Mechanical Ventilation for the Non-Intensivist: Theory

Ewan C. Goligher MD PhD
Assistant Professor,
Interdepartmental Division of Critical Care Medicine
University of Toronto
Educational Objectives

Concepts

- Goals of mechanical ventilation
- How breathing works
- How mechanical ventilation works
- Side effects of mechanical ventilation
Goals of Mechanical Ventilation

- Primum non nocere
- Oxygen delivery
- Acid-base homeostasis
How Breathing Works

- Gas exchange
  - Oxygen
  - Carbon dioxide
How Breathing Works

Lung Volumes and Capacities

- Maximum possible inspiration
- Inspiratory reserve volume
- Expiratory reserve volume
- Total lung capacity
- Residual volume
- Functional residual capacity
- Inspiratory capacity
- Tidal volume
- Maximum voluntary expiration
- Vital capacity

AnaesthesiaUK
How Breathing Works
How Breathing Works
How Breathing Works

- Control of breathing
  - Trigger
  - Target
  - Limit/cycling criterion
How Mechanical Ventilation Works

• CO₂ clearance - minute ventilation
  - Trigger
  - Target
  - Limit/cycling criterion

• Oxygenation
  - F₁O₂
  - PEEP
How Mechanical Ventilation Works

- Getting a respiratory rate (f)

<table>
<thead>
<tr>
<th>Controller</th>
<th>Trigger</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ventilator</td>
<td>Time (1/F set by RT)</td>
</tr>
<tr>
<td>Patient</td>
<td>Flow or pressure</td>
</tr>
</tbody>
</table>
How Mechanical Ventilation Works

• Getting a tidal volume (Vt)

<table>
<thead>
<tr>
<th>Mode</th>
<th>Target</th>
<th>Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume control</td>
<td>Flow</td>
<td>Volume</td>
</tr>
<tr>
<td>Pressure control</td>
<td>Pressure</td>
<td>Time</td>
</tr>
<tr>
<td>Pressure support</td>
<td>Pressure</td>
<td>Flow</td>
</tr>
</tbody>
</table>
How Mechanical Ventilation Works

Pressure

Flow

Volume
How Mechanical Ventilation Works

- How does mechanical ventilation improve oxygenation?
  - Improves V/Q matching
  - Reduces shunt
  - Allows delivery of assured high $F_{iO_2}$

<table>
<thead>
<tr>
<th>$F_{iO_2}$</th>
<th>Increases alveolar $P_AO_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive end-expiratory pressure (PEEP)</td>
<td>Keeps alveoli open (recruitment)</td>
</tr>
</tbody>
</table>

Goligher, Ferguson, Brochard *Lancet* 2016
Side Effects of Mechanical Ventilation

- Hemodynamic effects of positive pressure
- Ventilator-induced lung injury
- Ventilator-induced respiratory muscle weakness
Hemodynamic Effects

• Heart-lung interactions
• Specific examples
  - LV dysfunction
  - RV dysfunction
• Intubation considerations
Ventilator-Induced Lung Injury

VENTILATION WITH LOWER TIDAL VOLUMES AS COMPARED WITH TRADITIONAL TIDAL VOLUMES FOR ACUTE LUNG INJURY AND THE ACUTE RESPIRATORY DISTRESS SYNDROME
Ventilator-Induced Diaphragm Dysfunction

Fiber Size

Slow Myosin Heavy Chain

Fast Myosin Heavy Chain

Change in diaphragm thickness over time (% of baseline)

Group: Diaphragm Thickness Change
- >10% loss on or before day 8
- <10% change on or before day 8
- >10% gain on or before day 8
Mechanical Ventilation...

Is not a benign intervention!
Key Points

• Basic respiratory physiology

• How mechanical ventilation works

• Mechanical ventilation is not a benign intervention!