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Overview of Mechanical Ventilatory Support and Management of Patient- and Ventilator-Related Responses

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Nurses must be knowledgeable about the function and limitations of ventilator modes, causes of respiratory distress and dyssynchrony with the ventilator, and appropriate management in order to provide high-quality patient-centered care. Prompt recognition of problems and action by the nurse may resolve acute respiratory distress, dyspnea, and increased work of breathing and prevent adverse events. This article presents an overview of mechanical ventilation modes and the assessment and management of dyspnea and patient-ventilator dyssynchrony. Strategies to manage patients' responses to mechanical ventilatory support and recommendations for staff education also are presented. (*Critical Care Nurse.* 2011;31[3]:30-45)

Mechanical ventilatory support is routinely needed for critically ill adults in intensive care units and is also a common therapy in subacute and long-term care settings. The primary goals of mechanical ventilatory support are to normalize arterial blood gas levels and acid-base imbalance by providing adequate ventilation and oxygenation. Mechanical ventilation can decrease the patient's work of breathing by unloading respiratory muscles in a synchronous manner.[1] Mechanical ventilation can also maintain long-term respiratory support of patients with chronic ventilatory problems.

Critical care nurses encounter numerous issues related to ventilator support, including physiological conditions that impede optimal ventilator function, dyspnea, and patient-ventilator dyssynchrony. Responsibilities related to ventilator management may vary among acute care settings, but the nurse is usually the "first-line manager" challenged with patient- and ventilator-related problems. As a result, it is essential that nurses thoroughly understand the basics of ventilator support, including ventilator modes, settings, and alarms. It is also important to be skilled in promptly identifying and managing common patient- and ventilator-related problems in order to provide optimal patient-centered care and prevent complications. Prompt recognition of problems and action by the nurse may resolve acute respiratory distress, dyspnea, and increased work of breathing and prevent adverse events.

The purpose of this article is to present an overview of mechanical ventilation modes and the assessment and management of dyspnea and patient-ventilator dyssynchrony. Strategies are presented to manage patients' responses to mechanical ventilatory support. Finally,

CE Continuing Education

This article has been designated for CE credit. A closed-book, multiple-choice examination follows this article, which tests your knowledge of the following objectives:

1. Differentiate various (common) modes of mechanical ventilation
2. Identify management strategies for patient responses to mechanical ventilatory support
3. Discuss assessments and causes of patient-ventilator dyssynchrony

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Table 1 Definitions of ventilator and patient parameters

- Fraction of inspired oxygen (FIO_2): The concentration of oxygen in the inspired gas. It can be set from 0.21 (room air) to 1.0 (100%).
- Tidal volume (V_t): The volume of gas, either inhaled or exhaled, during a breath and commonly expressed in milliliters. V_t is generally set between 8 and 12 mL/kg but may be set lower (eg, 6 mL/kg or lower) to prevent lung overdistension and injury.
- Respiratory rate (RR) or frequency: The number of breaths per minute that the ventilator delivers. RR is commonly set between 10 and 20 breaths per minute. If the patient is making spontaneous breathing efforts, RR will be higher.
- Minute ventilation (VE): The average volume of gas entering, or leaving, the lungs per minute, commonly expressed in liters per minute. The product of V_t and RR = VE. Normal VE is between 5 and 10 L/min.
- Peak flow rate or peak inspiratory flow: The highest flow, or speed, that is set to deliver the V_t during inspiration, usually measured in liters per minute. When the flow rate is set higher, the speed of gas delivery is faster and inspiratory time is shorter.
- Inspiratory(I) and expiratory(E) time and I/E ratio: The speed at which the V_t is delivered. Setting a shorter inspiratory time (I) results in a faster inspiratory flow rate. Average adult I is 0.7 to 1.0 s; I/E ratio is usually 1:2 or 1:3.
- Peak airway pressure (P_{aw}): Represents the total pressure that is required to deliver the V_t and depends upon various airway resistance, lung compliance, and chest wall factors. It is expressed in centimeters of water (cm H_2O).
- Plateau pressure (P_{plat}): The pressure that is needed to distend the lung, which can be measured by applying an end-inspiratory pause setting on the ventilator. It is expressed in centimeters of water.
- Sensitivity or trigger sensitivity: Effort, or negative pressure, required by the patient to trigger a machine breath, commonly set so that minimal effort (-1 to -2 cm H_2O) is required to trigger the breath. Some ventilators may have flow triggering, which is more sensitive than pressure triggering if the flow setting is set correctly. A decrease in flow is sensed when the patient makes a spontaneous effort and triggers the machine to deliver the breath.
- Positive end-expiratory pressure (PEEP): The amount of positive pressure that is maintained at end-expiration. It is expressed in centimeters of water.The purpose of PEEP is to increase end-expiratory lung volume and reduce air-space closure at end-expiration.
- Continuous positive airway pressure (CPAP): Continuous pressurization of the breathing circuit when a patient breathes spontaneously. CPAP may be used as a last step in the weaning process or as a noninvasive method of providing a pneumatic splint to the upper airway in obstructive sleep apnea.[3]
- Mandatory breath: A breath in which the timing and/or size of the breath is controlled by the ventilator; the machine triggers and/or cycles the breath.[4]
- Spontaneous breath: A breath in which both the timing and size are controlled by the patient; the patient both triggers and cycles the breath.[4]
- Functional residual capacity: Volume of gas present in the lungs at the end of passive expiration.

recommendations for staff education are presented. Only a brief review of commonly used ventilation modes and basic operation is provided; interested readers are referred elsewhere for more in-depth information.[1-10]

Common Modes of Ventilatory Support

Ventilator parameters vary by manufacturer; however, basic parameters are present on all machines: percent oxygen, tidal volume and/or minute ventilation, respiratory rate, inspiratory time or flow rate, and alarm limit settings. A thorough understanding of common ventilator settings will assist nurses in optimizing patients' care to meet the overall oxygenation and ventilation goals, maintain safe lung pressures, and provide breathing comfort (Table 1).

Mode of ventilation refers to the method of inspiratory support provided by the mechanical ventilator. It is the specific combination of breathing pattern and control variables to deliver inspiration.[4] Selection of mode is based on the clinician's familiarity and experience

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Table 2 Differences in parameters between volume-targeted and pressure-targeted ventilator modes

Volume-targeted modes (Examples: CMV, VCV, A/C, SIMV)	Pressure-targeted modes (Examples: PSV, PCV)
Volume constant: Guarantees volume at expense of letting airway pressure vary	Volume variable: Guarantees pressure at expense of letting V_t vary
Inspiration: Terminates when preset V_t delivered	Inspiration: Terminates when preset pressure reached
Preset V_t delivered unless a specified pressure limit is exceeded (upper airway pressure alarm is set) or patient's cuff or ventilator tubing has air leaks that cause a decrease in V_t delivered	Preset pressure delivered: Volume is variable and determined by set pressure level, airway resistance, and lung compliance factors, specified time or flow cycling criteria
Peak airway pressure: Variable; determined by changes in airway resistance, lung compliance, or extrapulmonary factors. The peak airway pressure increases as needed to deliver prescribed V_t	Peak airway pressure: Fixed; determined by set pressure level; volume delivered is variable and decreases with increased airway resistance, decreased lung compliance, or extrapulmonary factors
Inspiratory flow rate: Fixed; if patient inspires faster or more vigorously, work of breathing increases; clinician needs to promptly correct airway resistance and/or lung compliance problems, readjust flow-rate setting higher to match inspiratory demands	Inspiratory flow rate: Variable; if patient inspires faster or more vigorously, variable flow rate may match change in inspiratory demand or may be insufficient; clinician needs to promptly correct airway resistance and/or lung compliance problems, may need to readjust pressure support, inspiratory, expiratory time settings

Abbreviations: A/C, assist control; CMV, controlled mechanical ventilation or continuous mandatory ventilation; PSV, pressure support ventilation; PCV, pressure control ventilation; SIMV, synchronized intermittent mandatory ventilation; VCV, volume controlled ventilation; V_t, tidal volume.

and the institutional preferences.[11] Some modes guarantee a constant volume (volume-targeted or volume-controlled) with each machine breath, whereas other modes guarantee a constant pressure (pressure-targeted or pressure-controlled). An additional option on some ventilators is a dual-controlled mode that combines the features of volume- and pressure-targeted ventilation to ensure a minimum tidal volume (V_t) or minute ventilation ($\dot{V}_E$) while limiting pressure. Table 2 summarizes differences between volume- and pressure-targeted ventilation.

Volume-Targeted Modes

In a volume-targeted mode, V_t is the targeted parameter, and a fixed V_t is delivered with each breath. Volume-targeted modes are the most commonly used modes.[12] The mode may be labeled by different names, including controlled mandatory ventilation, continuous mandatory ventilation, and assist/control mode ventilation.

In volume-targeted modes, the ventilator delivers machine-guaranteed breaths at the set respiratory rate and V_t if the patient is not making respiratory efforts due to sedation, paralysis, or other factors affecting drive to breathe. For example, if the clinician sets the V_t at 600 mL and the respiratory rate at 10 breaths per minute, the $\dot{V}_E$ delivered is 6 L/min (600 mL × 10 breaths per minute). The ventilator sensitivity dial is commonly set so that it takes minimal effort (-1 to -2 cm H_2O) for the patient to trigger the machine breath. If the patient is making inspiratory efforts, inspiration is triggered and the machine delivers additional machine breaths at the set V_t. The inspiratory flow rate, or the speed at which the breath is delivered, is fixed; therefore, it does not change to match the patient's respiratory rate and breathing pattern.

Studies have shown that patients' work of breathing can be substantial in assist/control mode, occurring throughout the inspiratory phase, especially if the patient is air hungry and the inspiratory flows provided by the ventilator are low.[2] The patient is dependent upon the clinician to readjust the flow rate setting to decrease work of breathing. For example, a patient who breathes faster requires adjustment to a higher flow rate to match inspiratory efforts. If the flow rate does not match inspiratory efforts, it is common for the patient to experience shortness of breath, anxiety, and agitation and for various other signs and symptoms of increased work of breathing to develop. Immediate adjustment to an appropriate flow rate setting may be the key intervention that prevents or alleviates breathing discomfort.

Pressure-Targeted Modes

Pressure is the ventilator's targeted parameter in pressure support ventilation. Breaths in this mode are triggered by the patient and augment or support a patient's spontaneous inspiratory effort with a preset positive pressure level. Inspiration ends after delivery of the set inspiratory pressure. Two pressure-targeted modes are common: pressure support ventilation and pressure control mode.

Pressure Support Ventilation. In pressure support ventilation, volume is variable, rather than a fixed V_t as in volume-targeted modes, and is determined by the patient's effort or drive, preset pressure level, and various airway resistance and lung compliance factors. Flow rate is also variable, depending on the patient's needs and not fixed by a clinician as it is in volume-targeted modes. The clinician does not set a respiratory rate setting, and the mode does not function if the patient is apneic. Although pressure support ventilation is commonly thought of as a weaning mode with low pressure support levels set to overcome resistance in the endotracheal tube and ventilator circuit, high pressure support levels may also provide almost total ventilator support.[13]

Pressure Control Mode. Pressure control ventilation operates in a manner similar to pressure support ventilation in that it relies on a preset pressure to determine the volume delivered and volume is variable depending on various factors that affect airway resistance and/or lung compliance. However, in pressure control mode, a respiratory rate is set by the clinician in order to support patients with apnea or an unreliable respiratory drive. Pressure control mode may be used in patients with acute respiratory distress syndrome to control plateau pressures and V_t. Patients with acute respiratory distress syndrome have low lung compliance; therefore, inappropriately high V_t and pressure settings can overstretch and injure the lung. Current strategies in such patients should be focused on limiting V_t and maximal lung stretch. An initial V_t of 6 mL/kg ideal body weight is a reasonable starting point and may be decreased to maintain maximal lung distending pressures less than 30 to 35 cm H_2O.[14,15]

Dual-Controlled Modes

Newer ventilators offer hybrid modes that combine features of volume-targeted and pressure-targeted ventilation in an attempt to avoid both the high peak airway pressures of volume ventilation and the varying tidal volumes that may occur with pressure ventilation.[2] Volume and pressure control variables adjust automatically to ensure a minimum V_t or $\dot{V}_E$. Several manufacturers incorporate this mode in their ventilators, with manufacturers using different names for the same dual-controlled modes. Examples of this type of mode are pressure-regulated volume control (Servo 300 and Servo-I, AVEA, CareFusion, San Diego, California) and volume ventilation plus (Puritan Bennett 840, Covidien Puritan Bennett, Boulder, Colorado). Pressure-targeted logic is used when the ventilator determines after each breath if the pressure applied to the airway was adequate to deliver the desired V_t. If the V_t did not meet the set target, the ventilator adjusts the pressure applied on the next breath. With some modes, such as volume-assured pressure support ventilation (Bird 8400 Sti, CareFusion) and pressure augmentation (BEAR 1000, CareFusion), inspiratory support is provided in the same manner as in pressure support ventilation, but the inspiratory pressure is adjusted within the current breath to obtain the assured V_t if the set V_t is not being achieved.[3,12] Although this technology seems promising, objective evidence has not shown that any of the alternative methods of ventilation are more successful than conventional mechanical ventilation with proper attention to V_t. No findings from randomized trials indicate improved outcomes, including mortality.[16]

Other Modes

Synchronized Intermittent Mandatory Ventilation (SIMV) Plus Pressure Support. Two modes are in operation on the SIMV plus pressure support mode: mandatory breaths are volume-targeted and spontaneous breaths are pressure-targeted. The patient receives a preset number of volume-targeted mandatory breaths at a set V_t. For example, if the SIMV rate is set at 4 breaths per minute and the V_t at 600 mL, the patient receives the mandatory V_t of 600 mL and 4 breaths, resulting in a $\dot{V}_E$ of 2400 mL/min (600 mL × 4 breaths per minute). Between mandatory breaths, the patient breathes spontaneously on pressure supported breaths. The ventilator recognizes spontaneous breaths and delivers mandatory breaths only between the spontaneous breaths, thereby preventing competition between the 2 breath types. Pressure support is routinely provided in SIMV mode to overcome circuit and tube resistance, thereby preventing increased work of breathing on the spontaneous breaths. If the patient is not taking spontaneous breaths while on a low SIMV rate, it is essential to increase the SIMV rate or switch to a full support mode like continuous mandatory ventilation in order to achieve adequate minute ventilation.

Continuous Positive Airway Pressure (CPAP). CPAP refers to delivery of a continuous level of positive airway pressure maintained throughout the respiratory cycle. The ventilator does not provide breaths during CPAP; the patient must initiate all breaths. If a patient is on CPAP of 5 cm H_2O, 5 cm of positive pressure is applied to the airway on inspiration and expiration. CPAP, similar to positive end-expiratory pressure (PEEP), is used to restore and maintain the amount of air left in the lungs at end expiration, or functional residual capacity. The application of positive pressure to the airways during expiration may keep alveoli open and prevent early closure during expiration. The presence of an artificial airway allows intrathoracic pressure to decrease to zero, which is below the usual level of intrathoracic pressure. PEEP/CPAP levels of 5 cm H_2O are often used to provide "physiologic PEEP."[17] CPAP may be used as a last step in the process of discontinuing mechanical ventilation. It is also used as a noninvasive method of providing a pneumatic splint to the airways in patients with obstructive sleep apnea.[3,11] Opening the airways with positive pressure prevents the upper airway from collapsing with each breath.

A thorough understanding of the ventilator being used, including delivery modes, function of settings, and specific patient settings assists in appropriately evaluating and managing patients' responses. This understanding can allow nurses to more quickly troubleshoot problems when they arise.

Patient- and Ventilator-Related Problems

General Considerations and Troubleshooting Interventions

Patients not tolerating mechanical ventilation support may be working to breathe and appear anxious, restless, agitated, and in respiratory distress. They may try to talk and sit up to improve breathing comfort. The ventilator may appear to be "out of sync" with breathing efforts, and ventilator alarms may sound. Usual signs and symptoms of problems may not be observed if patients are sedated, unconscious, paralyzed, or experiencing neuromuscular weakness. It is essential to appropriately set and interpret ventilator alarms and to promptly identify and correct patient- and/or ventilator-related problems. Table 3 provides a detailed list of physiological, psychological, and ventilator factors that contribute to respiratory distress and focuses on interventions for optimal care of all ventilator-dependent patients.

The troubleshooting process is guided by the severity of the distress and the stability of the patient's condition. If the patient is in severe acute respiratory distress or is hemodynamically unstable, the patient should be immediately disconnected from the ventilator and manually resuscitated with 100% oxygen. If the patient quickly improves with manual resuscitation, the likely problem is the ventilator settings or circuit.[12] When the patient appears anxious or short of breath, or if ventilator alarms sound, it is important to make immediate, systematic assessments. The initial focus should be patient-centered and not machine-centered. It is important to avoid the false sense of security that, because the patient is supported by the ventilator, he/she is receiving adequate ventilation. The ventilator alarm can be silenced for up to 2 minutes, during which the nurse can perform an assessment. The patient should be assessed for hemodynamic stability, adequate oxygenation, excess secretions, secure tubing connections to the ventilator, and other conditions such as anxiety or pain. Further assessments of the ventilator as needed include verification that ventilator settings and ventilator function are appropriate and confirmation that connections are secure and tubings are not kinked.

Alarm silencing once or repeated alarm silencing without evaluating and correcting the problem may cause prolonged periods of inadequate ventilation. Sedated or paralyzed patients may be severely hypoventilated and in deteriorating condition but not exhibit signs of respiratory distress because of the effects of sedative and other medications and conditions that blunt the normal responses to hypoxemia and hypercapnia. Patients may be unable to communicate distress through facial expressions and gestures. Pulse oximetry measurements of oxygen saturation (Spo_2) may remain greater than 90%, despite severe hypoventilation. If the patient initially has a high Spo_2 (eg, 98%), but is hypoventilated and respiratory acidemia develops, Spo_2 measurements will decrease but may continue to be 90% or greater. Staff may be comfortable with the value and not question why the Spo_2 decreased from 98% to 90%. As the Spo_2 reading decreases, the Fio_2

Table 3 Potential causes of anxiety and respiratory distress with suggested interventions[a]

Causes/triggers	Interventions
Peak airway pressure and low tidal volume may alarm	Correct problems causing increased airway resistance, decreased lung compliance, and pressure limit alarming; recheck ventilator to make sure prescribed tidal volume is delivered Notify physician of unexplained high airway pressure and to assist in evaluation including pneumothorax, pulmonary edema, or problems decreasing lung compliance Manually ventilate as needed and call for assistance
Airway irritation causing cough, secretions, bronchospasm	Prevent unnecessary cough, irritation, shortness of breath: • Suction only as needed for secretions • Do not instill normal saline • Ensure water condensation from tubing does not drain into patient's airway • Maintain thin secretions for better clearance by providing optimal airway humidification
Air leaks causing volume loss	Assess, correct air leaks in endotracheal tube, tracheostomy cuff, ventilator system; recheck ventilator to make sure prescribed tidal volume is delivered
Attempting to speak, inability to communicate wants and needs	Implement effective communication system (see article by Grossbach et al[19] in this issue of *Criitical Care Nurse*).
Airway irritation and discomfort due to tube jarring, movement, displacement	Prevent tube jarring and movement Guide and support artificial airway and tubing in manner that prevents tube from pulling and jarring during turning and movement; may disconnect, turn, reconnect airway adapter (may be contraindicated in patients in unstable condition) Obtain necessary assistance with turning, transferring so one person can provide specific attention to prevent pulling and jarring tube Properly support tube on ventilator arm; unclip ventilator tubing from ventilator support arm/reattach in manner that prevents tube from being pulled or jarred and maintains optimal tube alignment and support Stabilize artificial airway with 1 hand when reconnecting ventilator adapter or with airway suctioning
Biting down on orally placed tube, resulting in peak airway pressure alarming, decreased tidal volume delivery	Explain why not to bite down on tube, remind as needed; may be able to place tube in edentulous area of mouth; use tube-securing method with bite block if needed
Tube or securing device causing discomfort, agitation, and potential erosion from pressure on lips, cheeks, or in mouth; displaced tube	Inspect for proper tube position; secure tube in manner that prevents skin breakdown, maximizes comfort, and avoids displacement Reposition orally placed tube as needed Monitor for skin breakdown at endotracheal or tracheostomy tube location
Adverse drug effects; Sleep deprivation causing agitation, confusion, uncooperative behavior	Evaluate for adverse drug effects causing anxiety, agitation Provide calm, confident, reassuring approach Explain interventions, provide frequent orientation to surroundings and reassurance Maintain consistent staffing when possible
Intensive care unit environment (noises, unfamiliar people, procedures, fear of unknown, etc)	Coordinate interventions to allow periods of uninterrupted sleep; offer noise-canceling headsets, earplugs Implement relaxation techniques: coaching, touch, music, or other methods defined by patient Allow patients to participate in decision making as capable
Inadequate inspiratory flow rate to meet inspiratory demands resulting in feeling of not getting enough air	Adjust flow-rate setting to meet inspiratory demands Ventilate manually as needed, compressing bag in synchrony with patient's inspiratory efforts
Inappropriately set ventilator mode, alarm settings	Call for assistance to evaluate ventilator for appropriate mode, correct settings, and delivery of prescribed volume Avoid interventions that create shortness of breath (weaning when not ready, inappropriate ventilator modes, suboptimal position) Offer fan with airflow directed toward face, which may help decrease dyspnea, assuming that patient and/or ventilator-related problems are corrected; position for breathing comfort

[a] Based on evidence from Grossbach.[18]

may be increased without analyzing and correcting the underlying problems that are causing the oxygen desaturation, such as inadequate ventilation. Hypoventilation may result in both hypoxemia and hypercapnia. The resulting severe acute respiratory acidemia can lead to decreased blood pressure, cardiovascular decompensation, and cardiac arrest.

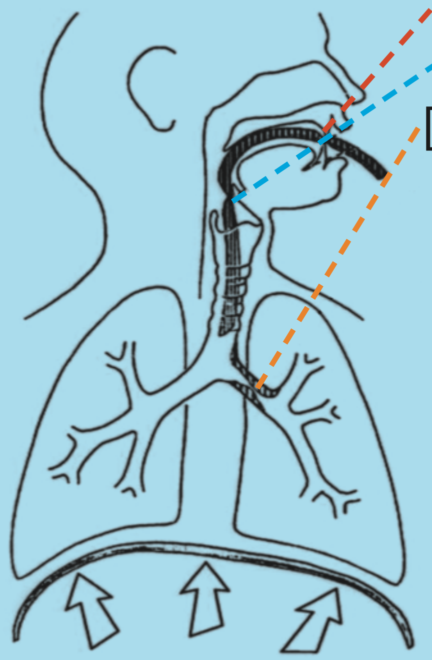

Figure 1 Factors that increase airway resistance and decrease lung compliance.
Reprinted from Grossbach[20] with permission.

Factors Influencing Volume Delivery Targets. The ability of the ventilator to deliver the preset tidal volume is influenced by the amount of pressure required to deliver that volume. Peak airway pressure, or force required to deliver the preset V_t, is variable and increases with increased airway resistance, decreased lung compliance, and factors that make it difficult for the chest wall to expand. Increased airway resistance describes mechanical factors that narrow the airway and impede the flow of inspired air to the lungs. Increased airway resistance can be caused by a smaller diameter endotracheal tube, biting on the endotracheal tube, obstruction with secretions, and bronchospasm. Faster respiratory rates also increase resistance because of greater air turbulence.

Lung compliance measures the ease of expansion of the lung and thorax. Decreased lung compliance requires more pressure to deliver volume and expand the lung because of various conditions including atelectasis, pulmonary edema, fibrosis, and pneumonia. Chest wall or extrapulmonary factors that contribute to increased peak airway pressure include certain positions that may restrict expansion of the chest wall and lung, abdominal distention, forced abdominal muscle contractions, and shivering (Figure 1).[20] As airway resistance increases or lung compliance decreases, the peak inspiratory airway pressure increases to deliver the preset V_t. The preset V_t is delivered unless the specified upper airway pressure alarm limit is reached. At that point, the ventilator stops delivery of volume.

Loss of the preset volume occurs if an air leak develops in the endotracheal or tracheostomy tube cuff or the ventilator system. A low volume alarm sounds if the V_t or $\dot{V}_E$ is less than the preset low volume limit set by the clinician. With volume losses, it is common for patients to exhibit anxiety, restlessness, increased work of breathing, and other signs and symptoms of acute respiratory distress. It is essential to correct airway resistance and/or lung compliance problems to maintain V_t delivery.

Factors Influencing Pressure Delivery Targets. Tidal volume in pressure-controlled modes is variable and changes with various factors that affect airway resistance and/or lung compliance. For example, the set pressure used to provide adequate V_t and breathing comfort may become inadequate if the patient develops mucous plugs or bronchospasm, resulting in respiratory distress and potential cardiopulmonary deterioration if the problem is not resolved. A sudden resolution of the resistance or compliance problem may increase V_t to an amount larger than desired. Clinicians must be alert to monitoring the patient's V_t and properly setting V_t and $\dot{V}E$ alarm limits, and be prepared to make frequent ventilator adjustments when managing a patient whose pulmonary status may change rapidly, as in acute asthma or pulmonary edema. Volume-targeted or dual-controlled strategies are favored to maintain a constant V_t in situations where the patient has frequent changes in airway resistance or pressure.[12] Pressure support ventilation is contraindicated if the patient is apneic or has an unreliable ventilatory drive due to central nervous depression from drugs or other situations.[18]

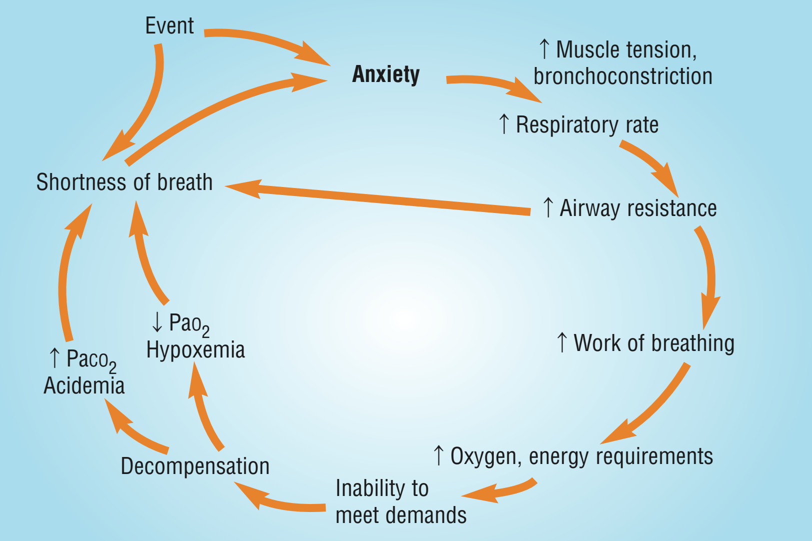

Figure 2 Anxiety–shortness of breath cycle.

Reprinted from Grossbach[18] with permission.

Dyspnea. Dyspnea is described in many ways, including feeling short of breath, having difficult or uncomfortable breathing, feeling breathless, running out of air, "hard to breathe," "can't get a deep breath," "can't breathe," feel like suffocating, a heavy chest, or "chest tightness." It is frequently described as air hunger, choking, or heavy breathing.[21,22] In general, only patients with chronic obstructive pulmonary disease, but not healthy individuals, volunteered affective words such as "frightening," "worried," "helpless," "depressed," and "awful" to describe their breathing difficulty.[22] These affective descriptions are intended to convey the threat perceived by the patients to their breathing difficulty.[23,24]

Various clinical conditions contribute to dyspnea.[25,26] Common situations or events can trigger a cycle of anxiety, agitation, frustration, fear, helplessness, and dyspnea. Examples include inability to communicate needs, unclear or inadequate explanations from caregivers, and inappropriate ventilator modes or settings that do not match the patient's respiratory demands. Even small losses in V_t can cause significant acute respiratory distress. Bronchospasm may worsen in patients with chronic obstructive pulmonary disease or asthma or in other susceptible patients, which further increases airway resistance, work of breathing, and shortness of breath. Increased work of breathing may increase anxiety, stress, and oxygen requirements and may result in hypoxemia and respiratory acidemia if the patient does not receive appropriate intervention (Figure 2).[18]

Signs of respiratory distress include increased respiratory rate, changes in mental state, anxiety, restlessness, distressed appearance, nasal flaring, making attempts to breathe through the mouth, diaphoresis, sitting upright or attempting to sit up in bed, use of accessory muscles in the neck, and forced abdominal muscle contractions during expiration. Blood pressure and heart rate may or may not change significantly, depending on the vasoactive medications the patient is receiving. Also, patients who are heavily sedated or experiencing severe muscle weakness or nonchemical paralysis will not exhibit the increased respiratory muscle activity normally observed. Respiratory distress and increased work of breathing may be caused by a combination of factors related to the patient and factors related to the equipment: air leaks, increased airway resistance, decreased lung compliance, inadequate ventilator settings, and anxiety or pain.

A patient-centered approach to optimal ventilator management should include routine assessment for dyspnea[27] by using an appropriate instrument for assessing dyspnea.[25]

Dyspnea assessment is useful to determine whether ventilator adjustments and various interventions, such as positioning, use of a fan, music, or other relaxation techniques, improve breathing comfort. One dyspnea evaluation protocol asked responsive patients: "Are you feeling short of breath right now?" and, if yes, "Is your shortness of breath mild, moderate, or severe?"[28] These 3 broad dyspnea ratings limit patients' responses to changes in dyspnea. The 2 most common instruments used to measure dyspnea in critical care are the visual analog scale (VAS) and the Borg scale.[25,29] The VAS is a 100-mm horizontal line with endpoints of 0 (no shortness of breath) and 100 (worst possible shortness of breath). The patient rates the degree of shortness of breath on this line. The modified Borg scale is a 12-item instrument with numbers corresponding to descriptions regarding the amount of dyspnea,[14] with no dyspnea rated as 0 and worst imaginable dyspnea rated as 10. Correlations between the 2 scales are strong, and validity and reliability have been determined with critically ill patients.[30] The use of these instruments requires that patients be alert and oriented. Furthermore, each instrument is 1-dimensional; only intensity or distress of dyspnea is measured.[25] Various physiological, psychological, and equipment factors contribute to dyspnea and acute respiratory distress. Evidence supports best practice in the assessment and management of critically ill patients experiencing dyspnea.[25] The following section describes the patient-ventilator interaction, focusing on the causes and management of dyssynchrony, a common cause of dyspnea and respiratory distress.

Patient-Ventilator Dyssynchrony

Patient-ventilator dyssynchrony is defined as a situation in which the patient's breaths fail to coincide or match exactly with the ventilator-assisted breaths. This common phenomenon can affect patients' outcomes, including duration of mechanical ventilation[31-35] and hospital length of stay.[36]

Patients exhibit various signs and symptoms of respiratory distress when the ventilator is not appropriately configured to meet the patient's inspiratory and expiratory demands. Sensations of "fighting the ventilator," being out of sync, and working to breathe are due to dyssynchrony between the patient's respiratory efforts and the ventilator. A nurse's first inclination may be to encourage the patient to "calm down," "relax," slow your breathing," and "breathe with the machine" rather than adjusting the ventilator to match the patient's demands, clearing the airway of secretions, or determining what the patient is trying to communicate in efforts to meet other needs, such as pain or a strong desire to see a family member.

Dyssynchrony often is serious during all 3 phases of breath delivery: the trigger phase, the flow delivery phase, and the breath cycling off phase.[31] To achieve patient-ventilator synchrony, the ventilator must sense and respond quickly to inspiratory efforts, provide inspiratory flow of oxygen gas that matches the patient's inspiratory demands, terminate the breath with the patient's termination of inspiration, and cycle to expiration to match the patient's exhalation phase. To optimize patients' comfort and reduce the work of breathing, it is crucial that the machine be adjusted to meet the patient's requirements, including appropriate trigger sensitivity settings, inspiratory flow, inspiratory time, V_t, and an exhalation phase that matches the patient's expiratory pattern. The patient is dependent upon the nurse to make accurate observations of the ventilator interface. Simple observations of the ventilator being "in sync" with the patient's efforts show easy ability to trigger the ventilator breath, delivery of the breath coinciding with inspiration, appropriate breath termination when the patient appears to stop inspiration, and the ventilator exhalation phase properly timed to coincide with when the patient appears to be exhaling. The patient appears comfortable, conveys breathing comfort, and is able to rest and sleep. Causes for and management of patient-ventilator dyssynchrony are described next.

Causes of Dyssynchrony

Appropriate ventilator modes must be selected and settings adjusted to match and be in synchrony with the patient's inspiratory efforts. Dyssynchrony may be due to delayed or ineffective triggering, auto-triggering, insufficient flow to meet the patient's demands, double triggering, and an exhalation phase that is out of sync with the patient's breathing pattern (Table 4).

Delayed or Ineffective Triggering. The most common cause of dyssynchrony is ineffective triggering,[37] which is defined as failure of the patient's inspiratory muscle effort

Table 4 Potential causes and suggested management of patient-ventilator dyssynchrony

Ventilator dyssynchrony	Causes	Management	Goals
1. Trigger phase Trigger setting delayed or ineffective in triggering breath; auto-triggering	Trigger sensitivity set too high or low Lung hyperinflation or "air trapping"	Prevent, manage lung hyperinflation by decreasing tidal volume, changing inspiratory and expiratory phase parameters, switching to another mode, and correcting physiological abnormalities that increase airway resistance	Patient exhibits easy ability to trigger ventilator breath Appears comfortable, conveys breathing comfort
	Air leaks that cause loss of positive end-expiratory pressure and automatic cycling of ventilator	Change to another mode of ventilation Correct air leaks in patient or ventilator system	
2. Flow delivery phase Inspiratory delivery of air too slow or fast	Inspiratory flow, inspiratory time, or inspiratory to expiratory ratio setting too low or high	Adjust flow rate setting to meet inspiratory demands, perhaps by setting a higher inspiratory flow rate or shorter inspiratory time to deliver air faster if the patient has a high respiratory rate and is working hard to breathe during inspiration	Inspiratory flow of gas matches patient's inspiratory effort Patient appears comfortable, conveys breathing comfort
3. Breath cycling off phase Exhalation timing appears to be "out of sync" with patient's attempt to exhale	Inspiratory flow, tidal volume, and/or respiratory rate settings are affecting expiratory timing	Adjust flow, volume, and/or respiratory rate setting to meet patient's needs Change to other mode of ventilation	Ventilator breath terminates when patient ends inspiratory effort Ventilator exhalation phase coincides with patient's exhalation phase Patient appears comfortable, conveys breathing comfort

to trigger or cycle a ventilator breath.[34] The patient feels short of breath and may demonstrate

- tachypnea,
- anxiety,
- restlessness,
- use of accessory muscles in the neck,
- tracheal tug (downward pull of the trachea),
- nasal flaring,
- paradoxical movement of the abdominal wall during inspiration,
- hypertension, or
- hypotension and decrease in arterial oxygen saturation.

Inability to trigger a breath can occur even though the patient is on optimal levels of ventilation support to maintain normal gas exchange and can occur on either volume or pressure modes of ventilation. Patients with frequent ineffective triggering may receive excessive levels of ventilatory support because of ventilator adjustments made in an effort to correct the problem.[38]

The main problems that can cause ineffective triggering are inappropriately set trigger sensitivity settings and lung hyperinflation. When the trigger sensitivity setting is set too negative, the patient must use increased respiratory muscle work to trigger the breath.[34] Triggering mechanisms for delivering breaths are based on detecting either a pressure change or a flow change. With pressure triggering, the machine sensitivity setting is commonly set so that the patient needs to generate only a minimal negative pressure (-1 or 2 cm) to trigger the breath. With flow triggering, continuous flow is maintained through the circuit and the ventilator is triggered once the patient is able to generate a preset inspiratory flow. Flow triggering has become the default triggering method; however, just like pressure triggering, setting the sensitivity level too sensitive can cause machine cycling without patient effort (autocycling) or failure to cycle.[39] Patients with high $\dot{V}_E$ and obstructive airway disease can have lung hyperinflation, also referred to as intrinsic PEEP, auto-PEEP, or "air trapping." Patients with intrinsic PEEP will have difficulty triggering the ventilator because of the need to create additional inspiratory muscle effort to reduce the airway pressure to the ventilator trigger level.[40,41] Wasted breathing efforts trying to trigger the ventilator can significantly increase the work of breathing.

Adverse effects of air trapping include increased intrathoracic pressure. Increased thoracic pressure can impede systemic blood return to the heart with resulting deterioration of blood pressure and cardiac output. The patient can be disconnected from the ventilator to check for an increase in blood pressure in cases of ventilator-related hypotension.[42] When the ventilator is initially disconnected, carefully observe for prolonged expiration of air and immediate clinical improvement, which can be diagnostic for lung hyperinflation. Do not hyperventilate with the manual resuscitation bag; rather, one should time the compressions with the bag to match the patient's inspiratory efforts. If the patient immediately improves with manual ventilation (and auto-PEEP is excluded), the likely problem is the ventilator settings or circuit.[12] The primary intervention should be to implement aggressive measures to correct physiological abnormalities that create increased airway resistance and intrinsic PEEP. The ventilator should be reassessed for proper function and, after the patient is reattached, appropriately adjusted. Adjustments may include changing inspiratory and expiratory phase parameters, switching to another mode, or increasing the set PEEP to the level of auto-PEEP. Increasing the ventilator PEEP level puts the sensitivity at a low, "easy to trigger" level again, making the ventilator more responsive to breathing efforts, but it may not eliminate ineffective triggering.[43]

Auto-Triggering. Patients exhibiting an unexplained high respiratory rate, but not making inspiratory muscle efforts visually or by ventilator readings, should be evaluated for a sensitivity setting that is too low and may be causing the machine to self cycle (auto-trigger). Auto-triggering can also be caused by air leaks, which cause loss of V_t and PEEP. In situations where PEEP is set, the machine sensitivity setting automatically readjusts to a positive value to maintain a minimal trigger level. For example, if PEEP is set at 5 cm, the sensitivity setting automatically readjusts to +3 or +4 cm. Air leaks in the patient or ventilator system cause loss of PEEP, which creates auto-triggering if the sensitivity is set at a positive level. If this problem goes unrecognized, the patient may be given unnecessarily high amounts of sedatives and neuromuscular blocking agents to decrease the respiratory rate and correct the respiratory alkalosis when the correct solution is to recognize the machine self-cycling problem and make appropriate adjustments in the sensitivity setting or correct air leak problems.

Insufficient Inspiratory Flow Delivery. Critically ill patients commonly have high respiratory demands, resulting in the need for higher inspiratory flow rates. The inspiratory flow, inspiratory time, or inspiratory to expiratory ratio setting determines the speed with which air is delivered to the patient. Setting a higher inspiratory flow rate or a shorter inspiratory time delivers the air faster on inspiration. Breathing can be very uncomfortable if the inflation time is set too short or too long. The patient may be on a full ventilator support mode yet be in severe acute respiratory distress and working hard to breathe if the peak flow is too low and the patient is demanding more gas than the ventilator is set up to supply. It is essential to adjust the ventilator flow rate setting to match the patient's inspiratory demands. These adjustments may need to be made frequently if the patient's respiratory status is labile.

Automatic tube compensation, a feature on some ventilators, applies a positive pressure to compensate for endotracheal tube resistance and may overcome work of breathing imposed by the endotracheal tube, improve patient-ventilator synchrony by varying flow as the patient's demand changes, and reduce air trapping by compensating for imposed expiratory resistance.[44] Several variables are entered into the ventilator system to achieve automatic tube compensation, including tube type, diameter, percentage of support, and trigger sensitivity. Although automatic tube compensation may be helpful for the uncomfortable, dyssynchronous patient with high inspiratory flow demands who is on high levels of pressure support ventilation,[45,46] entering incorrect information can cause respiratory discomfort and dyssynchrony. For example, setting an internal tube diameter lower than the actual diameter leads to overcompensation by the ventilator. Setting a diameter higher than the actual tube diameter leads to undercompensation. Narrowing of the tube due to accumulation of secretions or kinks in the endotracheal tube causes inaccurate calculations[47] and suboptimal performance of the automatic tube compensation feature. The patient should be continually monitored for increased work of breathing and adequacy of ventilation, such as V_t and respiratory rate.[47]

Double Triggering of the Ventilator. Double triggering, also known as breath stacking, is the delivery of 2 consecutive ventilator cycles separated by a very short expiratory time. This situation can occur if the V_t is set too low or the ventilatory demand is high and the inspiratory time set on the ventilator is shorter than the patient's inspiratory time. The patient's effort is not completed at the end of the first ventilator breath, and a second ventilator cycle is triggered. The problem occurs more commonly in assist/control modes, where inspiratory flow rates are fixed.[38] Double triggering may cause excessive lung pressures and V_t delivery. It can also aggravate hyperinflation, increasing the burden on respiratory muscles.[9] The patient appears to be dyssynchronous with the ventilator during inspiratory efforts, triggering an extra ventilator breath. Peak inspiratory airway pressure may be higher and may set off the upper airway pressure alarm. Because the goals are to reduce work of breathing and maintain safe lung pressures, management includes adjustment of inspiratory time to match inspiratory efforts and changing to pressure-targeted modes of ventilation.[48]

In volume-targeted modes, it may also be possible to increase the inspiratory time or V_t in small increments to the point where double triggering stops without creating undesirable high alveolar (lung) pressures. The appropriately adjusted V_t may completely result in cessation of all breathing efforts and appearance of breathing comfort. Other measures to strictly control undesirable lung volumes and pressures include sedation and/or chemical paralysis.

Dyssynchrony in Exhalation Phase. Expiration timing is affected by the inspiratory flow, V_t, and respiratory rate settings. For example, the patient breathing fast on a volume-control mode needs a high inspiratory flow rate and will be out of sync, as exhibited by the patient trying to exhale when the machine is still delivering the inspiration. Exhalation timing appears to be out of sync with the patient's attempt to exhale. Observations include work of breathing during exhalation with forced abdominal contractions. If the upper airway pressure alarm sounds, less V_t is delivered and may worsen this vicious cycle. Adjusting the machine to match inspiratory flow demands or changing to another ventilation mode may resolve the problem.

Achieving Optimal Patient-Ventilator Care

Comprehensive education about ventilator modes, function of dials, and various skills to prevent and manage various patient- and ventilator-related problems promotes optimal patient-centered care. Meaningful educational programs support competent performance[49] and empower nurses to be more proactive in the care of patients receiving mechanical ventilation. Teaching and evaluating clinical knowledge, skills, and problem-solving abilities should include didactic and interactive activities with regular training sessions to prevent the decrease in performance that may occur with time.[50] Ventilator simulator sessions in small groups can be incorporated as a teaching strategy for learning how to troubleshoot patient- and ventilator-related problems. Simulations could include use of a test balloon or commercial simulator. Learning would be enhanced by the student breathing through the ventilator circuit and actually experiencing the effects of various ventilator modes, dial adjustments, and simulated problems that cause alarm situations. Competency assessment tools should be evaluated to determine their benefit in assessing and maintaining respiratory care skills and improving patients' outcomes (Table 5). Orientation programs about the ventilator and patient management, including a mechanical ventilation learning laboratory, can be evaluated to determine whether they meet desired outcomes.

Many decisions regarding ventilator purchase for hospitals are made by respiratory therapists and physicians. Although newer, more advanced ventilators may be desirable for complex cases, attempts should be made to avoid using various ventilator brands. When several different ventilators are used in the hospital, it may impair the ability of nurses, respiratory therapists, and medical staff to achieve and maintain the unique knowledge and skills necessary to provide optimal ventilator management.

Basic competencies should be achieved in order to provide expert care to ventilator-dependent patients.

Table 5 Basic skill competencies for the care of ventilator-dependent patients

Competency	Pass/no pass/comments
Speaks directly to patient when providing any care	
Sets up manual resuscitation bag including adjustment of fraction of inspired oxygen (FIO_2)	
Demonstrates correct ventilation with manual resuscitation bag	
Verbalizes assessments used to determine whether patient requires suctioning Demonstrates correct suction procedure (open and closed suction catheter system) Educates patient as appropriate on purpose of suctioning, anticipated sensations, interventions to decrease discomfort	
Articulates plan for oral care Demonstrates correct oral care techniques	
Verbalizes methods used to communicate effectively with patient Verbalizes usual questions to ask when patient conveys that something is needed Articulates the communication care plan for individual patients Uses communication aids/devices appropriately to explore patient's needs Demonstrates clinical performance with a variety of patients	
Verbalizes assessments indicating properly secured endotracheal tube, tracheostomy tube; properly secures endotracheal or tracheostomy tube; meticulous skin care and skin assessment Repositions endotracheal tube	
Positions tubing on ventilator arm in manner that maintains optimal tube alignment and prevents pulling and tube movement	
Turns patient in manner that avoids pulling or jarring of tube	
Provides call light system for patient before leaving room	
Discusses appropriate use of sedatives and pain medications with ventilator patients	
Verbalizes causes for following alarms/conditions Demonstrates corrective actions for following alarms/conditions a. High pressure b. Low exhaled volume c. Low inspiratory pressure d. Apnea e. Disconnection f. Unplanned extubation	

Ventilator-specific "user friendly" quick reference guides, as presented in Table 6, can be provided during staff education and made available on each unit for reference. A picture of the ventilator's front control panel with a brief definition and description of dials and displays should also be provided to staff. Comprehensive patient-ventilator troubleshooting guides are also available for education and reference.[52-54]

Summary

Nurses must be knowledgeable about the function and limitations of ventilator modes, causes of respiratory distress and dyssynchrony with the ventilator, and appropriate management in order to provide high-quality patient-centered care. It is essential that critical care nurses strive to develop the knowledge and skills necessary for comprehensive and successful management of patients receiving ventilatory support. The health care team involved in the different aspects of ventilator care should collaborate and share their unique expertise with the goals of meeting the patient's needs, optimizing patients' comfort, and preventing complications during mechanical ventilation. CCN

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To learn more about mechanical ventilation, read "International Perspectives on the Influence of Structure and Process of Weaning From Mechanical Ventilation" in the *American Journal of Critical Care,* 2011;20:e10-e18. doi:10.4037/ajcc2011430. Available at **www.ajcconline.org.**

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Table 6 Quick reference guide: patient-ventilator-related problems/management[a]

Alarm problem	Causes	Interventions
1. High pressure Alarm occurs if 2 consecutive breaths are limited because they reach the high pressure setting; inspiratory pressure phase ends (no more volume is delivered) and the exhalation valve opens to prevent excessive pressure (determined by upper pressure alarm limit that was set)	Blocked or kinked tube, other increased airway resistance and/or decreased lung compliance factors that increase peak airway pressure to above limit, resulting in prescribed volume not being delivered	Suction secretions as needed Ensure water condensation from tubing does not drain into patient's airway Prevent tube jarring and movement during turning patient and disconnecting and reconnecting ventilator adapter Administer bronchodilators as ordered
	Attempting to speak, inability to communicate wants, needs	Implement effective communication system (see article by Grossbach et al[19] in this issue of *Critical Care Nurse*)
Continuous hi pres (high pressure) Alarm registers if pressures do not decrease to below high pressure setting	Biting down on orally placed tube resulting in peak airway pressure alarming, potential for decreased tidal volume delivery	Explain why not to bite down on tube, remind as needed; may be able to place tube in edentulous area of mouth; use tube securing method with bite block if needed
2. Low ex (exhaled) tidal volume Alarm occurs if delivered tidal volume less than **low tidal volume** alarm setting for 3 or 4 consecutive breaths	Air leaks due to loose, disconnected ventilator circuit or nebulizer connections, tear or crack in tubing; cuff leak	Evaluate patient, make sure attached to ventilator Assess, correct air leaks in endotracheal, tracheostomy cuff, ventilator system; recheck ventilator to make sure prescribed tidal volume is delivered; call for assistance as needed Correct problems causing high airway pressures as outlined in problem 1 Ventilate manually if patient is in acute respiratory distress and unable to immediately correct problem Check all tubing connections (including temperature probe, nebulizer attachment sites) to make sure tight, and secure as needed Evaluate, inflate cuff as needed for leaks Reevaluate ventilator to make sure patient is receiving prescribed tidal volume
3. Low insp (inspiratory) pressure Alarm occurs if monitored circuit pressure is low—below setting on low inspiratory pressure dial	Air leaks causing volume loss	Assess, correct air leaks in endotracheal, tracheostomy cuff, ventilator system Recheck ventilator to make sure prescribed tidal volume is delivered; call for assistance as needed
5. Apnea Alarm occurs if patient has not triggered a breath within the 20-second apnea interval; can occur only in spontaneous mode-pressure support ventilation	Apnea, unstable ventilatory drive because of medications depressing central nervous system, clinical condition	Check patient, ventilate manually as needed May need to switch to mode that provides more ventilation support Reevaluate need for medications that are depressing ventilation
6. Disconnect Alarm occurs if measured exhaled tidal volume is 15% or less of delivered volume for 4 consecutive breaths	Major air leaks: circuit disconnect, major cuff leak	Evaluate patient for major air leak (ventilator circuit disconnection), connect circuit Correct cuff leak problems Obtain assistance, ventilate manually as needed
7. Vent inop (Ventilator inoperable) Alarm occurs if hardware failure or critical software error that could compromise safe ventilation. Safety valve opens → state allows patient to breathe only room air unassisted	Hardware failure or critical software error	Ventilate manually; call respiratory therapy Respiratory therapist must evaluate/retest ventilator for proper function
8. Air intake blocked Alarm occurs if ventilator has detected above-normal resistance at the air intake filter (back of machine)	Back of ventilator occluded	Check patient; ventilate manually as needed Check for visible occlusions (curtain, clothing, or furniture blocking the air intake at back of machine); do not cover back of ventilator—keep open to air
9. Fan failed alert Alarm occurs if fan filter is occluded or fan is not operational	Ventilator not warmed up or fan filter occluded	Make sure ventilator has warmed up sufficiently Respiratory therapist should check fan filter for occlusions and clean as needed; replace air intake filter if needed Press alarm reset key; if this does not resolve problem, change ventilator

[a] List of alarm problems in left column adapted from Puritan Bennett 700 Series Operator's Manual.[51]

Financial Disclosures

None reported.

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CE Test

Test ID C31132: Overview of Mechanical Ventilatory Support and Management of Patient- and Ventilator-Related Responses

Learning objectives: 1. Differentiate various (common) modes of mechanical ventilation 2. Identify management strategies for patient responses to mechanical ventilatory support 3. Discuss assessments and causes of patient-ventilator dyssynchrony

1. When the flow rate to deliver tidal volume during inspiration is set higher, which of the following results?
a. The speed of gas delivery is slower and inspiratory time is shorter
b. The speed of gas delivery is faster and inspiratory time is longer
c. The speed of gas delivery is faster and inspiratory time is shorter
d. The speed of gas delivery is slower and inspiratory time is longer

2. Which of the following best describes the volume of gas inhaled or exhaled during a breath?
a. Minute ventilation
b. Peak flow rate
c. Tidal volume
d. Functional residual capacity

3. What is the minute ventilation on assist-control mode if the clinician sets the tidal volume at 700 mL and the respiratory rate at 12 breaths per minute?
a. 5 L/minute c. 7 L/minute
b. 6.4 L/minute d. 8.4 L/minute

4. Which of the following is a volume-targeted ventilator mode?
a. Volume variable
b. Fixed inspiratory flow rate
c. Preset pressure delivery
d. Fixed peak airway pressure

5. Which of the following is a pressure-targeted ventilator mode?
a. Assist/control
b. Pressure control
c. Continuous mandatory ventilation
d. Controlled mandatory ventilation

6. Which of the following factors increases airway resistance?
a. Bronchospasm
b. Pneumonia
c. Atelectasis
d. Pneumothorax

7. Which of the following factors decreases lung compliance?
a. Tachypnea
b. Pulmonary edema
c. Airway secretions
d. Cough

8. Which of the following is a potential result of inappropriate intervention in the anxiety-shortness of breath cycle?
a. Hypoxemia and metabolic alkalosis
b. Hypercapnia and metabolic acidemia
c. Hypoxemia and respiratory acidemia
d. Hypercapnia and metabolic alkalosis

9. Which of the following alarm problems is caused by a blocked or kinked endotracheal tube?
a. Apnea c. Low exhaled tidal volume
b. Low inspiratory pressure d. High pressure

10. Which of the following observations indicates that the ventilator flow rate setting matches the patient's inspiratory efforts?
a. Easy ability of the patient to trigger the breath and delivery of the breath coincides with inspiratory efforts
b. Easy ability of the patient to trigger the breath and neck accessory muscle use during inspiration
c. Effort required to trigger the breath with respiratory muscle contractions during inspiration
d. Effort required to trigger the breath with respiratory muscle contractions during inspiration and expiration

11. Which of the following changes should be made to match the inspiratory demands of a patient breathing fast?
a. Set a lower inspiratory flow rate or a longer inspiratory time to deliver the breath slower on inspiration
b. Set a higher inspiratory flow rate or a shorter inspiratory time to deliver the breath faster on inspiration
c. Coach the patient to relax and slow down breathing to coincide with the ventilator breath
d. Readjust the sensitivity setting on the ventilator to help slow down breathing

12. What is the potential result of alarm silencing once or repeated alarm silencing?
a. No problem as long as the patient does not exhibit signs and symptoms of respiratory distress
b. Severe acute respiratory academia, which can lead to cardiovascular decompensation and cardiac arrest
c. Severe hypoxemia and acute metabolic alkalosis
d. Acute metabolic acidosis

Test answers: Mark only one box for your answer to each question. You may photocopy this form.

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❑b	❑b	❑b	❑b	❑b	❑b	❑b	❑b	❑b	❑b	❑b	❑b
❑c	❑c	❑c	❑c	❑c	❑c	❑c	❑c	❑c	❑c	❑c	❑c
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Objective 3 was met	❑	❑
Content was relevant to my nursing practice	❑	❑
My expectations were met	❑	❑
This method of CE is effective for this content	❑	❑

The level of difficulty of this test was:
❑ easy ❑ medium ❑ difficult
To complete this program, it took me ______ hours/minutes.

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