Mechanical Ventilation: Pressure Support, Pressure Control, and Volume-Assured Pressure Support (Respiratory Therapy)

ALERT

Never disable ventilator alarms.

Always plug a ventilator into a power outlet that is supplied by an emergency generator.

OVERVIEW

Positive pressure ventilation (PPV) through an artificial airway is used to maintain or improve oxygenation and ventilation. Respiratory insufficiency or failure, evidenced by apnea, hypoxia, hypercarbia, and increased work of breathing, are indications for mechanical ventilation. Selection of volume or pressure modes is dependent on the available evidence, clinical goals, availability of modes, and the practitioner's preference. There is very little evidence indicating that one mode of ventilation is more effective than another in terms of clinical outcomes (i.e., mortality) and ventilator hours needed.

Positive pressure modes of ventilation have traditionally been categorized into volume mode and pressure mode. However, with the advent of microprocessor technology, sophisticated iterations of traditional volume and pressure modes of ventilation have evolved. Ventilator manufacturers have created different names for the modes, and parameters that require adjustment vary somewhat among the ventilators. Although many of the modes have names that are different from traditional volume and pressure modes, they are similar in function in many cases. There is little evidence that the newer modes improve outcomes.

With traditional pressure ventilation, the practitioner selects the desired pressure level, and the inspired tidal volume (V_T) is determined by the selected pressure level and the patient's resistance and compliance. This is an important characteristic to note when caring for an unstable patient on a pressure mode of ventilation. Careful attention to exhaled V_T is necessary to prevent inadvertent hyperventilation or hypoventilation. Permissive hypercapnia should not be attempted in patients with elevated intracranial pressure (ICP) or patients with myocardial ischemia, injury, or arrhythmias. Some patients receiving low-pressure ventilation, leading to permissive hypercapnia, require sedation to decrease spontaneous effort.

Many modes of pressure ventilation are available. Those modes include assist-control (A/C), synchronized intermittent mandatory ventilation (SIMV), pressure support ventilation (PSV), positive end-expiratory pressure (PEEP) and continuous positive airway pressure (CPAP), pressure-control/inverse ratio ventilation (PC/IRV), proportional assist ventilation (PAV), adaptive support ventilation (ASV), airway pressure release ventilation (APRV), and biphasic (Table 1).

Table 1 Volume and Pressure Modes and Corresponding Ventilator Parameters

Mode name and description	Main parameters	Comments
Assist control (A/C)	V_T Rate T_I	Generally considered a support mode. Must switch to another mode or method for weaning.

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	Sensitivity F_{IO_2} PEEP	
Synchronized mandatory ventilation (SIMV)	V_T Rate T_I Sensitivity F_{IO_2} PEEP	Originally used as a weaning mode; however, work of breathing is high at low SIMV rates. Often used in conjunction with PSV.
Pressure support ventilation (PSV)	Pressure support (PS) level Sensitivity F_{IO_2} PEEP	Often pressure is arbitrarily selected (e.g., 10–20 cm H_2O) then adjusted up or down to attain the desired tidal volume. Some use the plateau pressure if transitioning from volume ventilation as a starting point.
Pressure-controlled ventilation (PCV)	Inspiratory pressure limit (IPL) Rate T_I Sensitivity F_{IO_2} PEEP	Variants of PCV include volume-assured pressure options and some other modes, such as airway pressure release ventilation and bilevel ventilation.
Pressure-controlled inverse ratio ventilation	As for PCV, but an inverse inspiratory-to-expiratory (I:E) ratio is attained by lengthening the T_I. Inverse ratios include 1:1, 2:1, 3:1, and 4:1.	Some ventilators allow for the I:E ratio to be selected.
Bilevel positive airway pressure (bilevel or BiPAP)	P_{HIGH} P_{LOW} T_{HIGH} (similar to inspiratory time in PC) T_{LOW} (similar to expiratory time in PC) *or* Set T_{HIGH}/T_{LOW} ratio Rate F_{IO_2}	Similar in many ways to PCV in that an inspiratory pressure (P_{HIGH}) and PEEP (P_{LOW}) are set. However, unlike PCV, the patient may take spontaneous breaths as well. If additional support is desired for patient-initiated breathing, pressure support in bilevel mode (P_{SUPP}) may be selected as well. Attention to V_T is important because the patient can augment V_T significantly with supported spontaneous breaths.
Airway pressure release ventilation (APRV)	P_{HIGH}: high CPAP level P_{LOW} is generally 0–5 H_2O. T_{HIGH} T_{LOW} F_{IO_2}	APRV is a form of biphasic ventilation with a very short expiratory time. Generally, the CPAP level is adjusted to ensure adequate oxygenation while the rate of the releases is increased or decreased to meet ventilation goals. V_T is variably dependent on the CPAP level, compliance and resistance of the patient, and patient spontaneous effort.

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Dual control or volume-assured pressures modes (1–5 listed below)	These modes provide pressure breaths with a minimum tidal volume assurance.	These modes are ventilator-specific. Although the similarities are greater than the differences, they are called different names. Often the names suggest that the mode is a volume mode, yet a decelerating flow pattern (associated with pressure ventilation) is always provided.
1. Volume support (VS)	V_T Sensitivity F_{IO_2} PEEP	The pressure level is automatically adjusted to attain the desired V_T. If control of pressure is desired, it must be carefully monitored.
2. Pressure-regulated control (PRVC)	Rate and T_I set in addition to those set for VS.	As with VS. The difference is that this is a control mode. Spontaneous breaths, however, may also occur.
3. Volume control plus (VC+)	Rate and T_I are set in addition to those set for VS.	This is a mode option listed in the category called *Volume and Ventilation Plus*. To access this mode, the RT selects the SIMV or A/C (both control modes), then selects VC+. For some clinicians, this is confusing because it appears that the patient is on two different modes versus VC+.
4. Adaptive support ventilation (ASV)	Body weight %MinVol High pressure limit	Once basic settings are selected, ASV is started and %MinVol is adjusted if indicated. Spontaneous breathing is automatically encouraged, and when the inspiratory pressure (P_{INSP}) is consistently 0 and rate is 0, extubation may be considered.
5. Proportional assist ventilation (PAV)	Proportional pressure support (PPS): PEEP, F_{IO_2}, percent volume assist and flow assist Proportional assist plus: PEEP, F_{IO_2}, percent support	Depending on the ventilator, the amount of assistance that is provided is determined by the clinician, and different parameters are selected to do so. Default percent support numbers are recommended, but the clinician must determine the timing of reductions of same.
6. Automatic tube compensation (ATC)	Endotracheal tube internal diameter Percent compensation	This is not an independent mode, but rather a pressure option to offset the work associated with tube resistance. It can be combined with other modes or used alone, as in a CPAP weaning trial.

%MinVol, minute volume; *A/C*, assist control; *APRV*, airway pressure release ventilation; *ASV*, adaptive support ventilation; *ATC*, automatic tube compensation; *BiPAP*, bilevel positive airway pressure; *CPAP*, continuous positive airway pressure; F_{IO_2}, fraction of inspired oxygen; *I:E*, inspiratory-to-expiratory; *PAV*, proportional assist ventilation; *PAV+,* proportional assist plus; *PC*, pressure control; *PCV*, pressure-controlled ventilation; *PEEP*, positive end-expiratory pressure; P_{HIGH}, pressure high; P_{INSP}, inspiratory pressure; P_{LOW}, pressure low; *PPS*, proportional pressure support; *PRVC*, pressure-regulated control; P_{SUPP}, pressure support; *PSV*, pressure support ventilation; *SIMV*, synchronized mandatory ventilation; T_{HIGH}, time high; T_I, inspiratory time; T_{LOW}, time low; *VC+*, volume control plus; *VS*, volume support; V_T, tidal volume

(Adapted from Burns, S.M. [2008]. Pressure modes of mechanical ventilation: The good, the bad, and the ugly. *AACN Advanced Critical Care, 19*[4], 399-411.)

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Summary descriptions of modes, mode parameters, and ventilator alarms are provided within this procedure (Table 1) (Table 2).

Table 2 Alarms and Backup Ventilation Setting of Initial Ventilatory Setup (Adults)	
Alarm	**Setting**
Low pressure	5–10 cm H_2O below PIP
Low PEEP/CPAP	3–5 cm H_2O below PEEP
High pressure limit	50 cm H_2O, which is adjusted to 10–15 cm H_2O above PIP
Low exhaled V_T	100 ml or 50% below set V_T
Low exhaled MV	2–5 L/min or 50% below minimum SIMV or A/C backup MV
High MV	50% above baseline MV
Oxygen percentage (F_{IO_2})	5% above and below set oxygen percentage
Temperature	2°C (3.6°F) above and below set temperature, high temperature not to exceed 37°C (98.6°F)
Apnea delay	20 sec
Apnea values	V_T and rate set to achieve full ventilatory support (V_T 6–8 ml/kg, rate 10–12 breaths/min) with 100% oxygen

A/C, assist-control; *CPAP,* continuous positive airway pressure; *F_{IO_2},* fraction of inspired oxygen; *MV,* minute volume; *PEEP,* positive end-expiratory pressure; *PIP,* positive inspiratory pressure; *SIMV,* synchronized intermittent mandatory ventilation; *V_T,* tidal volume
(From R.M. Kacmarek, J.K. Stoller, A.J. Heuer. [2017]. *Egan's fundamentals of respiratory care* [11th ed.]. St. Louis: Elsevier.)

Humidity

Humidity is essential to prevent the drying effect of the gases provided by the ventilator. Inspired gases may be humidified with the use of standard cascade or high-volume humidifiers. Many organizations use disposable heat-moisture exchangers (HMEs) in place of conventional humidifiers because HMEs decrease the risk of infection and are inexpensive. HMEs prevent hypothermia, evaporation and thickening of secretions, atelectasis, and destruction of the epithelium in the airway.[1] The use of HMEs has been associated with decreased incidence of ventilator-associated pneumonia (VAP) in ventilated patients.[5]

Complications

Complications of PPV include pulmonary barotrauma, volume-pressure trauma, hemodynamic changes, and VAP.

- Pulmonary barotrauma is manifested by pneumothorax, pneumomediastinum, pneumopericardium, pneumoperitoneum, and subcutaneous emphysema.
- Volume-pressure trauma is evidenced by large volumes being translated into high plateau pressures and subsequent acute lung injury.

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- Hemodynamic changes can be caused by PPV, which can reduce venous return and decrease cardiac output. Auto-PEEP is a common complication of mechanical ventilation that can result in hemodynamic compromise and even death.

EDUCATION

- Clarify advance directives with the patient and family.
- During a life-threatening emergency, mechanical ventilation may need to be initiated quickly, with no time for staff to speak with the patient or family members beforehand. As soon as possible, educate the patient and family about mechanical ventilation.
- 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. Communicate in a way they understand; "respirator" and "life support" are commonly understood terms.
- Explain the procedure to the patient and family.
- Discuss the potential benefits of mechanical ventilation that the patient may experience (e.g., less shortness of breath, less difficulty with the breathing process).
- Discuss the unpleasant sensations that the patient may experience (e.g., gagging, anxiety). Explain to the patient that medications are given to promote relaxation and tolerance of the treatment. Explain that some patients may require sedation during mechanical ventilation.
- Explain 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 to the patient and family what they should expect while the patient is ventilated.
- Educate the patient and family about ventilator alarms and their meanings. 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 need for mechanical ventilation before initiating ventilator support.

a. Signs and symptoms of respiratory insufficiency or failure (e.g., hypercapnia secondary to hypoventilation, hypoxia)
b. Decreased peripheral oxygen saturation (SpO_2) and arterial oxygen saturation (SaO_2)
c. Altered level of consciousness
d. Adventitious breath sounds
e. Acid-base imbalance
f. Cyanosis
g. Hypotension or hypertension
h. Increased work of breathing
i. Hemodynamic instability

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Preparation

1. Before initiating mechanical ventilation, ensure that the ventilator and associated equipment are functioning properly per the manufacturers' specifications and the organization's practice. Check the system microprocessor or ventilation system, circuit compliance, HME or humidifier, and filters, and perform a circuit leak test.
2. Ensure that the patient is positioned with the head of the bed elevated 30 to 45 degrees, unless contraindicated.[3]

PROCEDURE

Pressure Support Ventilation (PSV)

1. Perform hand hygiene and don gloves.
2. Verify the correct patient using two identifiers.
3. Explain the procedure to the patient and ensure that he or she agrees to treatment.
4. Select the PSV level to lower the spontaneous respiratory rate to less than or equal to 20 breaths/min and to attain a V_T of 6 to 8 ml/kg ideal body weight (IBW).[3] If necessary, increase the V_T if the partial pressure of carbon dioxide ($PaCO_2$) increases or decreases below the normal values, causing the patient to become hypercarbic or alkalotic.

   Rationale: Increasing the pressure support (PS) allows for larger V_Ts, to decrease the risk for hypercarbia. Decreasing the PS leads to increased acidosis and smaller V_Ts.

5. Set the trigger sensitivity between −1 and −2 cm H_2O pressure.[3]

   Rationale: If the sensitivity is set too low, increased patient effort is necessary to initiate a ventilator breath. Dyssynchrony can result.

6. Select the PEEP level. In many cases, the initial setting is 5 cm H_2O.[3]

a. Adjust PEEP as needed after evaluation of tolerance (e.g., SaO_2, arterial partial pressure of oxygen [PaO_2], physical assessment).
b. Increase PEEP levels to restore functional residual capacity (FRC) and allow reduction of fraction of inspired oxygen (FIO_2) to safe levels (i.e., less than or equal to 0.5).[3]

   Rationale: A PEEP level of 5 cm H_2O is considered physiologic.[3] High levels of PEEP rarely should be interrupted because reestablishing FRC (and PaO_2) may take hours, especially in a patient with acute respiratory distress syndrome (ARDS).

7. Place the patient on 100% oxygen unless information is available that identifies a precise FIO_2.[3] Adjust the FIO_2 downward, as tolerated, using SaO_2 and arterial blood gas (ABG) values to guide level selection. Titrate the FIO_2 to obtain a PaO_2 of 60 to 80 mm Hg and an SpO_2 or SaO_2 of 90% or greater.[3]

   Rationale: Most patients in the acute care setting should be placed on 100% oxygen unless information is available identifying a precise FIO_2.[3] High levels of FIO_2 result in increased risk of oxygen toxicity, absorption atelectasis, and

reduction of surfactant synthesis. By initiating PPV with maximum oxygen concentration, hypoxemia can be avoided while optimal ventilator settings are being determined and evaluated. This also permits measurement of the percentage of venous admixture (shunt), which provides an estimate of the severity of the gas-exchange abnormality.

8. Ensure that the ventilator alarms are set appropriately (Table 2).
9. Provide circuit humidification.

a. For conventional humidifiers, make sure the humidifier has adequate fluid (sterile distilled water) and that the thermostat setting is adjusted according to the manufacturer's recommendations.
b. When using a humidifier, maintain the gas temperature between 34°C and 41°C (93.2°F and 105.8°F) at the circuit Y-piece with a relative humidity of 100%.[1]

Rationale: Gases are generally humidified before entering the artificial airway.

In a patient with thick or tenacious secretions, pay attention to the inspired temperature to prevent mucus plugging. In this situation, circuit temperature may need to be closer to body temperature.

c. Place an HME between the patient's airway and the ventilator circuit.

Rationale: The moisture in warmed, exhaled gases passes through the vast surface area of the HME and condenses. With inspiration, dry gases pass through the HME and become humidified.

i. Change the HME per the manufacturer's instruction. In many cases, an HME can be used for at least 48 hours; in some patients, it can be used for up to 1 week.[1]

Rationale: The longer the HME is inline, the more efficient the humidification; however, inspiratory resistance increases over time. In weaning patients, the additional resistive load added by these humidifiers may preclude their use.

ii. Do not use an HME if secretions are copious or bloody.

Rationale: Secretions may cause obstruction; an HME is contraindicated when secretions are copious or bloody.

10. Place the capnography device and appropriate adapter in the ventilator circuit, if ordered, or per the organization's practice.
11. Discard supplies, remove gloves, and perform hand hygiene.
12. Document the procedure in the patient's record.

Pressure Control (PC)

1. Perform hand hygiene and don gloves.
2. Verify the correct patient using two identifiers.
3. Explain the procedure to the patient and ensure that he or she agrees to treatment.

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4. Select PC.
5. Select the inspiratory pressure level (IPL).
6. Select the respiratory rate.
7. Select the inspiratory time (T_I) or inverse inspiratory-to-expiratory (I:E) ratio (ventilators vary). The patient likely will not tolerate the prolonged T_I in inverse ratio ventilation (IRV) without sedation and paralysis.

   Rationale: Because IRV may result in auto-PEEP, evaluating the total amount of PEEP present is important.

8. Select the PEEP level. When transitioning from volume ventilation to PC/IRV, initially maintain PEEP at the level used previously until the IRV's effect is assessed.

   Rationale: The goal of PC/IRV is to improve oxygenation. This is done in conjunction with PEEP.

   IRV may result in auto-PEEP (which may be a desirable outcome of the mode); regardless, anticipate and measure auto-PEEP regularly.

9. Set the trigger sensitivity to between –0.5 and –1.5 cm H_2O pressure.[4]

   Rationale: If the sensitivity is set too low, increased patient effort is necessary to initiate a ventilator breath. Dyssynchrony can result.

10. Place the patient on 100% oxygen unless information is available that identifies a precise F_{IO_2}.[3] Adjust the F_{IO_2} downward, as tolerated, using Sa_{O_2} and ABG values to guide level selection. Titrate the F_{IO_2} to obtain a Pa_{O_2} of 60 to 80 mm Hg and an Sa_{O_2} or Sp_{O_2} of 90% or greater.[3]

    Rationale: Most patients in the acute care setting should be placed on 100% oxygen unless information is available identifying a precise F_{IO_2}.[3] High levels of F_{IO_2} result in increased risk of oxygen toxicity, absorption atelectasis, and reduction of surfactant synthesis. By initiating PPV with maximum oxygen concentration, hypoxemia can be avoided while optimal ventilator settings are being determined and evaluated. This also permits measurement of the percentage of venous admixture (shunt), which provides an estimate of the severity of the gas-exchange abnormality.

11. Ensure that the ventilator alarms are set appropriately (Table 2).
12. Provide humidification of the circuit.

a. For conventional humidifiers, make sure the humidifier has adequate fluid (sterile distilled water) and that the thermostat setting is adjusted according to the manufacturer's recommendations.
b. When using a humidifier, maintain the gas temperature between 34°C and 41°C (93.2°F and 105.8°F) at the circuit Y-piece with a relative humidity of 100%.[1]

   Rationale: Gases are generally humidified before entering the artificial airway.

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In a patient with thick or tenacious secretions, pay attention to inspired temperature to prevent mucus plugging. In this situation, circuit temperature may need to be closer to body temperature.

c. Place an HME between the patient's airway and the ventilator circuit.

Rationale: The moisture in warmed, exhaled gases passes through the vast surface area of the HME and condenses. With inspiration, dry gases pass through the HME and become humidified.

i. Change the HME per the manufacturer's instruction. In many cases, an HME can be used for at least 48 hours; in some patients, it can be used for up to 1 week.[1]

Rationale: The longer the HME is inline, the more efficient the humidification; however, inspiratory resistance increases over time. In weaning patients, the additional resistive load added by these humidifiers may preclude their use.

ii. Do not use an HME if secretions are copious or bloody.

Rationale: Secretions may cause obstruction; an HME is contraindicated when secretions are copious or bloody.

13. Place the capnography device and appropriate adapter within the ventilator circuit, if ordered, or per the organization's practice.
14. Discard supplies, remove gloves, and perform hand hygiene.
15. Document the procedure in the patient's record.

Volume-Assured Pressure Support (VAPS)

1. Perform hand hygiene and don gloves.
2. Verify the correct patient using two identifiers.
3. Explain the procedure to the patient and ensure that he or she agrees to treatment.
4. Select VAPS.
5. Select the desired V_T.
6. Select the parameters (pressure, volume, rate). Consult the specific ventilator manual as needed for additional parameter settings.

Rationale: Volume-guaranteed pressure modes require that the practitioner select the desired V_T; some ventilators also require selection of the pressure level. Spontaneous breathing modes and controlled modes are available.

7. Place the patient on 100% oxygen unless information is available that identifies a precise F_{IO_2}.[3] Adjust the F_{IO_2} downward as tolerated using Sa_{O_2} and ABG values to guide level selection. Titrate the F_{IO_2} to obtain a Pa_{O_2} of 60 to 80 mm Hg and an Sa_{O_2} or Sp_{O_2} of 90% or greater.[3]

Rationale: Most patients in the acute care setting should be placed on 100% oxygen unless information is available identifying a precise F_{IO_2}.[3] High levels

of F_{IO_2} result in increased risk of oxygen toxicity, absorption atelectasis, and reduction of surfactant synthesis. By initiating PPV with maximum oxygen concentration, hypoxemia can be avoided while optimal ventilator settings are being determined and evaluated. This also permits measurement of the percentage of venous admixture (shunt), which provides an estimate of the severity of the gas-exchange abnormality.

8. Ensure that the ventilator alarms are set appropriately (Table 2).
9. Provide circuit humidification.

a. For conventional humidifiers, make sure the humidifier has adequate fluid (sterile distilled water) and that the thermostat setting is adjusted according to the manufacturer's recommendations.
b. When using a humidifier, maintain the gas temperature between 34°C and 41°C (93.2°F and 105.8°F) at the circuit Y-piece with a relative humidity of 100%.[1]

Rationale: Gases are generally humidified before entering the artificial airway.

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ii. Do not use an HME if secretions are copious or bloody.

iii. Rationale: Secretions may cause obstruction; an HME is contraindicated when secretions are copious or bloody.

10. Place the capnography device and appropriate adapter within the ventilator circuit, if ordered, or per the organization's practice.
11. Discard supplies, remove gloves, and perform hand hygiene.
12. Document the procedure in the patient's record.

MONITORING AND CARE

1. Check for secure stabilization and maintenance of the endotracheal (ET) tube. (Commercial ET tube holders are available.)

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2. Confirm ET tube placement, ideally by clinical assessment and continuous waveform capnography. If continuous waveform capnography is not available, use a nonwaveform numeric exhaled carbon dioxide monitor.
3. Monitor SpO_2 continuously.
4. Monitor the inline thermometer to maintain inspired gas temperature between 34°C and 41°C (93.2°F and 105.8°F).[1]

   Rationale: There is the risk of thermal injury from overheated inspired gas and risk of poor humidity from underheated inspired gas.

5. Keep the ventilator tubing clear of condensation. Drain tubing from the patient toward the expiratory limb.

   Rationale: Condensation in the tube that is drained toward the patient may cause a respiratory infection if the patient inhales the contaminated water droplets.

6. Ensure the availability of a self-inflating manual resuscitation bag (MRB) and appropriate-size face mask attached to supplemental oxygen at the head of the bed. Attach or adjust the PEEP valve if the patient is on PEEP.

   Rationale: Ventilation and oxygen may be needed immediately to relieve acute respiratory distress caused by hypoxemia or acidosis.

7. Check the ventilator settings on a routine basis to ensure that they match the prescribing order.
8. Explore any change in peak inspiratory pressure (PIP) or decreased (sustained) V_T on PSV. Immediately explore the cause of high-pressure alarms.

   Rationale: Acute changes in PIP or V_T 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 if the patient has a shift in the trachea, decreased breath sounds on one side, and increased peak pressures. If a tension pneumothorax occurs, perform a needle thoracotomy.

9. Place a bite block between the teeth if the patient is biting on the oral ET tube. If a bite block is unavailable, an oral airway may be used.

   Rationale: An oral airway serves the same purpose as a bite block.

   An oral airway may not be tolerated as well as the bite block because it may induce gagging.

10. Change the patient's body position as often as possible. Maintain the head of the bed or backrest elevation at 30 to 45 degrees.[4]

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Rationale: Continuous lateral rotation therapy may be helpful in improving oxygenation. Elevation is one of the most modifiable factors related to VAP.

11. Evaluate for patient–ventilator dyssynchrony.

    Rationale: Dyssynchrony occurs when the patient's intrinsic breaths oppose or challenge the ventilator and may occur because of patient fatigue or restlessness.

12. Observe for hemodynamic changes associated with increased V_T, 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, such as a tracheal shift, decreased breath sounds, and increased PIP readings on the ventilator.

13. Suction the patient, using the closed technique if possible, only when needed (i.e., not routinely).
14. On an ongoing basis, monitor the patient for complications of mechanical ventilation, such as barotrauma, volutrauma, VAP, pneumothorax, or accidental extubation.
15. Observe the patient for signs or symptoms of pain. If pain is suspected, report it to the authorized practitioner.

EXPECTED OUTCOMES

- Maintenance of adequate pH, $PaCO_2$, and PaO_2
- Maintenance of adequate breathing pattern
- Respiratory muscle rest

UNEXPECTED OUTCOMES

- Unacceptable pH, $PaCO_2$, or PaO_2
- Hemodynamic instability
- Pulmonary barotraumas or volutrauma
- Inadvertent extubation
- Malpositioned ET tube
- Nosocomial lung infection
- Respiratory muscle fatigue
- Excessive condensation in ventilator circuit
- Discrepancy between set and measured ventilator settings

DOCUMENTATION

- Patient and family education
- Completed ventilation system test (pass or fail), date, and initials or signature of respiratory therapist (RT) and credentials

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- Indication for ventilatory assistance
- Date and time ventilatory assistance was instituted
- Ventilator settings
  - F_{IO_2}
  - Mode of ventilation
  - V_T
  - Respiratory frequency (total and mandatory)
  - PEEP level
  - I:E ratio or T_I
  - PIP
  - Dynamic lung compliance
  - Static lung compliance
- ABG values
- Sa_{O_2} readings
- Patient's responses to PPV
- Hemodynamic values
- Vital signs
- Unexpected outcomes and related interventions
- Respiratory interventions
- Tube location verification

HOME CARE CONSIDERATIONS

- A patient who is eligible for invasive long-term care mechanical ventilation in the home requires a tracheotomy tube for ventilatory support but no longer requires intensive medical monitoring services.[2]

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

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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
- 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

- Gloves
- Cuffed ET tube or tracheostomy tube
- Electrocardiogram and pulse oximeter
- Self-inflating MRB (with PEEP adjusted to patient baseline level or with a PEEP valve)
- Appropriate-size resuscitation face mask
- Ventilator
- Suction equipment and disposables
- Capnography monitor and appropriate-size connections
- HME or humidifier
- Sterile water
- Inline circuit thermometer
- Bite block or oral airway, if indicated

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