Mechanical Ventilation

A Beginner's Guide
Determinants of Gas Concentration

$\text{PaO}_2$  $\text{PaCO}_2$
Determinants of Gas Concentration

- PaO$_2$
- PaCO$_2$
- FiO$_2$
Determinants of Gas Concentration

1. $\text{FiO}_2$
2. Alveolar Ventilation
Determinants of Gas Concentration

1. $\text{FiO}_2$
2. Alveolar Ventilation
3. Shunt / VQ mismatch
Determinants of Gas Concentration

1. $\text{FiO}_2$
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1. Metabolic Rate
Determinants of Gas Concentration

- **PaO₂**
  1. FiO₂
  2. Alveolar Ventilation
  3. Shunt / VQ mismatch

- **PaCO₂**
  1. Metabolic Rate
  2. Alveolar Ventilation
Respiratory Failure

Type 1

$O_2 \downarrow$

Type 2

$O_2 \downarrow$, $CO_2 \uparrow$
Type 1

- Pneumonia
- Bronchiolitis
- Contusions
- Atelectasis
- Pulmonary oedema
- ARDS
- PE

Type 2

- CNS depression
- Neuromuscular disorders
- Pulmonary fibrosis
- COPD
- Asthma
- Airway obstruction
Pneumonia
Bronchiolitis
Contusions
Atelectasis
Pulmonary oedema
ARDS
PE

CNS depression
Neuromuscular disorders
Pulmonary fibrosis
COPD
Asthma
Airway obstruction
Modes of Ventilation
Modes of Ventilation

Types of Breath

Mandatory  Spontaneous  Assisted
Modes of Ventilation

- **Types of Breath**
  - Mandatory
  - Assisted
  - Spontaneous

- **Trigger**
  - Flow
  - Pressure
  - Neuromuscular impulse
Modes of Ventilation

**Types of Breath**
- Mandatory
- Spontaneous
- Assisted

**Trigger**
- Flow
- Pressure
- Neuromuscular impulse

**Limit (cycle)**
- Volume
- Pressure (time)
- Neuromuscular impulse
Ventilation Limit
Ventilation Limit

Volume
Ventilation Limit

Volume

Pressure
Ventilation Limit

Volume

Pressure

Neuromuscular impulse
Modes
Modes

Continuous Mandatory Ventilation (CMV)
Modes

Continuous Mandatory Ventilation (CMV)
Assist Control (AC)
Modes

Continuous Mandatory Ventilation (CMV)

Assist Control (AC)

Intermittent Mandatory Ventilation (IMV)
Modes

Continuous Mandatory Ventilation (CMV)

Assist Control (AC)

Intermittent Mandatory Ventilation (IMV)

SIMV
Modes

Continuous Mandatory Ventilation (CMV)

Assist Control (AC)

Intermittent Mandatory Ventilation (IMV)
Modes

Continuous Mandatory Ventilation (CMV)

Assist Control (AC)

Intermittent Mandatory Ventilation (IMV)

Synchronised Intermittent Mandatory Ventilation (SIMV)
Modes

Continuous Mandatory Ventilation (CMV)

Assist Control (AC)

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Synchronised Intermittent Mandatory Ventilation (SIMV)

Synchronised Intermittent Mandatory Ventilation with PSV (SIMV + PSV)
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Pressure Support
Modes

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Synchronised Intermittent Mandatory Ventilation with PSV (SIMV + PSV)

Pressure Support

Neurally Adjusted Ventilatory Assist
Modes of Ventilation
Modes of Ventilation

Assist Control
(Pressure Control)
Modes of Ventilation

**Assist Control**
(Pressure Control)  
Greatest MAP for least PIP
Modes of Ventilation

Assist Control
(Pressure Control)  Greatest MAP for least PIP

SIMV + PS
(volume control)
## Modes of Ventilation

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Modes of Ventilation

**Assist Control**
*(Pressure Control)*

Greatest MAP for least PIP

**SIMV + PS**
*(volume control)*

easier control of tidal volume
less prone to accidental hyperventilation
breath stacking somewhat less likely

**Pressure Support**
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Lung Protective Ventilation
Lung Protective Ventilation

- Volutrauma
- Oxygen Toxicity
- Biotrauma

Ventilator Induced Lung Injury
Tidal Volume


10 University Hospitals of North America - The ARDS Network

RCT - $V_t$ 12 vs 6 mL/Kg ideal body weight

861 ventilated patients with ARDS / ALI

180 day mortality 31.0% vs 39.8% $P=0.007$

10 University Hospitals of North America - The ARDS Network

RCT - High PEEP vs Low PEEP strategy

861 ventilated patients with ARDS / ALI

180 day mortality 31.0% vs 39.8%  P=0.007

<table>
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<tr>
<th>Characteristic</th>
<th>ALVEOLI, a 2004</th>
<th>LOVS, b 2008</th>
<th>EXPRESS, c 2008</th>
</tr>
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<tbody>
<tr>
<td>Inclusion criteria</td>
<td>Acute lung injury with $\text{PaO}_2: \text{FiO}_2 \leq 300^a$</td>
<td>Acute lung injury with $\text{PaO}_2: \text{FiO}_2 \leq 250^a$</td>
<td>Acute lung injury with $\text{PaO}_2: \text{FiO}_2 \leq 300^a$</td>
</tr>
<tr>
<td>Recruiting hospitals (country)</td>
<td>23 (United States)</td>
<td>30 (Canada, Australia, Saudi Arabia)</td>
<td>37 (France)</td>
</tr>
<tr>
<td>Patients randomized to higher vs lower PEEP</td>
<td>276 vs 273</td>
<td>476 vs 509 b</td>
<td>385 vs 383 c</td>
</tr>
<tr>
<td>Validity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concealed allocation</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Follow-up for primary outcome, %</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Blinded data analysis</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Stopped early</td>
<td>Stopped for perceived futility</td>
<td>No</td>
<td>Stopped for perceived futility</td>
</tr>
<tr>
<td>Experimental intervention</td>
<td>Higher PEEP according to $\text{FiO}_2$ chart, recruitment maneuvers for first 80 patients</td>
<td>Higher PEEP according to $\text{FiO}_2$ chart, required plateau pressures $\leq 40$ cm H$_2$O, recruitment maneuvers</td>
<td>PEEP as high as possible without increasing the maximum inspiratory plateau pressure $&gt; 28-30$ cm H$_2$O</td>
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<tr>
<td>Control intervention</td>
<td>Conventional PEEP according to $\text{FiO}_2$ chart, required plateau pressures $\leq 30$ cm H$_2$O, no recruitment maneuvers</td>
<td>Conventional PEEP according to $\text{FiO}_2$ chart, required plateau pressures $\leq 30$ cm H$_2$O, no recruitment maneuvers</td>
<td>Conventional PEEP (5-9 cm H$_2$O) to meet oxygenation goals</td>
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<tr>
<td>Ventilator procedures</td>
<td>Target tidal volumes of 8 ml/kg of predicted body weight; plateau pressures $\leq 30$ cm H$_2$O (with exception as above); respiratory rate $\leq 35$/min, adjusted to achieve arterial pH 7.30-7.45; ventilator mode: volume-assist control (except higher PEEP group in LOVS required pressure control); oxygenation goals: $\text{PaO}_2$ 55-80 mm Hg and $\text{SpO}_2$ 88%-95%; standardized weaning</td>
<td></td>
<td></td>
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10 University Hospitals of North America - The ARDS Net RCT - High PEEP vs Low PEEP strategy

861 ventilated patients with ARDS / ALI

180 day mortality 31.0% vs 39.8%  P=0.007
# PEEP

## PEEP (cmH2O)

<table>
<thead>
<tr>
<th>FiO2</th>
<th>Low</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.3</td>
<td>5</td>
<td>12</td>
</tr>
<tr>
<td>0.4</td>
<td>8</td>
<td>14</td>
</tr>
<tr>
<td>0.5</td>
<td>10</td>
<td>16</td>
</tr>
<tr>
<td>0.6</td>
<td>12</td>
<td>18</td>
</tr>
<tr>
<td>0.7</td>
<td>14</td>
<td>20</td>
</tr>
<tr>
<td>0.8</td>
<td>14</td>
<td>22</td>
</tr>
<tr>
<td>0.9</td>
<td>18</td>
<td>22</td>
</tr>
<tr>
<td>1.0</td>
<td>20</td>
<td>24</td>
</tr>
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</table>

The graph shows the relationship between FiO2 and PEEP cmH2O for both high and low PEEP conditions. The y-axis represents PEEP cmH2O, ranging from 0 to 30, while the x-axis represents FiO2, ranging from 0.3 to 1.0. The blue line indicates high PEEP, and the green line indicates low PEEP.
Lung Protective Ventilation

- Volutrauma
- Oxygen Toxicity
- Biotrauma
- Atelectatrauma

Ventilator Induced Lung Injury
Healthy Lung
Healthy Lung

![Graph showing pressure-volume relationship in healthy lungs with PEEP and PIP points.](image-url)
Poorly Compliant Lung

![Graph showing Volume on the y-axis and Pressure on the x-axis. The graph illustrates a curve starting from PEEP and reaching PIP.](image)
Poorly Compliant Lung

Volume

Pressure

PEEP

PIP
Heterogeneous Lung

Volume

Pressure

PEEP

PIP
Heterogeneous Lung
High Frequency Oscillatory Ventilation
High Frequency Oscillatory Ventilation

\[ f = 3 - 10 \text{ Hz} \]

\[ V_t = 5 - 30 \text{ ml} \]

\[ \text{Mean Airway Pressure} = 35 - 45 \text{ mmHg} \]
High Frequency Oscillatory Ventilation

- \( f \) - 3 - 10 Hz
  (180 - 600 breaths per minute)
### High Frequency Oscillatory Ventilation

| $f$   | 3 - 10 Hz  
|       | (180 - 600 breaths per minute) |
| $V_t$ |              |
# High Frequency Oscillatory Ventilation

<table>
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<tr>
<th>Variable</th>
<th>Range</th>
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**High Frequency Oscillatory Ventilation**

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<th>Parameter</th>
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## High Frequency Oscillatory Ventilation

<p>| | |</p>
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</table>
| **f** | 3 - 10 Hz  
     | (180 - 600 breaths per minute) |
| **Vt** | 5 - 30 ml |
| **Mean Airway Pressure** | 35 - 45 mmHg |
High Frequency Oscillatory Ventilation

Key Points

• Understand the nature of your patient’s respiratory failure

• Choose the mode of ventilation appropriate for your patient

• $V_t$ 6 ml/Kg (ideal body weight)

• Titrate PEEP to FiO$_2$ or recruit and use the open lung tool