by inflammation leading to increased pulmonary vascular permeability and loss of aerated lung tissue.
- The hallmarks of the clinical syndrome are hypoxemia and bilateral radiographic opacities (standard chest x-ray or CT scan).

Acute Respiratory Distress Syndrome

"... uncontrolled septicemia leads to frothy pulmonary edema that resembles serum, not the sanguineous transudative fluid seen in dropsy or congestive heart failure."

Opler W, McCrae T. The principles and practice of medicine, designed for the use of practitioners and students of medicine. 10th ed., 1233 pp. New York, Appleton; 1925

<table>
<thead>
<tr>
<th>ARDS</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timing</td>
<td>Acute onset within 1 week of a known clinical risk factor or new/incipient respiratory symptoms</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hyoxemia</td>
<td>$\text{PaO}_2/\text{FiO}_2 \geq 200$ with PEEP/CPAP $\geq 5$</td>
<td>$\text{PaO}_2/\text{FiO}_2 \geq 200$ with PEEP $\geq 5$</td>
<td>$\text{PaO}_2/\text{FiO}_2 \geq 100$ with PEEP $\geq 10$</td>
</tr>
<tr>
<td>Origin of Edema</td>
<td>Respiratory failure not fully explained by cardiac failure or fluid overload**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiological Abnormalities</td>
<td>Bilateral opacities*</td>
<td>Bilateral opacities*</td>
<td>Opacities involving 3 or 4 quadrants*</td>
</tr>
<tr>
<td>Additional Physiological Disturbance</td>
<td>N/A</td>
<td>N/A</td>
<td>$V_E \leq 10 \text{ L/min}$ or $C_\text{O}_2 \geq 40 \text{ mEq/L}$</td>
</tr>
</tbody>
</table>

**ARDS induced by diffuse, nodular, masses, or interstitial lung collapse, use scoring out of COP 3 criteria

* Bilateral opacities assessment if no risk factor present (See table)

$V_E = V_A \times \text{PAO}_2/40$
Acute Respiratory Distress Syndrome

(a) Capillary stress fracture with incipient extravasation of erythrocyte.

(b) Higher power view of stress fracture showing exposure of collagen filaments.

Probability of survival of being discharged home and breathing without assistance during the first 180 days after randomization in patients with acute lung injury and the acute respiratory distress syndrome.

Main Outcome Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Group Receiving Lower Tidal Volumes</th>
<th>Group Receiving Traditional Tidal Volumes</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Death before discharge home and breathing without assistance (%)</td>
<td>31.9</td>
<td>39.8</td>
<td>0.007</td>
</tr>
<tr>
<td>Breathing without assistance by day 28 (%)</td>
<td>66.7</td>
<td>55.0</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>No. ventilator-free days, days 1 to 28</td>
<td>12±11</td>
<td>10±11</td>
<td>0.807</td>
</tr>
<tr>
<td>Ranquins, days 1 to 28 (%)</td>
<td>10</td>
<td>11</td>
<td>0.43</td>
</tr>
<tr>
<td>No. of days without failure of nonpulmonary organs or systems, days 1 to 28</td>
<td>15±11</td>
<td>12±11</td>
<td>0.806</td>
</tr>
</tbody>
</table>

"There ain't no such thing as weaning"
“There ain’t no such thing as weaning”

• Reasons to stay intubated
  – Sick
  – Sicker
  – Not Spontaneously breathing
  – Secretions/suctioning requirement
  – Studies planned
  – Sedation

“Pneumonia 48hrs after initiation of mechanical ventilation”

• New or progressive infiltrate
• Leukocytosis
• Purulent secretions

Ventilator Acquired Pneumonia (VAP)

• Pneumonia 48hrs after initiation of mechanical ventilation
• New or progressive infiltrate
• Leukocytosis
• Purulent secretions

VAP Prevention

• Recommended
  – Noninvasive ventilation
  – Orotracheal intubation
  – Ventilator circuit change for new patient or when soiled
  – Hand washing
  – Closed endotracheal suction system
  – Continuous aspiration of subglottic secretions
  – Minimize sedation
  – Oral decontamination with chlorhexidine
  – Semi-recumbent position

• Not Recommended
  – Selective gut decontamination

Liberate from mechanical ventilation ASAP!

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Case #1

• A 40 year-old obese man (weight = 100kg) with a recent sick contact presents with shortness of breath and is found to be hypoxic. Chest X-ray shows bilateral multifocal pneumonia. He is intubated using etomidate and succinylcholine and admitted to the ICU. Which of the following initial ventilator settings would be most appropriate?

a) Pressure Support 10/5  FiO₂ 0.4
b) Pressure Support 15/5  FiO₂ 1.0
c) A/C 600mL x 20bpm PEEP 5  FiO₂ 1.0
d) A/C 425mL x 20bpm PEEP 5  FiO₂ 1.0
e) Pressure Control 35/5 20bpm  FiO₂ 1.0
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Case #2

- The same 40 year-old man with pneumonia/ARDS improves with antibiotics and time. What is the fastest way to liberate from mechanical ventilation?
  
a) Pressure support wean 2cmH₂O per day  
b) Wean PEEP 1cmH₂O per day  
c) Spontaneous breathing trial  
d) Spontaneous breathing trial paired with interruption of sedation  
e) Rest patient on AC at night, pressure support wean during the day

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References
