Mechanical Ventilation: Settings and Basic Modes

Mechanical ventilation is a lifesaving tool utilized in the intensive care unit, during surgical procedures requiring general anesthesia, and in long-term acute care settings to assist patients who require additional respiratory support. Invasive mechanical ventilation requires an endotracheal tube that is connected to a ventilator, whereas non-invasive ventilation delivers oxygen through a face mask. Both types can be used for acute or chronic hypoxemic or hypercarbic respiratory failure, which is defined as insufficient oxygenation, insufficient alveolar ventilation, or both. Invasive mechanical ventilation is also useful for those who require airway protection to reduce the risk of aspiration (i.e., depressed mental status from an overdose or brain injury) as well as in the operating room during procedures requiring general anesthesia.

Mechanical ventilation aids in improving gas exchange, decreases work of breathing and supports the patient during treatment of the underlying condition. Ventilator settings integrate volume, flow, pressure and time. Use this handy reference guide to help you safely manage and optimize oxygenation and ventilation goals for your patients with invasive/non-invasive mechanical ventilation.

MECHANICAL VENTILATION: IMPORTANT TERMS TO KNOW	
Term	**Clinical Considerations**
Fraction of inspired oxygen (FiO_2)	• Concentration of oxygen in the inspired air • Use the lowest FiO_2 that achieves the targeted oxygenation • Avoid prolonged FiO_2 > 0.60, as this may cause oxygen toxicity and worsen hypoxia
Frequency (f) or respiratory rate (RR) (10-20 breaths/min)	• Set number of ventilator breaths per minute • Actual RR includes the spontaneous breaths taken by the patient • Hypoventilation may cause respiratory acidosis; hyperventilation may cause respiratory alkalosis
Trigger	Breaths can be triggered by: • Timer (ventilator-initiated breaths); occur at the set respiratory rate or frequency (f) • Patient effort (patient- initiated breaths); occur when the patient causes sufficient change in either the pressure or flow in the circuit
Target	• Flow of air into the lung can target a predetermined flow rate (i.e. peak inspiratory flow rate) or pressure limit
Termination	• Signal for a ventilator to end inspiration • May be related to volume (i.e. tidal volume), time (i.e. predetermined duration of inspiration), or flow (decrease in inspiratory flow to a percentage of peak value)

Tidal volume (V_T) (4-8 mL/kg of ideal body weight [IBW] to prevent barotrauma)	• Volume of gas exchanged with each breath • A lower V_T, or lung protective ventilation, is indicated in patients with stiff, non-compliant lungs, such as in acute respiratory distress syndrome (ARDS) • Higher V_T may cause tachycardia, decreased blood pressure and lung injury or barotrauma
Minute ventilation (V_E) (5-10 L/minute)	• Volume of gas exchanged per minute • V_E = RR X V_T
Inspiratory: expiratory (I:E) ratio	• Normal: longer expiratory phase than inspiratory phase (1:2, 1:3) • Inverse ratios provide a longer inspiratory phase (1:1, 2:1, 3:1, 4:1) • Reduced I:E allows more time for exhalation and reduces breath stacking; used for patients who have obstructive airway disease with acute respiratory acidosis
Peak inspiratory pressure (PIP)	• Highest proximal airway pressure reached during inspiration • Target PIP is < 35 cm H_2O • Low PIP may result in hypoventilation; high PIP may cause lung damage or barotrauma
Peak flow rate	• Maximum flow delivered by the ventilator during inspiration

Plateau pressure (Pplat)
(Target Pplat < 30)
	• Reflects pulmonary compliance and is measured by applying a brief inspiratory pause after ventilation
	• Assess Pplat with peak inspiratory pressure (PIP):
	  ○ A high PIP with normal Pplat = increased resistance to flow (i.e., endotracheal tube obstruction or bronchospasm)
	  ○ High PIP and high Pplat = decreased lung compliance (i.e., interstitial pulmonary fibrosis, pneumonia, ARDS, pulmonary edema)

Positive end expiratory pressure (PEEP) (3-10 cm H_2O)	• Pressure remaining in the lungs at end expiration • Used to keep alveoli open and "recruit" more alveoli to improve oxygenation for patients • High levels may cause barotrauma, increased intracranial pressure and decreased cardiac output

Pressure support (PS) (8-20 cm H_2O)	• Provides additional pressure during inspiration to ensure a larger V_t with minimal patient effort • Used to help overcome the work of breathing through ventilator tubing • Can be used as weaning method while working towards ventilator liberation

MODES OF MECHANICAL VENTILATION	
MODE	**DESCRIPTION**
VOLUME-LIMITED VENTILATION Clinician sets the peak flow rate, flow pattern, V_T, RR, PEEP, and FiO_2; inspiration ends once the set inspiratory time has elapsed.	
Controlled mechanical ventilation (CMV)	• V_E is determined entirely by the set RR and V_T. • No patient effort required.
Assist control (AC)	• Minimal V_E is determined by setting the RR and V_T. • Patient can increase the V_E by triggering additional breaths. • Each patient-initiated breath receives the set V_T from the ventilator.
Pressure regulated volume control (PRVC) (also called volume control plus [VC+])	• V_T is set and the applied airway pressure changes to attain the target V_T. • The initial applied inspiratory pressure is determined by the change in pressure required by the previous breath to attain the V_T.
Intermittent mandatory ventilation (IMV)	• Minimal V_E is determined by setting the RR and V_T; patient can increase the V_E by spontaneous breathing, rather than patient-initiated ventilator breaths.
Synchronized intermittent mandatory ventilation (SIMV)	• A variation of IMV; ventilator breaths are synchronized with patient inspiratory effort; can be used to titrate the level of ventilatory support.
PRESSURE-LIMITED VENTILATION Clinician sets the inspiratory pressure level, I:E ratio, RR, PEEP, and FiO_2; inspiration ends after delivery of the set inspiratory pressure.	
Pressure-limited CMV (also called pressure control ventilation)	• V_E is determined entirely by the set RR and inspiratory pressure. • Patient does not initiate additional V_E above that set on the ventilator.
Pressure-limited AC	• Set RR and inspiratory pressure determine the minimum V_E. • The patient can increase the V_E by triggering additional ventilator-assisted, pressure-limited breaths.
Pressure-limited IMV or pressure-limited SIMV	• The set RR and inspiratory pressure determine the minimum V_E. • The patient can increase the V_E by initiating spontaneous breaths.

Pressure support	• Flow-limited mode that delivers inspiratory pressure until the inspiratory flow decreases to a predetermined percentage of its peak value. • Clinician sets the pressure support (inspiratory pressure), applied PEEP, and FiO_2. The patient must trigger each breath because there is no set RR. The V_T, RR, and V_E are dependent on multiple factors, including ventilator settings and patient-related variables. • The work of breathing is inversely proportional to the pressure support level and the inspiratory flow rate.
Continuous positive airway pressure (CPAP)	• Delivery of a continuous level of positive airway pressure. • Functionally similar to PEEP. • The ventilator does not cycle during CPAP and no additional pressure above the level of CPAP is provided; patients must initiate all breaths.
Bilevel positive airway pressure (BiPAP)	• Noninvasive positive pressure ventilation (NPPV) that delivers a preset inspiratory positive airway pressure (IPAP) and expiratory positive airway pressure (EPAP). The V_T correlates with the difference between the IPAP and the EPAP.
Airway pressure release ventilation (APRV)	• High continuous positive airway pressure (P high) is delivered for a long duration (T high) and then falls to a lower pressure (P low) for a shorter duration (T low). • Alveolar recruitment is maximized by the high continuous positive airway pressure. • V_T is related to both the driving pressure and the compliance.
Inverse ratio ventilation (IRV)	• The inspiratory time exceeds the expiratory time. • Strategy employed during volume-limited or pressure-limited mechanical ventilation to increase the mean airway pressure and potentially improve oxygenation.

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