INTRODUCTION TO MECHANICAL VENTILATION

THEORY
Mechanical ventilation is an important therapy used to treat a variety of underlying conditions in the intensive care unit. It is important to understand the terminology, basic concepts, and strategies for minimizing injury to the lung.

INDICATIONS
- Hypoxia: patient cannot adequately oxygenate, as occurs in acute lung injury, atelectasis, pneumonia, bronchiolitis
- Hypercarbia: patient cannot adequately exhale CO₂, as occurs in obstructive airway disease
- Loss of airway control: patient cannot protect airway, as occurs in head injury, drug intoxication, or altered mental status

TERMINOLOGY
- Peak inspiratory pressure (PIP): the highest pressure that the patient normally sees throughout the respiratory cycle. (Figure 1 - A)
- Positive end expiratory pressure (PEEP): the pressure present during expiration, preventing the lung from experiencing end expiratory collapse (Figure 1 - B)
- Mean-airway pressure (MAP): the area under the pressure waveform. It is not directly set on the ventilator, but is affected by peak airway pressure, PEEP, and inspiratory time. (Figure 1 - C)
- Respiratory rate (RR): the amount of breaths generated by the ventilator per minute. *Note: The respiratory rate is usually set on the ventilator, but the patient may be breathing above that value (Figure 1 - D)
- Inspiratory time (IT): time over which the tidal volume is delivered (Figure 1 - E); set based on the age of the patient: neonates: 0.4-0.5 seconds, children: 0.8-1 second, adolescents/adults: 1.2 - 1.4 seconds

MODES OF VENTILATION
Synchronized Intermittent Mandatory Ventilation (SIMV)
- The patient can trigger the ventilator spontaneously within a certain timeframe before the ventilator delivers a breath automatically.
- SIMV exists in both volume and pressure control modes and has both a flow and pressure trigger.
- Most modern ventilators are equipped with a flow trigger that requires the patient to generate a negative flow at the airway opening in order for the mechanical breath to be delivered.
- Some older ventilators have a pressure trigger where patients have to generate a negative pressure at the airway opening. This can be harder for small children to trigger.

**Note: Compliance = Δ volume/ Δ pressure.** It is both age and weight specific, so it is relatively impractical to compare the compliance between two different patients. However, it is useful to evaluate an individual patient’s progression.

Pressure Control
- Pressure is set and the tidal volume is a result of the patient’s lung compliance.

Volume Control
- Tidal volume is set and the pressure required to generate this volume is a result of the patient’s compliance.

**Note: The difference between volume and pressure control can be seen in the shape of the inspiratory flow (Figure 2).**

![Image](image-url)
Pressure Support
- The patient must be breathing spontaneously, and while the PIP and PEEP are controlled, the inspiratory time is determined by the patient.
- The ventilator measures the inspiratory flow, and once that drops to a certain number, completes inspiration.
- Because the patient has control over the respiratory rate and inspiratory time, it is considered a spontaneous mode of inspiration, allowing the patient to use more of their own respiratory muscles.
- This can lead to a recruitment of lung volume, and an overall increased patient comfort.

ACUTE RESPIRATORY DISTRESS SYNDROME (ARDS)
- The American-European Consensus Criteria for ARDS defines ARDS when a patient:
  - has bilateral infiltrates in the chest x-ray
  - no evidence of left atrial hypertension
  - PaO2/FiO2 (P/F ratio) < 200.
- Acute lung injury (ALI) is a less severe form of ARDS and is classified by a P/F ratio < 300.
- To help determine if a patient is improving or getting worse, calculate:
  - Oxygenation Index= [(mean airway pressure * FiO2) /PaO2] x 100.
    - An increasing oxygenation index indicates that the patient is getting worse.
  - P/F ratio=PaO2/FiO2.
    - A decreasing P/F ratio indicates that the patient is getting worse.

LUNG PROTECTIVE STRATEGIES
- Ventilator-associated lung injury can occur in three potential ways:
  - Volutrauma- over-distension of normal alveoli.
  - Atelectrauma- a repetitive opening and closing of atelectasis.
  - Biotauma- a release of inflammatory cytokines that fuel the lung injury being treated.
- Main strategies for providing lung protection to a ventilated patient:
  - Use a tidal volumes of no more than 6mL/kg.
  - Use the amount of PEEP that will give adequate lung recruitment.
    - This is the level of PEEP that allows the FiO2 to equal 60% or less.
  - Allow permissive hypercapnia: as long as the patient is not acidic (usual goal pH >7.25), allow the PaCO2 to rise in order to reduce the ventilator settings.
  - Allow permissive hypoxia: a goal PaO2 of 55-65 mmHg (7.3-8.7 kPa), or oxygen saturation of 89-92%.

EXTUBATION READINESS
- In preparing for extubation, the following steps should be taken:
  - Ensure the patient is awake and spontaneously breathing by weaning or stopping sedative drugs
  - Discontinue feeds prior to extubation, often 6 hours prior to extubation
  - Wean the FiO2 to 50% or less
  - Wean the PEEP to minimal levels, often 5cm H2O
  - Wean the pressure support to just overcome the resistance of the endotracheal tube (ETT) (based on ETT size)
    - For a 3.0-3.5mm ID ETT, use pressure support = 10cm H2O
    - For a 4.0-4.5mm ID ETT, use pressure support = 8cm H2O
    - For a 5.0 mm ID and greater ETT, use pressure support = 6cm H2O
  - If the patient tolerates these criteria (no tachypnea, normal blood gas), then the patient may be ready to extubate.

REFERENCES