ALERT
Never silence the ventilator alarms. Always ensure that the ventilator is connected to a power outlet supplied by an emergency generator.

The nurse’s role in setting ventilator parameters varies according to the organization’s practice and state nurse practice act.

OVERVIEW
Initiating and maintaining positive-pressure ventilation (PPV) through an artificial airway is done to maintain or improve oxygenation and ventilation. Indications for the initiation of mechanical ventilation include apnea, acute ventilatory failure, impending ventilatory failure, and respiratory muscle fatigue. The selection of volume or pressure modes is dependent on the available evidence, clinical goals, availability of modes, and the practitioner’s preference. Research has not revealed much evidence that specific modes of ventilation affect clinical outcomes (mortality and ventilator hours). Respiratory insufficiency or failure, evidenced by tachypnea, hypoxemia, hypercapnia, and increased work of breathing, is an indication for mechanical ventilation. The nurse should manage mechanical ventilation in collaboration with the practitioner and respiratory therapist.

Ventilators are categorized as either negative pressure or positive pressure. With a negative-pressure ventilator (also called an iron lung) the patient is placed in a cylinder up to his or her neck. A vacuum is then created around the patient, which results in expansion of his or her chest. Negative-pressure ventilators are rarely used in the critical care setting. With a positive-pressure ventilator, an artificial airway is placed in the patient and air is blown mechanically into his or her lungs. The positive airway pressure causes the inspiratory gas to flow into the lungs until the breath is terminated.

Positive-pressure ventilators generally involve two primary modes of ventilation: volume and pressure. A wide variety of modes combining these main categories is available to allow for different levels of patient participation. Ventilator settings allow for selection of a specific mode and individualization of the ventilator parameters. Not all modes are available on all ventilators, and different manufacturers may use different names for the same mode of ventilation. The choice depends on the patient’s situation, the goals of treatment, and the practitioner’s preference.

Each ventilator includes a system for monitoring the patient and for managing alarms. The goal of a mechanical ventilator alarm is to warn the nurse of an event. An event is any condition that requires awareness or action on the part of the nurse. Events can be divided into two categories—mechanical or technical events and patient-generated events.

Complications
Complications of PPV discussed below include auto–positive end-expiratory pressure (auto-PEEP), pulmonary barotrauma, volume pressure trauma, hemodynamic changes, and ventilator-
associated pneumonia (VAP). (Complications of PPV not covered in this skill include deep vein thrombosis [and subsequent pulmonary embolus] and gastrointestinal bleeding.)

- **Auto-PEEP** is the result of air-trapping in the lungs at the end of expiration due to incomplete expiration and is a common complication of mechanical ventilation, particularly in patients with underlying lung disease. It can also cause hemodynamic compromise. Auto-PEEP increases intrathoracic pressure, resulting in decreased cardiac output. Auto-PEEP is associated with prolonged inspiratory time (Ti), short expiratory times, high minute ventilation (MV) requirements, bronchospasm, low elastic recoil, mucus hypersecretion, increased wall thickness, airway closure or collapse, and mechanical factors (e.g., water in the ventilator circuit, pinched ventilator tubing). Correcting these factors reduces auto-PEEP.

- **Pulmonary barotrauma** (or air-leak disease) is damage to the lung from extrapulmonary air that may result from changes in intrathoracic pressure during PPV. Barotrauma is manifested by pneumothorax, pneumomediastinum, pneumopericardium, pneumoperitoneum, and subcutaneous emphysema. The risk of barotrauma in a patient receiving PPV is increased with preexisting lung lesions (e.g., blebs, asthma, other chronic airway disease), high inflation pressure (e.g., large tidal volume [VT], positive end-expiratory pressure [PEEP], main stem bronchus intubation, patient–ventilator asynchrony), and invasive thoracic procedures (e.g., subclavian catheter insertion, bronchoscopy, thoracentesis). Barotrauma from PPV may be prevented by controlling peak and plateau pressure, optimizing PEEP, preventing auto-PEEP, ensuring patient–ventilator synchrony, and ensuring proper artificial airway position.

- **Volume pressure trauma**, in contrast to barotrauma, was first described in animals with stiff, noncompliant lungs that were ventilated with traditional lung volumes while their chests were bound, thus worsening their lung compliance. The investigators observed that the large volumes translated into high plateau pressure (i.e., static, distending, or alveolar pressure) and subsequent acute lung injury. Determining safe airway plateau pressure and VT must be based on the clinical scenario and on the goals and outcomes desired for each individual patient.

- Studies in humans followed the recognition that a large VT may be associated with lung injury and revealed that lower volume ventilation resulted in a lower mortality rate. As a result, current recommendations are to limit volume (and lower pressure) in a patient with stiff lungs. With pressure ventilation, pressure is limited by definition; however, until additional evidence emerges on the efficacy of controlling pressure versus volume in acute respiratory distress syndrome (ARDS), a goal should be to ensure a VT of less than 6 ml/kg. A VT of less than 6 ml/kg in patients with ARDS may improve mortality. Another lung-protective strategy is that of lung recruitment (restoration of functional residual capacity [FRC]) and the prevention of derecruitment. Investigators demonstrated that stiff, noncompliant lungs were at risk of trauma from the repetitive opening associated with tidal breaths. The application of higher levels of PEEP was associated with better lung recruitment and a lower mortality rate.

- The extent of hemodynamic changes associated with PPV depends on the level of applied positive pressure, the duration of positive pressure during different phases of the breathing cycle, the amount of pressure transmitted to the vascular structures, the patient’s
intravascular volume, and the adequacy of hemodynamic compensatory mechanisms. PPV can reduce venous return and cardiac output, shift the intraventricular septum to the left, and increase right ventricular afterload as a result of increased pulmonary vascular resistance. The hemodynamic effects of PPV may be prevented or corrected by optimizing filling pressure to accommodate the PPV-induced changes in intrathoracic pressure; by minimizing the peak pressure, plateau pressure, and PEEP; by optimizing the inspiratory-to-expiratory (I:E) ratio; and by allowing spontaneous respirations when appropriate.

VAP is pneumonia that develops after mechanical ventilation is delivered by means of an endotracheal (ET) tube or tracheostomy. VAP results when microorganisms invade the lower respiratory tract and lungs. The following evidence-based interventions help to prevent VAP:

- Use of noninvasive positive-pressure ventilation (NIPPV) whenever feasible
- Management of ventilated patients without sedatives whenever possible
- Interruption of sedation once a day (spontaneous awakening trials) for patients without contraindications
- Assessment of readiness to extubate once a day (spontaneous breathing trials) in patients without contraindications
- Pairing of spontaneous breathing trials with spontaneous awakening trials
- Early implementation of exercise and mobilization
- Minimization of pooling of secretions above the ET tube cuff
- Use of ET tubes with subglottic secretion drainage (SSD) ports
- Elevation of the head of the bed between 30 and 45 degrees unless contraindicated
- Changing of the ventilator circuit only if visibly soiled or malfunctioning
- Adherence to Centers for Disease Control and Prevention (CDC) and Healthcare Infection Control Practices Advisory Committee guidelines for sterilization and disinfection of respiratory care equipment
- Use of selective decontamination of the oropharynx to decrease the microbial burden
- Implementation of oral care with chlorhexidine
- Administration of prophylactic probiotics

PATIENT AND FAMILY EDUCATION

- Provide the patient and family with an explanation of the procedure and the equipment, including the potential benefits of mechanical ventilation that the patient may experience (e.g., less shortness of breath, less difficulty with the breathing process).
- Before intubation, ensure that the patient and family understand the implications of intubation and mechanical ventilation specific to the situation, including why a ventilator is being used. Use words that are easily understood; for example, respiration and life support are common terms.
- Discuss with the patient and family the unpleasant sensations that the patient may experience (e.g., gagging, anxiety). Explain to the patient and family that medications are given to promote relaxation and treatment tolerance. Explain that the patient may require sedation during mechanical ventilation.
- Explain to the patient and family that the patient will be unable to speak. Establish a method of communication in conjunction with the patient and family before initiating mechanical ventilation, if necessary.
- Explain what to expect while the patient is ventilated. Consider giving the family a task, such as performing passive range of motion with the patient, to decrease anxiety through participation in the patient’s care.
- Educate the patient and family about the ventilator alarms and their meaning. Assure them that staff do hear the alarms and will respond accordingly.
- Encourage questions and answer them as they arise.

**ASSESSMENT AND PREPARATION**

**Assessment**

1. Perform hand hygiene before patient contact.
2. Introduce yourself to the patient.
3. Verify the correct patient using two identifiers.
4. Assess the patient for signs and symptoms of acute ventilatory failure and fatigue.
   a. Rising arterial partial pressure of carbon dioxide tension (PaCO₂)
   b. Chest-abdominal dyssynchrony
   c. Shallow or irregular respirations
   d. Tachypnea, bradypnea, or dyspnea
   e. Decreased mental status
   f. Restlessness, confusion, or lethargy
   g. Increasing or decreasing arterial blood pressure
   h. Tachycardia, atrial or ventricular arrhythmias

5. Determine the arterial pH and PaCO₂.
6. Assess the patient for signs and symptoms of inadequate oxygenation.
   a. Decreasing partial pressure of arterial oxygen tension (PaO₂) and oxygen saturation
   b. Tachypnea or dyspnea
   c. Central cyanosis
   d. Alterations in level of consciousness
   e. Restlessness, confusion, or agitation
   f. Tachycardia or bradycardia, arrhythmias
   g. Intercostal and suprasternal retractions
   h. Increasing or decreasing arterial blood pressure
   i. Adventitious breath sounds
   j. Decreasing urine output
   k. Metabolic acidosis

7. Determine the PaO₂ or arterial oxygen saturation (SaO₂).
8. Assess the patient for signs and symptoms of inadequate breathing.
Mechanical Ventilation: Volume and Pressure Modes - CE

**a.** Dyspnea

**b.** Chest-abdominal dyssynchrony

**c.** Rapid-shallow breathing pattern

**d.** Irregular respirations

**e.** Intercostal or suprasternal retractions

**f.** Inability to say a whole sentence

**Preparation**
1. Clarify advance directives at admission with the patient and family.
2. Administer analgesia and sedation as needed and as ordered. Reassess the patient’s pain and sedation status, allowing for sufficient onset of action per medication, route, and the patient’s condition.
3. Ensure that the patient is positioned with the head of the bed elevated between 30 and 45 degrees, unless contraindicated.\(^2\)

**PROCEDURE**

**Volume Modes**
1. Perform hand hygiene.
2. Introduce yourself to the patient.
3. Verify the correct patient using two identifiers.
4. Explain the procedure to the patient and family and ensure that they agree to treatment.
5. Collaborate with the practitioner in selecting the most appropriate mode of ventilation for the patient: assist-control (AC) or synchronized intermittent mandatory ventilation (SIMV).

Rationale: Mode selection varies depending on the clinical goal and the practitioner’s preference.

6. Collaborate with the practitioner and the respiratory therapist in selecting the ventilator settings.

a. Establish a tidal volume (VT). Generally, an initial VT of 6 to 8 ml/kg ideal body weight (IBW) is set unless the patient has ARDS, in which case a smaller initial VT of 4 to 6 ml/kg IBW is then used.\(^2\)

Rationale: VT is selected in conjunction with rate to attain a minute ventilation (MV) that is appropriate based on the clinical scenario.

**Permissive hypercapnia** refers to a ventilatory strategy for acute respiratory failure in which the lungs are ventilated with a low inspiratory volume and pressure. The aim of this strategy is to minimize lung damage during mechanical ventilation; the limitation of this strategy is the resulting hypoventilation and carbon dioxide retention. Permissive hypercapnia is generally well tolerated if the retention of carbon dioxide and the resulting decrease in pH occurs gradually. Do not attempt
permissive hypercapnia in a patient who has elevated intracranial pressure (ICP) or myocardial ischemia, injury, or arrhythmias.

b. Establish a rate (also called respiratory frequency [f]). Generally, the frequency is set at a rate of 12 to 16 breaths per minute.²

Rationale: VT and rate are set to maintain an acceptable arterial partial pressure of carbon dioxide (PaCO₂). Generally, once VT is set, the rate is adjusted to attain a desired PaCO₂; the rate selected depends on whether the goal is to rest or to work the respiratory muscles.

c. Establish an inspiratory-to-expiratory (I:E) ratio.

i. Determine the inspiratory time (TI).
ii. Determine the inspiratory flow to achieve the desired I:E ratio.

Rationale: Inspiratory flow refers to the speed with which a VT is delivered during inspiration.

d. Establish the sensitivity level.

Rationale: Most ventilators have pressure-sensing mechanisms that trigger inspiratory flow. This means that the patient must generate a decrease in the system pressure with an inspiratory effort. When the ventilator senses the drop in pressure, flow (or a breath) is delivered.

Be aware that when auto–positive end-expiratory pressure (auto-PEEP) is present, the patient has to generate a negative pressure equal to the set sensitivity plus the level of auto-PEEP to trigger a breath.

e. Establish the fraction of inspired oxygen (FiO₂). Generally, the FiO₂ is titrated to obtain a partial pressure of arterial oxygen (PaO₂) of 60 to 80 mm Hg and an oxygen saturation of 90% or greater.²

f. Establish the positive end-expiratory pressure (PEEP) level.

Rationale: The initial setting is usually 5 cm H₂O (considered to be physiologic PEEP).² PEEP levels can be increased to restore functional residual capacity (FRC) and to allow for reduction of FiO₂ to decrease the risk of developing oxygen toxicity.

Do not interrupt PEEP administration unless absolutely necessary, because the subsequent derecruitment of alveoli may delay reestablishment of FRC (and partial pressure of arterial oxygen [PaO₂]) for hours. High PEEP levels may be necessary in a patient with noncompliant lungs (i.e., those with acute respiratory distress syndrome [ARDS]) if alveolar derecruitment persists as evidenced by refractory hypoxemia. When stiff alveoli open and close repeatedly, they can become
damaged. High PEEP levels help keep alveoli distended during mechanical ventilation, serving as a protective measure for the lungs. In general, when high PEEP levels are used, VT will be lower than normal, leading to hypercapnia. In most cases, use of muscle relaxants, sedatives, and analgesics is necessary to prevent the patient's spontaneous breathing.

7. Ensure that the ventilator alarms are set appropriately.
8. Perform hand hygiene.

**Pressure Modes**
1. Perform hand hygiene.
2. Introduce yourself to the patient.
3. Verify the correct patient using two identifiers.
4. Explain the procedure to the patient and family and ensure that they agree to treatment.
5. Collaborate with the practitioner in selecting the most appropriate mode of ventilation for the patient: pressure support ventilation (PSV), pressure-control (PC), pressure-controlled/inverse ratio ventilation (PC/IRV), volume-assured pressure support ventilation (VAPSV), airway pressure release ventilation (APRV), adaptive support ventilation (ASV), or high-frequency ventilation (HFV).

Rationale: Mode selection varies depending on the clinical goal and the practitioner’s preference.

Refer to the manufacturer's instructions for the specific ventilator for detailed information. Many new modes employing microprocessor technology are available on specific ventilators. Although many are similar to traditional modes, others are not. Parameter names also vary.

6. Collaborate with the practitioner and the respiratory therapist in selecting the ventilator settings.

a. Pressure support ventilation (PSV):

**PSV sometimes is used between synchronized intermittent mandatory ventilation (SIMV) breaths to offset the work of breathing associated with artificial airways and circuits during spontaneous breathing. Generally, PSV is considered a weaning mode of ventilation, necessitating the patient’s stability; however, high levels of PSV may provide almost total ventilator support. If respiratory muscle rest is the goal of using intermittent mandatory ventilation (IMV) plus PSV, the level of PSV should be high enough to provide a VT of 4 to 8 ml/kg and to maintain a total rate (IMV plus PSV breaths) of less than or equal to 20 breaths per minute.³**

i. Establish the PSV level.
**Mechanical Ventilation: Volume and Pressure Modes - CE**

Rationale: The amount is determined by what is needed to attain an appropriate minute ventilation (MV) based on the patient’s condition, while maintaining a safe and adequate tidal volume (VT). Pressure level, in conjunction with compliance and resistance, determines the delivered VT.

ii. Establish the trigger sensitivity.

iii. Establish the positive end-expiratory pressure (PEEP) level.

iv. Establish the fraction of inspired oxygen (FiO₂).

b. Pressure control (PC) and pressure-controlled/inverse ratio ventilation (PC/IRV):

   Rationale: The PC/IRV mode is used to enhance lung recruitment by prolonging inspiration. Shortening expiration decreases the potential for derecruitment.

i. Establish the inspiratory pressure support (IPS) level.

ii. Establish the rate.

iii. Establish the inspiratory time (Ti) or inverse inspiratory-to-expiratory (I:E) ratio. Generally, flow rates of approximately 60 to 80 L/min are used initially and adjusted to provide a Ti that synchronizes with the patient’s effort. A typical Ti for an adult is less than 1 second.

   *Be aware that the patient will probably not tolerate the prolonged Ti in IRV without sedation and paralysis.*

iv. Establish the PEEP level.

   Rationale: The goal of PC/IRV is to improve oxygenation and allow for reduction of FiO₂ to prevent oxygen toxicity. This is done in conjunction with the addition of PEEP. Because IRV may result in auto-PEEP, evaluating the total amount of PEEP present is important.

   *Be aware that IRV may result in auto-PEEP (which may be a desirable outcome of the mode). Regardless, anticipate and measure auto-PEEP regularly.*

v. Establish the FiO₂.

vi. Establish the sensitivity level.

   *Always set the sensitivity level so that the patient can get a breath if needed.*

c. Volume-assured pressure support ventilation (VAPSV):

i. See the manufacturer’s instructions for the ventilator for specific names of parameter settings.

ii. Establish the PEEP, FiO₂, and sensitivity levels, along with rate and Ti, if the mode is a control mode.
d. Airway pressure release ventilation (APRV), adaptive support ventilation (ASV), and high-frequency ventilation (HFV): See the manufacturer’s instructions for the ventilator for specific names of parameter settings and ventilator setup.

7. Ensure that the ventilator alarms are set appropriately.
8. Perform hand hygiene.

**MONITORING AND CARE**

1. Ensure that all ventilator alarms are on.

   Rationale: Ensuring that the ventilator alarms are on provides patient safety. Ventilator alarms should never be silenced. The alarm limits should be set appropriately to properly alert the nurse of any problem (Table 3).

   **Reportable condition: Inoperable alarms**

2. Monitor the inline thermometer to maintain the inspired gas temperature between 34°C and 41°C (93.2°F and 105.8°F).1

   Rationale: Monitoring the inline thermometer reduces the risk of thermal injury from overheated inspired gas and the risk of poor humidity from underheated inspired gas.

   **Reportable conditions: Temperature alterations, secretions that are very thick and difficult to clear**

3. Keep the ventilator tubing clear of condensation. Drain any condensation in the ventilator tubing toward condensation collection reservoirs on the expiratory limb of the circuit (clean to dirty). Do not drain condensation back toward the patient.

   Rationale: Keeping the ventilator tubing clear of condensation reduces the risk of respiratory infection by decreasing inhalation of contaminated water droplets.

   **Reportable condition: Continued condensation**

4. Ensure the availability of a manual self-inflating resuscitation bag attached to supplemental oxygen at the head of the bed. Attach or adjust the positive end-expiratory pressure (PEEP) valve if the patient is on PEEP.

   Rationale: A manual resuscitation bag provides capability for immediately delivering ventilation and oxygen to relieve acute respiratory distress caused by hypoxemia or acidosis.
5. Check the ventilator settings on a routine basis to ensure that they match the prescribing order.
6. Explore any change in peak inspiratory pressure (PIP) or decreased (sustained) tidal volume (VT) on pressure support ventilation (PSV). Immediately explore the cause of high pressure alarms.

   Rationale: Acute increases or decreases in PIP or VT may indicate mechanical malfunction, such as tubing disconnection, cuff or connector leaks, tubing or airway kinks, or changes in resistance and compliance.

   **Always consider the possibility of a tension pneumothorax.**

   **Reportable condition: Unexplained high pressure alarms**

7. Maintain the head of the bed at 30 to 45 degrees of elevation.2,3
8. Evaluate the patient for the presence of patient–ventilator dyssynchrony. If patient–ventilator dyssynchrony is present, take the patient off the ventilator and manually ventilate with a self-inflating manual resuscitation bag.

   **Reportable condition: Patient–ventilator dyssynchrony**

9. Observe for hemodynamic changes associated with increased VT, PEEP, or decreased cardiac output.

   Rationale: Hemodynamic changes may indicate functional changes in circulating volume caused by positive intrathoracic pressure.

   **Always consider the potential for pneumothorax with acute changes.**

   **Reportable conditions: Decreased blood pressure, change in heart rate, decreased cardiac output, decreased mixed venous oxygen tension, increased arterial-venous oxygen difference**

10. On an ongoing basis, monitor the patient for complications of mechanical ventilation, such as barotrauma, volutrauma, ventilator-associated pneumonia (VAP), or pneumothorax.
11. Assess, treat, and reassess pain.

**EXPECTED OUTCOMES**
- Maintenance of adequate pH, arterial partial pressure of carbon dioxide (PaCO₂), and partial pressure of arterial oxygen (PaO₂) levels
- Maintenance of adequate breathing pattern
- Respiratory muscle rest

**UNEXPECTED OUTCOMES**
- Unacceptable pH, PaCO₂, or PaO₂ levels
- Hemodynamic instability
Mechanical Ventilation: Volume and Pressure Modes - CE

• Pulmonary barotrauma or volutrauma
• Ventilator-associated pneumonia (VAP)
• Respiratory muscle fatigue

DOCUMENTATION

• Patient and family education
• Indication, date, and time ventilatory assistance was instituted
• Ventilator settings
• Arterial blood gas (ABG) values
• Vital signs and oxygen saturation
• Patient’s response to procedure
• Hemodynamic values
• Unexpected outcomes and related nursing interventions
• Pain assessment and management
• Sedation assessment and management

REFERENCES


ADDITIONAL READINGS


*In these skills, a “classic” reference is a widely cited, standard work of established excellence that significantly affects current practice and may also represent the foundational research for practice.

Elsevier Skills Levels of Evidence

• Level I - Systematic review of all relevant randomized controlled trials
• Level II - At least one well-designed randomized controlled trial
• Level III - Well-designed controlled trials without randomization
Mechanical Ventilation: Volume and Pressure Modes - CE

- Level IV - Well-designed case-controlled or cohort studies
- Level V - Descriptive or qualitative studies
- Level VI - Single descriptive or qualitative study
- Level VII - Authority opinion or expert committee reports

SUPPLIES
- Electrocardiogram
- Pulse oximeter
- Self-inflating manual resuscitation bag with positive end-expiratory pressure (PEEP) adjusted to patient’s baseline level or with a PEEP valve
- Suction equipment
- Ventilator

Clinical Review: Kathleen M. Stacy, PhD, RN, APRN-CNS, CCNS
Published: July 2019

Table 1 Modes of Mechanical Ventilation

<table>
<thead>
<tr>
<th>Mode of Ventilation</th>
<th>Clinical Application</th>
<th>Nursing Implications</th>
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<tbody>
<tr>
<td>Continuous mandatory ventilation (CMV), also known as assist-control (AC) ventilation: delivers gas at preset tidal volume or pressure (depending on selected cycling variable) in response to patient’s inspiratory efforts and initiates breath if patient fails to do so within preset time.</td>
<td>Volume-controlled CMV (VC-CMV) is used as the primary mode of ventilation in spontaneously breathing patients with weak respiratory muscles. Pressure-controlled CMV (PC-CMV) is used in patients with decreased lung compliance or increased airway resistance, particularly when the patient is at risk for volutrauma.</td>
<td>Hyperventilation can occur in patients with increased respiratory rates. Sedation may be necessary to limit the number of spontaneous breaths. Patient on VC-CMV should be monitored for volutrauma. Patient on PC-CMV should be monitored for hypercapnia.</td>
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<tr>
<td>Pressure-regulated volume-controlled ventilation (PRVCV): a variation of CMV that combines volume and pressure features and delivers a preset tidal volume using the lowest possible airway pressure; airway pressure will not exceed preset maximum pressure limit.</td>
<td>PRVCV is used in patients with rapidly changing pulmonary mechanics (airway resistance and lung compliance), limiting potential complications.</td>
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<td>Mode of Ventilation</td>
<td>Clinical Application</td>
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<tr>
<td>Pressure-controlled/inverse-ratio ventilation (PC/IRV): PC-CMV mode in which the inspiratory-to-expiratory (I:E) time ratio is greater than 1:1.</td>
<td>PC/IRV is used in patients with hypoxemia refractory to positive end-expiratory pressure (PEEP); the longer inspiratory time increases functional residual capacity and improves oxygenation by opening collapsed alveoli, and the shorter expiratory time induces auto-PEEP, which prevents alveoli from recollapsing.</td>
<td>Requires sedation or pharmacologic paralysis, or both because of discomfort. Increased intrathoracic pressure can result in excessive air trapping and decreased cardiac output.</td>
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<tr>
<td>Intermittent mandatory ventilation (IMV), also known as synchronous intermittent mandatory ventilation (SIMV): delivers gas at preset tidal volume or pressure (depending on selected cycling variable) and rate while allowing patient to breathe spontaneously; ventilator breaths are synchronized to patient’s respiratory effort.</td>
<td>Volume-controlled IMV (VC-IMV) is used as a primary mode of ventilation in many clinical situations and as a weaning mode. Pressure-controlled IMV (PC-IMV) is used in patients with decreased lung compliance or increased airway resistance when the need to preserve the patient’s spontaneous effects is important.</td>
<td>May increase the work of breathing and promote respiratory muscle fatigue. Patient should be monitored for hypercapnia, particularly with PC-IMV.</td>
</tr>
<tr>
<td>Adaptive support ventilation (ASV): ventilator automatically adjusts settings to maintain 100 ml/min/kg of minute ventilation; provides pressure support.</td>
<td>ASV is a computerized mode of ventilation that increases or decreases ventilatory support based on patient needs; can be used with any patient requiring volume-controlled ventilation.</td>
<td>Not intended as a weaning mode. Adapts to changes in patient position.</td>
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<tr>
<td>Continuous positive airway pressure (CPAP): positive pressure applied during spontaneous breaths; patient controls rate, inspiratory flow, and tidal volume.</td>
<td>CPAP is a spontaneous breathing mode used in patients to increase functional residual capacity and improve oxygenation by opening collapsed alveoli at end expiration; it is also used for weaning.</td>
<td>Side effects include decreased cardiac output, volutrauma, and increased intracranial pressure. No ventilator breaths are delivered in PEEP or CPAP mode unless used with CMV or IMV.</td>
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<tr>
<th>Mode of Ventilation</th>
<th>Clinical Application</th>
<th>Nursing Implications</th>
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<tbody>
<tr>
<td>Airway pressure release ventilation (APRV)</td>
<td>APRV is a spontaneous breathing mode used to maintain alveolar recruitment without imposing additional peak inspiratory pressures that could lead to barotrauma.</td>
<td>Patient needs to be monitored for hypercapnia.</td>
</tr>
<tr>
<td>Pressure support ventilation (PSV): preset</td>
<td>PSV is a spontaneous breathing mode used as the primary mode of ventilation in patients with stable respiratory drive to overcome any imposed mechanical resistance (e.g., artificial airway).</td>
<td>Patient should be monitored for hypercapnia.</td>
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<td>inspiratory effort is used to augment patient’s</td>
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<td>Advantages include reduced patient work of breathing and improved patient–ventilator synchrony.</td>
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<td>inspiratory efforts; patient controls rate,</td>
<td>PSV can also be used with IMV to support spontaneous breaths.</td>
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<td>inspiratory flow, and tidal volume.</td>
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<tr>
<td>Volume-assured pressure support ventilation</td>
<td>VAPSV is a spontaneous breathing mode used to treat acute respiratory illness and to facilitate weaning.</td>
<td>Advantages include increased patient comfort, decreased work of breathing, decreased respiratory muscle fatigue, and promotion of respiratory muscle conditioning.</td>
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<td>(VAPSV), also known as pressure augmentation</td>
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<td>(PA): a variation of PSV with a set tidal</td>
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<td>volume to ensure that patient receives minimum</td>
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<td>tidal volume with each pressure support breath.</td>
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<tr>
<td>Neurally adjusted ventilatory assist (NAVA):</td>
<td>NAVA delivers an assisted breath in proportion to and in synchrony with the patient’s respiratory effort.</td>
<td>Requires an esophageal catheter (similar to a nasogastric tube) that measures the electrical signal to the diaphragm (Edi).</td>
</tr>
<tr>
<td>Independent lung ventilation (ILV): each lung</td>
<td>ILV is used in patients with unilateral lung disease, bronchopleural fistulas, or bilateral asymmetric lung disease.</td>
<td>Requires a double-lumen endotracheal tube, two ventilators, sedation, pharmacologic paralysis, or all of the above.</td>
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<tr>
<td>is ventilated separately.</td>
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### Table 1 continued from previous page

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<tr>
<th>Mode of Ventilation</th>
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<tr>
<td>High-frequency ventilation (HFV)</td>
<td>HFV is used in situations in which conventional mechanical ventilation compromises hemodynamic stability, in patients with bronchopleural fistulas, during short-term procedures, and with diseases that create a risk of volutrauma.</td>
<td>Patient requires sedation, pharmacologic paralysis, or both. Inadequate humidification can compromise airway patency. Assessment of breath sounds is difficult.</td>
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<tr>
<td>High-frequency positive-pressure ventilation (HFPPV)</td>
<td>delivers 60–100 breaths/min. High-frequency jet ventilation (HFJV) delivers 100–600 cycles/min. High-frequency oscillation (HFO) delivers 900–3000 cycles/min.</td>
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<td>High-frequency oscillation (HFO)</td>
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### Table 2 Ventilator Settings

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<tr>
<th>Parameter</th>
<th>Description</th>
<th>Typical Settings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respiratory rate or frequency (f)</td>
<td>Number of breaths the ventilator delivers per minute</td>
<td>6–20 breaths/min</td>
</tr>
<tr>
<td>Tidal volume (VT)</td>
<td>Volume of gas delivered to patient during each ventilator breath</td>
<td>6–8 ml/kg 4–6 ml/kg in acute respiratory distress syndrome (ARDS)</td>
</tr>
<tr>
<td>Oxygen concentration (FiO₂)</td>
<td>Fraction of inspired oxygen delivered to patient</td>
<td>May be set between 21% and 100%; adjusted to maintain arterial partial pressure of oxygen (PaO₂) level greater than 60 mm Hg or oxygen saturation greater than 92%</td>
</tr>
<tr>
<td>Positive end-expiratory pressure (PEEP)</td>
<td>Positive pressure applied at the end of expiration of ventilator breath</td>
<td>3–5 cm H₂O</td>
</tr>
<tr>
<td>Pressure support (PS)</td>
<td>Positive pressure used to augment patient’s inspiratory efforts</td>
<td>5–10 cm H₂O</td>
</tr>
<tr>
<td>Inspiratory flow rate and time</td>
<td>Speed with which the tidal volume is delivered</td>
<td>40–80 L/min 0.8–1.2 sec</td>
</tr>
<tr>
<td>Inspiratory-to-expiratory (I:E) ratio</td>
<td>Ratio of duration of inspiration to duration of expiration</td>
<td>1:2 to 1:1.5 unless inverse ratio ventilation is desired</td>
</tr>
</tbody>
</table>
### Table 2 Ventilator Settings

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Typical Settings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
<td>Determines the amount of effort the patient must generate to initiate a ventilator breath; it may be set for pressure-triggering or flow-triggering.</td>
<td>Pressure trigger: 0.5–1.5 cm H(_2)O below baseline pressure Flow trigger: 1–3 L/min below baseline flow.</td>
</tr>
<tr>
<td>High-pressure limit</td>
<td>Regulates the maximal pressure the ventilator can generate to deliver the tidal volume; when the pressure limit is reached, the ventilator terminates the breath and spills the undelivered volume into the atmosphere.</td>
<td></td>
</tr>
</tbody>
</table>


### Table 3 Troubleshooting Ventilator Alarms

<table>
<thead>
<tr>
<th>Problem</th>
<th>Causes</th>
<th>Interventions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low exhaled VT</td>
<td>Altered settings; any condition that triggers high- or low-pressure alarm; patient stops spontaneous respirations; leak in system preventing VT from being delivered; cuff insufficiently inflated; leak through chest tube; airway secretions; decreased lung compliance; spirometer disconnected or malfunctioning.</td>
<td>Check settings; evaluate patient, check respiratory rate; check all connections for leaks; suction patient’s airway; check cuff pressure; calibrate spirometer.</td>
</tr>
<tr>
<td>Low inspiratory pressure</td>
<td>Altered settings; unattached tubing or leak around ET tube; ET tube displaced into pharynx or esophagus; poor cuff inflation or leak; tracheoesophageal fistula; peak flows that are too low; low VT; decreased airway resistance resulting from decreased secretions or relief of bronchospasm; increased lung compliance resulting from decreased atelectasis; reduction in pulmonary edema; resolution of ARDS; change in position.</td>
<td>Reset alarm; reconnect tubing; modify cuff pressures; tighten humidifier; check chest tube; adjust peak flow to meet or exceed patient demand and correct for the patient’s VT; reposition or change ET tube.</td>
</tr>
</tbody>
</table>

*Table 3 continued on next page*
### Table 3 continued from previous page

<table>
<thead>
<tr>
<th>Problem</th>
<th>Causes</th>
<th>Interventions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low exhaled minute volume</td>
<td>Altered settings; leak in system; airway secretions; decreased lung compliance; malfunctioning spirometer; decreased patient-triggered respiratory rate resulting from medications, sleep, hypocapnia, alkalosis, fatigue, change in neurologic status</td>
<td>Check settings; assess patient’s respiratory rate, mental status, and work of breathing; evaluate system for leaks; suction airway; assess patient for changes in disease state; calibrate spirometer.</td>
</tr>
<tr>
<td>Low PEEP/CPAP</td>
<td>Altered settings; increased patient inspiratory flows; leak; decreased expiratory flows from ventilator</td>
<td>Check settings and correct; observe for leaks in system; if unable to correct problem, increase PEEP settings.</td>
</tr>
<tr>
<td>High respiratory rate</td>
<td>Increased metabolic demand; medication administration; hypoxia; hypercapnia; acidosis; shock; pain; fear; anxiety</td>
<td>Evaluate ABGs; assess patient; calm and reassure patient.</td>
</tr>
<tr>
<td>High-pressure limit</td>
<td>Improper alarm setting; airway obstruction resulting from patient fighting ventilator (holding breath as ventilator delivers VT); patient circuit collapse; tubing kinked; ET tube in right main stem bronchus or against carina; cuff herniation; increased airway resistance resulting from bronchospasm, airway secretions, plugs, and coughing; water from humidifier in ventilator tubing; decreased lung compliance resulting from tension pneumothorax, change in patient position, ARDS, pulmonary edema, atelectasis, pneumonia, or abdominal distention</td>
<td>Reset alarms; clear obstruction from tubing; unkink and reposition patient off of tubing; empty water from tubing; check breath sounds; reassure patient and sedate if necessary; check ABG levels for hypoxemia; observe for abdominal distention that would put pressure on the diaphragm; check cuff pressures; obtain chest radiograph and evaluate for ET tube position, pneumothorax, and pneumonia; reposition ET tube; give bronchodilator therapy.</td>
</tr>
<tr>
<td>Low-pressure oxygen inlet</td>
<td>Improper oxygen alarm setting; oxygen not connected to ventilator; dirty oxygen intake filter</td>
<td>Correct alarm setting; reconnect or connect oxygen line to a 50-psi source; clean or replace oxygen filter.</td>
</tr>
<tr>
<td>I:E ratio</td>
<td>Inspiratory time longer than expiratory time; use of an inspiratory phase that is too long with a fast rate; peak flow setting too low while rate too high; machine too sensitive</td>
<td>Change inspiratory time or adjust peak flow; check inspiratory phase or hold; check machine sensitivity.</td>
</tr>
</tbody>
</table>
### Table 3 continued from previous page

<table>
<thead>
<tr>
<th>Problem</th>
<th>Causes</th>
<th>Interventions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>Sensor malfunction; overheating resulting from too low or no gas flow; sensor picking up outside airflow (from heater, open door or window, air conditioner); improper water levels</td>
<td>Test or replace sensor; check gas flow; protect sensor from outside source that would interfere with readings; check water levels.</td>
</tr>
</tbody>
</table>