Complications and Adverse Effects of Mechanical Ventilation

Identify & Prevention Strategies

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Overview

- Goals of Mechanical Ventilation
- Types of Complications and Adverse Effects
- Ventilator-Induced Lung Injury
- Ventilator-Associated Pneumonia
- Take home messages
Goals of Mechanical Ventilation

- Provide adequate gas exchange
- Deliver alveolar ventilation and maintain alveolar recruitment
- Minimise work of breathing
- Promote patient-ventilator synchrony
- Prevent or minimise the potential complications of Mechanical Ventilation (M.V)
Types of Complications and Adverse Effects

Patient-Ventilator Associated Complications

- Airway dislodgment or disconnection
- Circuit leaks
- Tracheal and Oral Injury
- Inadequate humidity
- Excessive rain out in ventilator tubing
- Airway obstructions

(Hess, MacIntyre, Mishoe et. al, 2011 p. 465)
Types of Complications and Adverse Effects

Pulmonary Complications

- **Ventilator-Induced Lung Injury (VILI)**
  - Volutrauma
  - Barotrauma
  - Biotrauma
  - Atelectrauma
  - Oxygen Toxicity

- **Ventilator-Associated Pneumonia (VAP)**

(Hess, MacIntyre, Mishoe et. al, 2011 p. 465)
Types of Complications and Adverse Effects

Cardiovascular and Renal Complications
- Reduced venous return, cardiac output and hypotension
- Decline in urine output

Gastrointestinal and Nutritional Complications
- Gastritis and ulcer formation
- Malnutrition

Neuromuscular and Psychological Complications
- ICU acquired weakness, DVT and pressure ulcers
- Sleep deprivation, sedation, delirium, depression

**Ventilator-Induced Lung Injury (VILI)**

The delivery of positive pressure to the airways during mechanical ventilation can potentially cause the lungs to be damaged in varying circumstances;

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volutrauma</td>
<td>Alveolar over-distension</td>
</tr>
<tr>
<td>Barotrauma</td>
<td>High to excessive alveolar pressures</td>
</tr>
<tr>
<td>Biotrauma</td>
<td>Inflammatory mediators</td>
</tr>
<tr>
<td>Atelectrauma</td>
<td>Repeated recruitment and collapse</td>
</tr>
<tr>
<td>Oxygen Toxicity</td>
<td>High FiO2</td>
</tr>
</tbody>
</table>

VILI may occur in previously healthy lungs or aggravate pre-existing conditions such as ALI, ARDS

Approximately 25% of patients who are M.V develop VILI.

(Hess, MacIntyre, Mishoe et. al, 2011, p 465-467)
Volutrauma and Barotrauma

Damage to the lung occurs as a result of repeated stretching (over-distention) of alveolar structures and excessive transpulmonary pressures to the point of rupture.

As a result, air leaks into the plural space resulting in conditions including pneumothorax, pneumomediastinum and subcutaneous emphysema (Slutsky and Ranieri, 2013, p. 2128-2130, and Chang 2014, p. 90).

Volutrauma = transpulmonary pressures >30 to 35 cm H2O.
Barotrauma = increasing transpulmonary pressures >50cm H2O.
Biotrauma

Widespread alveolar damage may lead to an increase in inflammatory cytokines in the lungs, resulting in VILI.

Systemic cytokine release with bacterial translocation are involved in the systemic inflammatory response (SIRS), potentially leading to multiple organ dysfunction (MODS), increasing mortality (Slutsky and Ranieri, 2013, p. 2130 and Hess, MacIntyre, Mishoe et. al, 2011, p 466).
Atelectrauma

Recurrent alveolar re-opening and collapsing of the under-recruited alveoli during ventilation causes injury affecting surfactant functioning, collapse of the dependant portions of the lung and regional hypoxia (Soni and Williams, 2008 p. 448-449).

Alveoli 1 has more surfactant per area & will inflate at a faster rate than 2, until equal in size.

Alveoli 1 has a higher pressure (small radius) & will likely collapse & it’s harder to inflate.

Airflow travels the path of least resistance.

Shearing Injury.
Oxygen Toxicity

Oxygen concentrations nearing 100% are known to cause oxidant injuries in the airways. Increased reactive oxygen species (ROS) lead to inflammation, secondary tissue injury, depletion of cellular antioxidant defences and cell death (Hess, MacIntyre, Mishoe et. al, 2011, p 466).
Lung Protective Ventilation Strategies

Volutrauma and Barotrauma are the most common causes of ventilated-associated lung injuries, resulting from tidal volume settings that generate high or excessively high pressures.

Mortality rates prior to 2000 was as significant as 40-50% from acute lung injury and acute respiratory distress syndrome (Ventilation with lower tidal volumes as compared with traditional tidal volumes for ALI and the ARDS, 2000).

Lung protective ventilation strategies were implemented as a result of the ARDS Network Trial (2000), demonstrating lung protection strategies lead to a 22% reduction in mortality.
# Lung Protective Ventilation Strategies

<table>
<thead>
<tr>
<th>Aim to Prevent Injury</th>
<th>Variable</th>
<th>ARDSnet Protocol Protective Ventilation Strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recruit alveoli without volutrauma</td>
<td>Tidal Volume</td>
<td>≤ 6ml/kg of predicted body weight</td>
</tr>
<tr>
<td>Recruit alveoli without barotrauma</td>
<td>Plateau Pressure</td>
<td>≤ 30 cm H2O</td>
</tr>
<tr>
<td>Biotrauma</td>
<td>Set VT and target Plateau Pressures</td>
<td>As above, use of neuromuscular blockers may help</td>
</tr>
<tr>
<td>Volutrauma &amp; barotrauma</td>
<td>Ventilation Rate</td>
<td>6-35bpm, adjusted to achieve an arterial pH 7.3 to 7.45</td>
</tr>
<tr>
<td></td>
<td>Ratio of breath Duration (Insp/Exp)</td>
<td>1:1 to 1:3</td>
</tr>
<tr>
<td>Atelectrauma, shearing Injury</td>
<td>Positive-End Expiratory Pressure (PEEP)</td>
<td>≥ 8 cm H$_2$O, PaO$_2$ 55-80 mm Hg, open lung ventilation strategies</td>
</tr>
<tr>
<td>Oxygen Toxicity</td>
<td>Oxygenation goal</td>
<td>PaO$_2$ 55-80 mm Hg, SpO$_2$ 88-95%, Higher PEEP, recruitment strategies</td>
</tr>
</tbody>
</table>

(Nickson & LITFL, 2013 and Hess, Maclntyre, Mishoe et. al, 2011, p 466-467).
Lung Protective Ventilation Strategies

How to Calculate Predicted Body Weight

Tidal volume ($V_t$) is the volume of the patient’s breath, measured in mls.

Measuring the patient’s height is a must to calculate a patient’s predicted body weight (PBW).

Evidence from the ARDS Network (2000) recommends aiming for 6-8ml/kg $V_t$ in all ventilated patients, to achieve a mortality benefit (Ventilation with lower tidal volumes as compared with traditional tidal volumes for ALI and the ARDS, 2000 cited in Slutsky and Ranieri, 2013, p. 2131).
ARDSnet calculation for PBW for females and males

Demi-span
This is measured with the arm outstretched straight, palm forwards, from the base of the middle/ring finger to the sternal notch using a non-stretch tape measure (Bassey, 1986).

Females: Height in cm = (1.35 x demi-span cm (84.5)) + 60.1
Males: Height in cm = (1.4 x demi-span cm) + 57.8

Females: (height in cm - 152.4) x 0.91 + 45.5
e.g. (174 -152.4) = 21.6 x 0.91 + 45.5 = **65.2 PBW**
65.2 x 6 ml = **390 mls**

Males: (height in cm - 152.3) x 0.91 + 50
e.g. (183 -152.3) = 30.7 x 0.91 + 50 = **77.9 PBW**
77.9 x 6 = **467 mls**

(NHLBI ARDS network, 2014)
# Predicted Body Weight


## Ideal Body Weight
Calculates ideal body weight by the Devine formula.

<table>
<thead>
<tr>
<th>Sex</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Height</th>
<th>170 cm</th>
</tr>
</thead>
</table>

**Desired Tidal Volume**

Ventilator tidal volumes should be based on ideal body weight. Set your target tidal volume in mL/kg, and get a total tidal volume for your settings.

| mL/kg | 6 |
Ventilator-Associated Pneumonia (VAP)

- Is a nosocomial pneumonia occurring in patients who are mechanically ventilated >48 hours.

- The incidence of VAP increases to 10-30% after this timeframe.

- Depending on individual comorbidities and causative organism, mortality rates can range from 25-70%.

- VAP increases a patient’s time being ventilated, hospital LOS, healthcare costs, morbidity and mortality.

How to Identify VAP

- Often seen on chest X-rays as new infiltrates or
- when clinical signs of infection begin to develop;
  - raised white cell counts
  - purulent sputum
  - decrease in oxygen saturations, with difficulty improving saturations with interventions
  - patient becomes febrile

(Elliott, Aitken, Chaboyer, 2012, p. 358)
Treatment of VAP

Most cases (60%) of VAP involve gram-negative bacilli of *Pseudomonas aeruginosa* and *Acinetobacter* spp.

With 20% of cases are associated with gram-positive *Staphylococcus aureus*.

**Timely administration of antibiotic therapy is a priority with treatment**, as mortality increases with delay (if not given within 24 hours of diagnosis).

Obtain endotracheal secretions from a bronchoalvoelar lavage (BAL) to confirm causative organism and treat with antibiotics (Elliott, Aitken, Chaboyer, 2012, p. 358-359).
Prevention is the Key to VAP

STOP GERMS!
Wash your Hands
Prevention is the Key

5 moments of hand washing +

Ventilation Care Bundle

1. Head of bed elevated at least 30 degrees/upright positioning
2. Daily sedation breaks with assessment to ween/extubate
3. Stress ulcer prophylaxis
4. Deep vein thrombosis (DVT) prophylaxis
5. Thorough regular teeth brushing with subglottic suctioning

Regular checks on cuff pressures, early mobilisation, regular PAC, use of vibration functions on beds

A comparison of Listerine® and sodium bicarbonate oral cleansing solutions on dental plaque colonisation and incidence of ventilator associated pneumonia in mechanically ventilated patients: A randomised control trial

A.M. Berry*
Current Research (Berry)

<table>
<thead>
<tr>
<th></th>
<th>No result</th>
<th>No change</th>
<th>More growth</th>
<th>Less growth</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control n (%)</td>
<td>86 (62)</td>
<td>34 (27.6)</td>
<td>16 (11.5)</td>
<td>2 (1.4)</td>
<td>138</td>
</tr>
<tr>
<td>Bicarbonate</td>
<td>76 (57)</td>
<td>39 (29.3)</td>
<td>10 (7.5)</td>
<td>8 (6)</td>
<td>133</td>
</tr>
<tr>
<td>Listerine b</td>
<td>83 (65.3)</td>
<td>27 (21.2)</td>
<td>10 (7.8)</td>
<td>7 (5.5)</td>
<td>127</td>
</tr>
<tr>
<td>Total</td>
<td>245</td>
<td>100</td>
<td>36</td>
<td>17</td>
<td>398</td>
</tr>
</tbody>
</table>

- a No longer in study at Day 4.
- b Values are expressed as number (%) of samples.
- c By $\chi^2$ test.

(Berry, 2013)
Take Home Messages

- Prevention is the Key
- Reflect on own practice to improve patient’s cares and reduce ventilator induced or associated complications
- Think about the Ventilator Care Bundle and actively practice this
- Advocate for your patients
- Measure all ventilated patients demi-span for calculation of 6mls/kg of tidal volume.
References


References


