# Mechanical Ventilatory Support

Chapter 313 | Harrison's 22e

### KEY CLINICAL POINTS

1. Mechanical ventilation provides positive pressure to treat hypoxemic (V/Q mismatch, shunt) and hypercapnic (obstructive disease, muscle weakness) respiratory failure.
2. Lung compliance is significantly reduced in ARDS; these 'stiff' lungs require higher pressures to achieve the same tidal volume (V_T).
3. Protective ventilation aims to balance adequate oxygenation with the prevention of barotrauma and volume trauma by targeting specific areas on the pressure-volume curve.
4. PEEP is essential to prevent alveolar collapse at end-exhalation, but must be balanced against the risk of overdistension (e.g., optimal PEEP in ARDS identified as ~20 cmH_2O).
5. Transalveolar pressure in breathing patients is higher than what is measured by the ventilator because it cannot 'see' the patient's negative 'pulling' pressure.
6. Assist control–volume control guarantees V_T but carries a risk of barotrauma; Pressure-regulated volume control allows for variable inspiratory flow and improved comfort.
7. Noninvasive ventilation (NIV) is contraindicated in patients with encephalopathy, aspiration risk, airway obstruction, or hemodynamic instability.
8. Hypercapnia leads to pulmonary vasoconstriction, cerebral vasodilation, and increased intracranial pressure.
9. Optimal tidal volume ventilation target: 6 mL/kg of ideal body weight.
10. Plateau pressures should be kept < 30 cmH_2O to minimize lung injury during protective ventilation.

## DEFINITION & CLASSIFICATION

- **Definition:** Mechanical ventilation refers to devices that deliver positive pressure gas, of varying oxygen content, to patients with acute or chronic respiratory failure.
- **Primary Indications:**
  - **Hypoxemic Respiratory Failure:** Often due to ventilation-perfusion (V/Q) mismatch or shunt caused by pneumonia, pulmonary edema, alveolar hemorrhage, ARDS, or sequelae of trauma/surgery.
  - **Hypercapnic Respiratory Failure:** Most frequently caused by severe exacerbations of obstructive lung disease (asthma, COPD); loss of central respiratory drive (stroke, intracranial hemorrhage, drug overdose); or respiratory muscle weakness (Guillain-Barré syndrome).
  - **Airway Protection:** Required for patients with an artificial airway due to poor protection (coma, large upper GI hemorrhage/vomiting) or large airway obstruction (laryngeal edema).
  - **Adjument Therapy:** Useful for reducing the work of breathing in shock and multiorgan system failure.

## ETIOLOGY & PATHOPHYSIOLOGY

- **Lung Mechanics:**
  - Transpulmonary pressure depends on the elastic properties of the lungs and chest wall.
  - ARDS Pathophysiology: Lungs are "stiff" or poorly compliant, requiring significantly more pressure to achieve a physiologic tidal volume (V_T).
  - Risk of Injury:

→ **Underinflation:** Causes cycles of alveolar recruitment then collapse.

→ **Overinflation:** Leads to barotrauma and volume trauma.

  - **Protective Ventilation Strategy:**

→ Goal: Identify the point on the pressure-volume curve where respiratory system compliance is greatest (smallest change in pressure leads to largest increase in volume).

→ **Tidal Volume Target:** 6 mL/kg of ideal body weight.

→ **Role of PEEP:** Maintains a specified positive pressure at end-exhalation to prevent alveolar collapse.

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# DIAGNOSTIC APPROACH

1. **Daily Assessment for Extubation Readiness:**

Evaluate criteria: Underlying process improved, Awake/minimal sedation, FiO_2 < 0.5, PEEP < 8 cmH_2O, SaO_2 > 90%, Stable hemodynamics, Minimal secretions/good cough.

→ If NO → **Continue mechanical ventilation**.

→ If YES → Proceed to Spontaneous Breathing Trial (SBT).

2. **Spontaneous Breathing Trial (SBT):**

Assess patient's ability to breathe independently on reduced support.

→ If NO → **Continue mechanical ventilation**.

→ If YES → Assess for High-Risk Factors.

3. **High-Risk Assessment:**

Identify risk factors: Age >65, Congestive heart failure, COPD, APACHE-II > 12, BMI > 30, Significant secretions, >2 medical comorbidities, >7 days on mechanical ventilation.

→ If NO → **SUCCESS (off mechanical ventilation)**.

→ If YES → Assess stability on high-flow O_2 or NIV.

→ If NO → **Failure/reintubation**.

→ If YES → **SUCCESS (off mechanical ventilation)**.

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# MANAGEMENT & TREATMENT

1. **Selection of Ventilation Mode (Table 313-1):**

- **Assist control–volume control:**
  - Advantages: Guarantees minimum V_T and V_{TE}; allows clinician to control V_T.
  - Disadvantages: Risk of barotrauma from high plateau pressure; potential for patient-ventilator dyssynchrony.
- **Pressure-regulated volume control:**

– Advantages: Patient effort can vary inspiratory flow (improved comfort/synchrony); guarantees minimum V_T and V_{TE}.

– Disadvantages: Variable patient effort can lead to V_T larger than set V_T; requires monitoring to prevent volume trauma.

2. **Protective Ventilation Strategy:**

• **Goal:** Maintain plateau pressures < 30 cmH_2O to minimize lung injury.

• **PEEP Selection:** Identify optimal PEEP (e.g., ~20 cmH_2O) to move past the area of greatest alveolar collapse while avoiding overdistension.

3. **Noninvasive Ventilation (NIV) Assessment (Table 313-2):**

• **Contraindications for NIV:**

– Inability to protect airway (e.g., severe encephalopathy).

– High risk for aspiration (vomiting, severe upper GI bleed).

– Difficulty clearing respiratory secretions.

– Facial trauma or surgery.

– Upper airway obstruction or compromise.

– Significant hemodynamic instability.

4. **Management of Hypercapnia (Table 313-3):**

• **Clinical effects to monitor:**

– Pulmonary arterial vasoconstriction (may worsen right heart failure).

– Rightward shift of the oxyhemoglobin curve.

– Cerebral vasodilation and increased intracranial pressure.

– Sympathetic-adrenal stimulation.

– Reduced cardiac contractility (especially with β-adrenergic blocking therapy).

## KEY PEARLS & HIGH-YIELD POINTS

• **Transalveolar Pressure:** In patients breathing spontaneously, the actual pressure across the alveoli is higher than what is measured by the ventilator because the machine cannot measure the patient's negative "pulling" pressure (Figure 2).

– Clinical Risk: A breathing patient may be at risk for barotrauma even if the ventilator-displayed pressure remains within safe limits.

• **Lung Compliance:** ARDS lungs are "stiff"; a significantly higher pressure is required to move the same volume compared to normal lungs (Figure 1).

• **Protective Ventilation:** The target is to maintain plateau pressures < 30 cmH_2O while ensuring PEEP is sufficient to prevent alveolar collapse (Figure 3).

### REFERENCE TABLES

#### TABLE 313-1

**Key Features of Commonly Used Mechanical Ventilation Modes MODE Assist control–volume control**

| MODE | VARIABLES SET BY CLINICIAN (INDEPENDENT) | MONITORED VARIABLES (DEPENDENT) | ADVANTAGES | DISADVANTAGES |
|---|---|---|---|---|
| **Assist control–volume control** | V<br>T<br>Respiratory rate<br>PEEP<br>Fio<br>2<br>Inspiratory flow rate | Peak inspiratory airway pressure<br>End-inhalation (plateau) pressure<br>V<br>E | Guarantee minimum V and<br>V<br>T E<br>Control V, limiting volume trauma<br>T | Barotrauma from high plateau pressure<br>Patient-ventilator dyssynchrony, increased work of breathing |
| | Inspiratory driving pressure<br>Respiratory rate<br>PEEP<br>Fio<br>2 | Tidal volume<br>V<br>E | Limit barotrauma (if patient respiratory efforts minimal)<br>Inspiratory flow can vary with patient effort (improved comfort/ synchrony) | |
| **Pressure-regulated volume control** | V<br>T<br>Respiratory rate<br>PEEP<br>Fio<br>2 | Peak inspiratory airway pressure<br>End-inhalation (plateau) pressure<br>V<br>E | Patient effort can vary inspiratory flow, increasing comfort, and ventilator synchrony<br>Guarantee minimum V and<br>V<br>T E | Variable patient effort can lead to<br>V<br>T<br>larger than set V; monitor to prevent<br>T<br>volume trauma |
| | Inspiratory pressure<br>PEEP<br>Fio<br>2 | V<br>T<br>Respiratory rate<br>V<br>E | Patient effort preserved and controls V, inspiratory flow, and<br>T<br>respiratory rate, allowing for ventilator synchrony | |

TABLE 313-2

**Common Contraindications to Noninvasive Ventilation Inability to protect the airway, such as severe encephalopathy High…**

- Inability to protect the airway, such as severe encephalopathy
- High risk for aspiration, such as vomiting or severe upper gastrointestinal bleeding
- Difficulty clearing respiratory secretions
- Facial trauma or surgery
- Upper airway obstruction or compromise
- Significant hemodynamic instability

TABLE 313-3

**Adverse Effects of Hypercapnia a Pulmonary arterial vasoconstriction (possible worsening of right heart failure)…**

- Pulmonary arterial vasoconstriction (possible worsening of right heart failure)
- Rightward shift of the oxyhemoglobin curve
- Cerebral vasodilation
- Increased intracranial pressure
- Sympathetic-adrenal stimulation
- Reduced cardiac contractility (especially in the presence of β-adrenergic blocking therapy)