INTRODUCTION TO MECHANICAL VENTILATION

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OVERVIEW

What is mechanical ventilation?
What are the indications for mechanical ventilation?
How is normal ventilation different from mechanical ventilation?
What are the different modes and settings involved with mechanical ventilation?
Relate to clinical examples
Summary and Conclusions

MECHANICAL VENTILATION

2 major functions of the lung:
- Ventilation
- Respiration

Definition: Utilization of machines or devices to assist or replace spontaneous breaths during ventilation.
INDICATIONS FOR MECHANICAL VENTILATION

- Hypoxic Respiratory Failure
  - Severe hypoxemia with PaO2 < 50 mm Hg with supplemental oxygen.

Hypercapnic Respiratory Failure

Airway Protection
- Protection against aspiration
- Relieve upper airway obstruction

INTENTIONS OF MECHANICAL VENTILATION

Reverse oxygenation problems

Improve ventilation problems
- Reduce ventilatory muscle fatigue
- Reduce the work of breathing

Improve respiration
- Support or manipulate pulmonary gas exchange

MUSCLES OF VENTILATION

- Inspiration:
  - Rest
  - Exercise/ forced inspiration

- Expiration:
  - Rest
  - Exercise/ forced expiration
BIOMECHANICS OF NORMAL VENTILATION

Diaphragmatic Contraction
Compression of Abdominal Contents, thus Increasing Intra-Abdominal Pressure causing:
(a) Lateral Transmission of Pressure to the Lower Ribs Laterally = Expansion of Lower Rib Cage
(b) Upward and Outward Motion of Lower Ribs = Bucket Handle Motion
(c) Anterior/Posterior Motion of Upper Ribs = Pump Handle Motion
Increase in Thoracic Volume Vertically and Transversely
Decrease in Intrathoracic Pressure
Facilitates Inspiration & Venous Return

INSPIRATION: MUSCLES OF VENTILATION

• Diaphragm (2 hemi diaphragms each with a central tendon)
  − Arched high in the thorax at rest (dome) and pulled downward flattening the dome when contracted -> protrusion of the abdominal wall during inhalation.

• External Intercostals
  − Bucket handle movement of the rib cage.

LUNG VOLUMES AND CAPACITIES
PHYSIOLOGY INVOLVED WITH THE MECHANICS OF BREATHING

- **Airway Resistance**: Inflation entails the inspiratory muscles overcome:
  - The tendency of the lung to recoil inward
  - Resistance to flow offered by the airway

- **Lung Distensibility/Compliance**:
  - A change in volume for a given change in pressure.
  - Compliance = \( \frac{\Delta \text{Volume}}{\Delta \text{Pressure}} \)

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ARTERIAL OXYGENATION

- The ability of arterial blood to carry oxygen
- **PaO₂ / PO₂**
  - Hyperoxemia
  - Hypoxemia/hypoxia

- **SpO₂**

- **FiO₂**

- **Supplemental oxygen**

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RELATIONSHIP BETWEEN OXYGEN SATURATION AND PARTIAL PRESSURE O₂

<table>
<thead>
<tr>
<th>SpO₂</th>
<th>PaO₂</th>
<th>Signs and Symptoms</th>
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<tr>
<td>97-99</td>
<td>90-100</td>
<td>None</td>
</tr>
<tr>
<td>95</td>
<td>80</td>
<td>None</td>
</tr>
<tr>
<td>90</td>
<td>60</td>
<td>Tachycardia, tachypnea, restlessness</td>
</tr>
<tr>
<td>85</td>
<td>50</td>
<td>Incoordination, impaired judgment, labored respirations, confusion</td>
</tr>
<tr>
<td>80</td>
<td>45</td>
<td>As above</td>
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TWO TYPES OF VENTILATION

Negative Pressure Ventilation
• Pressure lower than the atmosphere allows inspiration to occur.
• Former Iron lung

Positive Pressure Ventilation
• Pressure higher than atmospheric pressure is provided to the intraalveolar space during inspiration.
• Current mechanical ventilator devices

2 TYPES OF POSITIVE PRESSURE VENTILATION

Non Invasive Positive Ventilation (NPPV)

Invasive Positive Pressure Ventilation

NON INVASIVE POSITIVE PRESSURE VENTILATION (NPPV)

Benefits of NPPV
Types of masks
• Nasal masks
• Face masks

Types of NPPV
• CPAP
• BiPAP
MODES OF MECHANICAL VENTILATION

3 important aspects of mechanical ventilation

• What triggers the ventilator?
• What aspect of inspiration is controlled by the ventilator?
• What aspect terminates the delivery of inspiration?

Most commonly used ventilator modes

WHAT TRIGGERS THE VENTILATOR?

No Spontaneous Breaths

• Time is the trigger
  • Provides RR 14-20 bpm

Presence of Spontaneous Breaths

• Negative Pressure as the Trigger
  • Triggers inspiration when a threshold negative pressure of 0.5-0.2 cm H2O is detected.
• Flow as the Trigger
  • Triggers inspiration when a threshold flow rate of 2-3 L/min is detected.

WHAT ASPECT OF INSPIRATION IS CONTROLLED BY THE VENTILATOR?

Pressure controlled: Pressure delivered during inspiration is constant regardless of airway resistance or compliance.

• Pressure is controlled to provide tidal volume of 6-8 ml/kg body weight.

Flow controlled (Volume Controlled): Flow is controlled as a function of the preset tidal volume.
WHAT ASPECT TERMINATES INSPIRATION?
Volume cycled ventilation: Ventilator ceases inspiration following delivery of a pre-set volume of inspiration.
Flow cycled ventilation: Ventilator stops inspiration when flow drops below a pre-set threshold, usually 25% of the peak flow.

IMPORTANT TERMINOLOGY AND PARAMETERS TO MONITOR ON THE VENTILATOR
- $F_{IO_2}$
- Respiratory Rate (RR)
- Tidal volume (TV)
- Minute ventilation ($V_T$)
- Pressure support
- Positive End Expiratory Pressure (PEEP)

INVASIVE MECHANICAL VENTILATION MODES
- Assist Control
- Synchronized Intermittent Mandatory Ventilation (SIMV)
- Pressure Support Ventilation
- Continuous Positive Airway Pressure
ASSIST CONTROL
Non weaning mode
Ventilator delivers a minimum minute ventilation by setting
the TV and RR.
With spontaneous breaths – ventilator delivers the preset TV.
Advantages
Disadvantages:
• Periods of high respiratory rate patient can develop
hyperinflation. Barotrauma, pneumothorax or auto PEEP
(severe decrease in venous return).

SIMV
Weaning mode
Ventilator ensures a minimum minute ventilation by setting
RR and TV.
Patient is able to breathe spontaneously between ventilator
breaths.
For spontaneous breaths, VT is variable depending on the
patient's inspiratory effort.
Advantages – Exercises respiratory muscles
Disadvantages – Increase the work of breathing

PRESSURE SUPPORT
VENTILATION
Weaning mode
Ventilator works only with spontaneous breaths.
For spontaneous breaths, a preset positive pressure is
delivered.
Volume is not preset, pressure support augments the TV.
Patient controls RR and inspiratory time.
Advantages: Decreases the work of breathing.
Disadvantages: No guaranteed minute ventilation
CPAP

Weaning mode
Provides continuous positive pressure within the airways.
Pressure support augments TV.

CLINICAL IMPLICATIONS

Modes and settings
Weaning times and PT/OT
Level of Sedation
Passy Muir Speaking Valve
Portable ventilators and ambulation
Ambulation with an Ambu Bag
Bronchopulmonary hygiene
Suctioning

REFERENCES


