Mechanical Ventilation Management

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ALERT

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

PURPOSE:

To provide comprehensive nursing approach about mechanical ventilation for ICU- KAAUH staffs, its indications and nursing care.

OBJECTIVES:

After completing the modules, nurses will able to:

- Define and determine special considerations regarding its nursing care and roles
- Minimize the risk of infection, damage, displacement and another associated with the care and use mechanical ventilator
- Recognize the nursing management of patient on mechanical ventilator
- Maintain consistent standards for monitoring patient on mechanical ventilator
- Know about different modes and its specific indications of use
- Determine about the two techniques in delivering ventilation with its own indications and objectives

Nursing Roles:

- Coordinating patient care
- Evaluating patient response of plan of care
- Identifying and preventing complications
- Providing comfort and system of communication
- Weaning the patient from ventilator

INTRODUCTION

Mechanical ventilation is defined as the use of a mechanical device to assist the respiratory muscles in the work of breathing and to improve gas exchange. In this chapter, mechanical ventilation is divided into **two techniques:**

- Requiring a tube in the trachea to deliver ventilation (**invasive**)
- Applied with a mask (**non-invasive**).

INVASIVE MECHANICAL VENTILATION

Indications

Mechanical ventilation is indicated to support the patient with respiratory failure when adequate gas exchange cannot otherwise be maintained.

There are two major categories of acute respiratory failure:

1.) hypoxemic (type 1)

2.) hyper capneic (type 2)

Patients with either of these often need mechanical ventilation. Many patients present with a mixture of the two types of respiratory failure, and of course, these patients also respond to mechanical ventilation. Invasive mechanical ventilation is often chosen over noninvasive methods when altered mental status or hemodynamic instability accompany acute respiratory failure. The timing of intubation and initiation of mechanical ventilation is a source of controversy, and the decision is often more a matter of art and experience than science.

Objectives

Mechanical ventilation is supportive and meant to reverse abnormalities in respiratory function, while specific therapies are used to treat the underlying cause of respiratory failure.

The physiologic goals of mechanical ventilation are reversal of gas exchange abnormalities, alteration of pressure-volume relationships in the respiratory system, and reduction in the work of breathing.

These physiologic goals are interrelated and attain specific clinical results, as shown in.

Other goals in specialized circumstances include allowing use of heavy sedation or neuromuscular blockade and stabilization of the chest wall when injury has disrupted its mechanical function.

Indications for Intubation and Invasive Mechanical Ventilation

• Cardiac arrest

• Respiratory arrest

• Refractory hypoxemia (unresponsive to maximal supplemental oxygen administration and non - invasive ventilator support)

• Progressive respiratory acidosis (unresponsive to medical therapy, oxygen administration, and noninvasive ventilator support)

• Symptoms of progressive respiratory fatigue (unresponsive to medical therapy, oxygen administration, and noninvasive ventilator support)

• Clinical signs of respiratory failure (unresponsive to medical therapy, oxygen administration, and noninvasive ventilator support)

• Tachypnea

• Use of accessory muscles (e.g., sternocleidomastoid, scalene, intercostal, abdominal)

• Paradoxical inward abdominal movement during inspiration

• Progressive alteration of mental status

• Airway protection (in a patient with an extremely impaired level of consciousness)

• Relief of upper airway obstruction (often manifested by stridor on physical examination)

Modes

Mechanical ventilators were popularized during the polio epidemics of the 1950s. The initial ventilators were primarily negative pressure ventilators, or "iron lungs." Later, positive pressure ventilators gained popularity and today are used almost exclusively. As ventilator technology has progressed, the ways of delivering positive pressure mechanical ventilation have proliferated. In daily practice, however, four basic modes of positive pressure ventilation are most commonly used. **These modes can be classified on the basis of how they are triggered to deliver a breath, whether these breaths are targeted to a set volume or pressure, and how the ventilator cycles from inspiration to expiration.**

1) **CONTROLLED MECHANICAL VENTILATION**- CMV, or volume control (VC), was the first volume-targeted mode. As its name suggests, it is a pure "control" mode; that is, the minute ventilation (VE,) is completely governed by the machine (VE=VT × respiratory rate).

The physician sets the respiratory rate, tidal volume, inspiratory flow rate, ratio of inspiratory to expiratory time (I:E) fraction of inspired oxygen (FIO2), and positive end expiratory pressure (PEEP). In VC, the patient is unable to trigger the ventilator to deliver additional breaths.

This mode works well for patients who are unresponsive or heavily sedated, but not for conscious patients, whose respiratory efforts are not sensed by the ventilator, which leads to patient discomfort and increased work of breathing. As a result, this mode has largely been abandoned.

2.) **ASSIST-CONTROL VENTILATION** - **This mode is similar to VC mode except that the ventilator senses respiratory efforts by the patient**. As in VC**, the physician sets a respiratory rate, tidal volume, flow rate, I : E , FIO2, and PEEP. Breaths are delivered automatically, regardless of patient effort ("control").** In assist-control (AC) mode, however, the ventilator detects patient effort and responds by delivering a breath identical to the controlled one ("assist"). The patient can therefore breathe faster than the back-up control rate, but all breaths have the same tidal volume, flow rate, and inspiratory time. So AC mode allows better synchrony between patient and ventilator than VC mode, while still providing a baseline minute ventilation.

A more **descriptive and accurate name for this mode is "volume-targeted assist-control ventilation."** Like all modes of mechanical ventilation, AC has disadvantages.

If the back-up respiratory rate is set too far below the patient's spontaneous rate, exhalation time progressively decreases, since inspiratory time is fixed by the back-up respiratory rate and flow rate. In the extreme, this may result in inadequate time for exhalation. As a result, lung volume remains above functional residual capacity (FRC) when the next breath is delivered, a process called dynamic hyperinflation. This increased lung volume is associated with elevation in the alveolar pressure at end-exhalation, or "auto-PEEP". Another problem occurs when patients with high minute ventilation requirements make persistent inspiratory efforts while a breath is being delivered. If this effort is strong enough, the patient may trigger the ventilator again, a phenomenon known as "breath-stacking." This can cause wide swings in airway pressure and increase the risk of barotrauma or ventilator-associated lung injury. Finally, in volume-targeted modes, the inspiratory flow rate is fixed. Many acutely ill patients strive for high inspiratory flow rates. If ventilator delivered air flow is below patient demand, the work of breathing increases as the patient makes futile efforts to augment inspiratory flow.

3.) **SYNCHRONIZED INTERMITTENT MANDATORY VENTILATION** - Like AC mode, synchronized intermittent mandatory ventilation (SIMV**) is also a volume-targeted mode and provides a guaranteed VE**. For the mandatory breaths, **tidal volume and respiratory rate are chosen, guaranteeing a baseline minute ventilation**. **The practitioner also sets FIO2, PEEP, and flow rate.**

As in AC mode, the patient can make inspiratory efforts between the mandatory breaths. If a sufficient effort occurs shortly before the mandatory breath is delivered (a time interval known as the "synchronization period"), a breath identical to the mandatory breath is delivered. If a patient effort occurs outside this synchronization period, the airway pressure, flow rate, and tidal volume are purely patient-generated, and no assistance is provided by the ventilator.

While this reduces the likelihood of air-trapping and breath-stacking, it also can increase the work of breathing. Interestingly, if the mandatory respiratory rate is less than approximately 80% of the patient's actual rate, the high level of work expended during the spontaneous breaths will also be expended during the mandatory breaths. This occurs because the respiratory center in the brain has a lag time and is unable to alter its output on a breath-to-breath basis. So if high neurologic output is required for a significant percentage of breaths, that same output will be given for all of the breaths, including those that are delivered by the ventilator. Therefore, attempting to "exercise" the respiratory muscles by setting the SIMV rate at half of the patient's spontaneous rate is counterproductive, because it simply increases the work of breathing and results in respiratory muscle fatigue and weaning failure. To prevent excessive work while still allowing the patient to breath above the SIMV rate, this mode is often combined with pressure-support ventilation, discussed later.

4.) **PRESSURE-CONTROL VENTILATION** more accurate name for pressure control ventilation (**PCV) mode is "<u>pressure targeted assist-control ventilation</u>".** The mode is similar to the assist-control mode described above, except that a defined inspiratory pressure (IP) is set, instead of a tidal volume. This allows absolute control over peak pressure delivered by the ventilator, which can have advantages in certain types of lung disease. Other **defined settings are similar to assist-control: respiratory rate, I:E ratio, FIO2, PEEP, and trigger sensitivity. When the ventilator detects patient effort, it delivers a breath identical to the backup-controlled breaths, allowing the patient to breathe faster than the back-up rate.** Tidal volume is determined by IP, inspiratory time, airway resistance, respiratory system compliance, and patient effort. The delivered volume is predictable if sufficient time is given to allow equalization between the delivered inspiratory pressure and alveolar pressure.If inspiratory time is too short or airway resistance is too high, this equilibration does not occur, resulting in a tidal volume lower than predicted and a decrease in minute ventilation. In response, the patient increases respiratory rate. Paradoxically, the increase in respiratory rate causes a decrease in minute ventilation because, as respiratory rate increases, expiratory time also decreases. The result is inadequate time for complete exhalation, dynamic hyperinflation, and auto-PEEP. The resulting decrease in respiratory system compliance reduces the tidal volume attained for the given IP. This is one of the major disadvantages of PCV, and is most often seen in the setting of obstructive lung disease. Inspiratory flow rate is not fixed in PCV.

It varies with IP, inspiratory time, respiratory mechanics, and patient effort. This can be advantageous, because flow rate increases with patient effort, unlike the volume-targeted modes, in which flow rate is fixed. As a result, patients with high minute-ventilation requirements may feel more comfortable on PCV, because they can regulate and increase flow as needed. This variable flow rate has another potential advantage: the flow pattern changes as respiratory system compliance decreases during lung inflation. Thus, flow is high early in inspiration when the system is very compliant and decreases as inflation proceeds and compliance decreases. The result is a lower peak airway pressure and a flow pattern that more closely mimics normal physiology. Whether this leads to any improvements in clinical outcome is unclear.

5.) PRESSURE-SUPPORT VENTILATION The **unique feature of pressure-support ventilation (PSV) is that it is flow-cycled instead of time-cycled.** So IP ceases when the flow rate drops to about 20% of peak flow rate, and passive exhalation occurs. **The practitioner sets pressure-support level, FIO2 and PEEP.**

Respiratory rate, inspiratory flow rate, tidal volume, and I:E ratio are determined by the patient's effort and respiratory system mechanics (resistance and compliance). PSV is an "apnea mode," that is, there is no back-up mandatory respiratory rate, so it can only be used for patients with adequate respiratory drive. PSV is often combined with SIMV. This reduces the work of breathing in comparison to SIMV alone and provides a back-up mandatory minute ventilation not available with PSV alone.

ALTERNATIVE MODES The number of available modes of ventilation has increased rapidly. These include high-frequency ventilation, airway pressure release ventilation, proportional-assist ventilation, and servo-controlled pressure support modes. A review of these modes is beyond the scope of this chapter, and the reader is referred to in-depth discussions of mechanical ventilation and a recent review article.

GOALS IN PROVIDING MECHANICAL VENTILATION

- OXYGENATION- refers to oxygen control (O_2 up)
- VENTILATION- refers to carbon dioxide control (CO_2 down)

Settings

The parameters that need to be set vary, depending on the mode of ventilation used.

- Trigger Sensitivity- refers to what causes or means the ventilator to deliver a breath
- Respiratory Rate- refers to how many breaths the ventilator deliver per minute, it is the main way to control CO_2 (goal is CO_2 down)
- Tidal Volume- refers to how much air coming in within each breath
- PEEP- refers to how much pressure in the lungs (alveoli) still in there
- Flow Rate- refers to how fast or slow the Tidal Volume being delivered
- Flow Pattern- refers to where from a given flow rate-what are the constant or change in speed of delivering air
- FIO2- this the key to control oxygenation (O_2 up)

RESPIRATORY RATE There is a wide range of mandatory ventilator-delivered respiratory rates that can be used. The number varies and is dependent on the minute ventilation goal, which varies with individual patients and clinical circumstances. In general, the range for respiratory rate is between 4/min and 20/min and falls between 8/min and 12/min in most stable patients. In adult respiratory distress syndrome (ARDS), the use of low tidal volumes sometimes necessitates respiratory rates up to 35/min to maintain adequate minute ventilation.

TIDAL VOLUME Evidence is accumulating that tidal volumes should be lower than traditionally recommended, especially in acute respiratory distress syndrome. When setting tidal volume in volume-targeted modes, a rough estimate for patients with lung disease is 5 to 8 mL/kg of ideal body weight. In patients with normal lungs who are intubated for other reasons, slightly higher tidal volumes can be considered: up to 12 mL/kg of ideal body weight. Tidal volume should be adjusted to maintain a plateau pressure of less than 35 cm H_2O. The plateau pressure is determined by performing an inspiratory-hold maneuver, which approximates end-inspiratory alveolar pressure in a relaxed patient.

Elevation in the plateau pressure may not always increase the risk of barotrauma. This risk rises with transalveolar pressure, which is the alveolar pressure minus the pleural pressure. In patients with chest-wall edema, abdominal distention, or ascites, compliance of the chest wall is reduced. As a result, pleural pressure rises during lung inflation and the rise in transalveolar pressure is lower than occurs with normal chest compliance. In such circumstances, the tidal volume ranges previously discussed should be used.

INSPIRATORY PRESSURE In PCV and PSV, the IP is generally set to keep the plateau pressure at or below 35 cm H_2O. The resulting tidal volume should be kept in the suggested ranges.

FRACTION OF INSPIRED OXYGEN In most cases, FIO_2 should be 100% when the patient is first intubated and placed on mechanical ventilation. Once proper tube placement is assured and the patient has stabilized, FIO_2 should be progressively reduced to the lowest concentration that maintains adequate oxygen saturation of hemoglobin, because high concentrations of oxygen produce pulmonary toxicity. Maintaining oxygen saturation of 90% or more is the usual goal. Occasionally, this goal is superseded by the need to protect the lung from excessive tidal volumes, pressures, or oxygen concentrations. In these circumstances, the target may be lowered to 85%, while optimizing the other factors involved in oxygen delivery.

POSITIVE END-EXPIRATORY PRESSURE (PEEP), as its name implies, maintains a set level of positive airway pressure during the expiratory phase of respiration. It differs from continuous positive airway pressure (CPAP) in that it is only applied during expiration, whereas CPAP is applied throughout the entire respiratory cycle. The use of PEEP during mechanical ventilation has several potential benefits.

In acute hypoxemic respiratory failure (type 1), PEEP increases mean alveolar pressure, promotes re-expansion of atelectatic areas, and may force fluid from the alveolar spaces into the interstitium. This allows previously closed or flooded alveoli to participate in gas exchange.

In cardiogenic pulmonary edema, PEEP can reduce left ventricular preload and afterload, improving cardiac performance. In hyper capneic respiratory failure (type 2) resulting from airflow obstruction, patients often have insufficient time to exhale, resulting in dynamic hyperinflation. This results in an end-expiratory alveolar pressure that is above atmospheric pressure, or “auto-PEEP.” This pressure can be estimated with an expiratory hold maneuver in the relaxed patient. Triggering the ventilator in the presence of auto-PEEP requires a negative airway pressure that exceeds both trigger sensitivity and auto-PEEP. If the patient is unable to achieve this, inspiratory efforts are futile and merely increase the work of breathing. Applying PEEP can counteract this problem. In effect, a given amount of applied PEEP subtracts an equivalent portion of auto-PEEP from the total negative pressure required for ventilator triggering. Generally, PEEP is slowly increased until patient efforts consistently trigger the ventilator, up to a maximum of 85% of the estimated auto-PEEP. Disadvantages of PEEP include elevation in the mean airway pressure which if excessive, can result in barotrauma. Elevation in the mean airway pressure can also impair cardiac output, especially in the setting of volume depletion.

TRIGGER SENSITIVITY -It is the negative pressure that the patient must generate to initiate a ventilator-supported breath. It should be low enough to minimize the work of breathing but high enough to avoid oversensitivity and the delivery of breaths without true patient effort.

In general, this pressure is −1 to −2 cm H2O. A more recent adaptation, known as “flow-by,” employs a baseline flow rate through the ventilator circuit; patient effort is detected when flow rate decreases. Some studies suggest that flow-by reduces the work of breathing in comparison to pressure-triggering.

In general, ventilator triggering occurs when the patient decreases baseline flow by 1 to 3 L/min.

FLOW RATE - This is often the “forgotten ventilator setting” on volume-targeted modes. Although the respiratory therapist usually sets flow rate without the need for a physician order, this rate is of critical importance because it affects the work of breathing and patient comfort and directly affects dynamic hyperinflation and auto-PEEP. On some ventilators, it is set directly, and on others (e.g., Siemens 900c), it is determined indirectly from the respiratory rate and I:E ratio. This is demonstrated in the following example:

Respiratory rate = 10

Respiratory cycle time = 6 sec

I:E ratio = 1:2

Inspiratory time = 2 sec

Expiratory time = 4 sec

Tidal volume = 500 mL

Flow rate = volume/inspiratory time

= 500 mL every 2 sec

= 250 mL/sec ×60 sec = 15 L/min

When flow rate is set directly, inspiratory time is determined by inspiratory flow rate divided by tidal volume. In turn, inspiratory time and set respiratory rate determine I:E ratio. Under most circumstances, flow rate is set between 40 and 100 L/min. An inspiratory flow rate that is set too low for patient demand (as might be expected in the example) causes the patient to "tug" on the ventilator, thus increasing the work of breathing. During volume-targeted ventilation, the prescribed flow rate cannot be exceeded. If patient demand for inspiratory flow exceeds the set rate, the patient's efforts will be ineffective, increasing the likelihood of patient distress. Moreover, slower flow rates lengthen inspiratory time, shorten expiratory time, and predispose the patient to dynamic hyperinflation and auto-PEEP. Conversely, an excessive inspiratory flow rate increases peak airway pressures and may cause patient discomfort and patient-ventilator asynchrony. In general, it is best to err on the side of high flow rates. In pressure-targeted ventilation, inspiratory flow rate is a function of inspiratory time, patient effort, and respiratory system mechanics (compliance and resistance). In these modes, it is possible for patients to alter flow rate on demand, potentially enhancing comfort.

RATIO OF INSPIRATORY TO EXPIRATORY TIME - As with inspiratory flow rate, the respiratory therapist sets the I:E ratio without need for a physician order. However, the clinician must understand how alterations in this ratio can affect respiratory system mechanics and patient comfort. A typical I:E ratio is 1:2. In acute hypoxemic respiratory failure, this ratio may be increased (lengthened inspiratory time), increasing mean airway pressure and recruiting collapsed or fluid-filled alveoli, which results in improved oxygenation. In severe hypoxemia, the I:E ratio is sometimes completely reversed to 2:1, while vigilance is maintained for adverse effects on hemodynamics and lung integrity. A complete review of inverse ratio ventilation is beyond the scope of this chapter. In obstructive lung diseases, the inspiratory time may be reduced to allow more time for exhalation and reduce the risk for dynamic hyperinflation and auto PEEP.

Complications

1. Dynamic hyperinflation and auto-PEEP - These complications are more common in patients with expiratory airflow obstruction but can occur in any patient if the respiratory system cannot return to FRC because of short expiratory time.
2. Another complication of over ventilation is respiratory alkalosis. This is potentially life-threatening because extreme alkalosis predisposes the patient to seizures, coma, ventricular arrhythmias, and hemodynamic collapse. Alkalosis of this severity is almost always an iatrogenic complication.

   To avoid this, a good rule of thumb is to set the ventilator rate a few breaths per minute below the patient's intrinsic rate. When the patient is not triggering the ventilator, periodic ABG samples should be drawn and analyzed to rule out unintended alkalosis. A critical step in evaluating the deteriorating patient on mechanical ventilation is to separate problems with the patient and endotracheal tube from problems with the ventilator. This can be done by simply disconnecting the patient from the machine and ventilating by hand with a bag-valve-mask apparatus.

However, the patient should not be bagged too vigorously, because it may cause auto-PEEP and can result in catastrophic complications, including pneumothorax, hypotension, and cardiovascular collapse. Tidal volumes of more than 1 L are commonly generated when “bagging” via an endotracheal tube with two hands, so maintaining gentle ventilation at 15 to 20 breaths per minute (one breath every 4 to 5 seconds) is critical in avoiding complications.

Discontinuation of Mechanical Ventilation

Discontinuation is commonly referred to as “weaning”.

- Weaning implies a gradual process of withdrawal from mechanical ventilation, during which the patient gradually regains the ability to breathe spontaneously.

In most cases however, the capacity for spontaneous breathing is regained when the underlying illness that made mechanical ventilation necessary resolves sufficiently. This process has less to do with ventilator manipulation and more to do with accurate diagnosis and effective treatment of the underlying condition causing respiratory failure. Weaning also implies gradual withdrawal of a benevolent life-sustaining process, when, in fact, mechanical ventilation should be considered a “necessary evil” to be removed at the earliest opportunity. Therefore, terms such as “discontinuation” and “liberation” probably are more appropriate. Nevertheless, the term “weaning” remains pervasive in the vernacular of the ICU.

Identifying the precise time when spontaneous breathing capacity returns is difficult, but attempting to do so is important because the risks accompanying mechanical ventilation increase with time.

- So, when the patient has medically stabilized, the patient should be assessed daily for the ability to breathe independently.
- From a mechanistic perspective, the ability to breathe independently after an episode of respiratory failure can be viewed as a restoration of the normal relationship between neuromuscular competence (“supply”) and the load on the respiratory system (“demand”).

Respiratory failure implies an imbalance in this relationship. Other basic considerations in the decision to initiate the discontinuation process are oxygenation needs and cardiovascular function. Spontaneous breathing trials should not generally be considered until the FIO2 is 0.5 or less and the PEEP is 5 cm H20 or less. Patients with impaired cardiac function may benefit from the afterload and preload-reducing effects of even small amounts of PEEP.

At extubation, PEEP removal may increase preload and afterload, causing pulmonary edema and recurrent respiratory failure. Cardiac performance should be medically optimized before attempting extubation in such patients.

Psychological factors are probably important, especially in patients subjected to prolonged mechanical ventilation. However, effective treatment of pain, anxiety, delirium, or depression probably does increase the likelihood of successful liberation from mechanical ventilation.

Once the decision has been made to initiate the process of discontinuation, one must assess the patient’s readiness at the bedside.

Various “weaning criteria” have been developed. These indices are applied during a trial of spontaneous breathing, when the ventilator provides either no support (T-piece trial) or minimal support.

The latter typically consists of 3 to 5 cm H2O of PEEP and 5 of 10 cm H2O of pressure support. Pressure support is provided to overcome the resistance of the endotracheal tube, which may result in an “unfair” resistive load. The exact amount of pressure support required to overcome tube resistance in any individual patient is difficult to predict, but it increases with decreasing size of the endotracheal tube.

Independently, most of the criteria listed have a limited ability to predict successful discontinuation of mechanical ventilation. In clinical practice, these criteria are often used in combination. Like the data derived from different elements of a complete history and physical examination, the data obtained from these weaning criteria should be synthesized to arrive at a working theory: does the patient have the capacity to breathe spontaneously or not?

Criteria for Discontinuation of Mechanic Ventilation

One of the most powerful predictive criteria is the **rapid shallow breathing** index. This is calculated by dividing the respiratory rate (in breaths per minute) by the tidal volume (in liters) when the patient is breathing on a T-piece, typically after 1 minute has elapsed. The volume is measured with a simple spirometer briefly attached to the T-piece. An index of less than 105 breaths per minute per liter identifies most patients who are capable of spontaneous breathing (i.e., the test has high sensitivity), although it may underestimate the capability of women and patients with small endotracheal tubes. The specificity of the index (i.e., the likelihood of an index greater than 105 breaths per minute per liter if the patient is incapable of spontaneous breathing) is poor, however.

So while the rapid shallow breathing index is a good screening test for capturing patients who can breathe spontaneously, it should be followed by a more sustained trial to “weed out” patients with a false-positive screening test who are incapable of sustaining spontaneous respiration.

Most commonly, **the T- piece or pressure-support trial** is continued for 30 to 120 minutes. Failure is evident if the **patient develops discomfort, diaphoresis, acute respiratory acidosis, or vital sign abnormalities. The latter are defined as progressive tachypnea, tachycardia with a heart rate more than 20 beats/min above the baseline, or hypertension with systolic or diastolic blood pressure more than 20 mm Hg above baseline. If such events occur, mechanical ventilation should be resume**d, while further efforts are directed at treating the underlying cause of respiratory failure. If the patient remains comfortable with stable vital signs and without acute respiratory acidosis, it is very likely that spontaneous breathing can be sustained.

Extubation should be considered, presuming mental status and spontaneous secretion clearance are adequate. These criteria for discontinuation of ventilation are not able to predict extubation failure resulting from upper airway obstruction, a complication that occurs in 1% to 5% of extubated patients.

Treatment for this emergent complication includes nebulized racemic epinephrine and high-dose intravenous corticosteroids to reduce airway edema. Heliox, a helium and oxygen gas mixture with a density lower than room air, can reduce turbulent flow and thereby reduce airflow resistance through the upper airway. Noninvasive mechanical ventilation has also been suggested as a temporizing measure, while medical therapy is being initiated.

NONINVASIVE MECHANICAL VENTILATION

Noninvasive mechanical ventilation (NIMV) is positive-pressure ventilation delivered by means of a cushioned facial or nasal mask that is maintained over the appropriate area with elastic straps. NIMV has the advantage of not requiring an endotracheal tube. Risks of the endotracheal tube (including upper airway injury and iatrogenic infection from bypassing the barrier defenses of the airway) are therefore obviated. Moreover, speaking and eating are possible with NIMV, providing potential advantages in quality of life.

Indications and Objectives

Indications and objectives of NIMV are similar to those of invasive mechanical ventilation. NIMV has benefits in both hypoxemic (type 1) and hypercapneic (type 2) respiratory failure. Application of NIMV requires an otherwise medically stable patient who is cooperative and can protect their airway. NIMV is not appropriate in patients with severely altered mental status, hemodynamic instability, excessive tracheobronchial secretions, or facial fractures. Proper patient selection is the key to success with NIMV.

There are advantages and disadvantages to both facial and nasal masks in the delivery of NIMV. In general, facial masks are more effective in patients with acute respiratory failure, because they typically breathe through their mouth, which results in unacceptable leaks with a nasal mask.

Modes

CONTINUOUS POSITIVE AIRWAY PRESSURE - Continuous positive airway pressure (CPAP) mode involves the application of positive pressure to the airway throughout the respiratory cycle. Benefits result from:

1) Improved oxygenation via increased mean alveolar pressure in acute hypoxemic respiratory failure

2) Improved ventricular performance via increased pleural pressure in cardiac dysfunction

3) Reduced threshold workload in severe obstructive lung disease complicated by auto-PEEP

4) Reduced upper airway resistance in obstructive sleep apnea

POSITIVE AIRWAY PRESSURE Bi-level positive airway pressure (BiPAP) - Provides different inspiratory and expiratory pressures. The inspiratory assistance can be either time-cycled (pressure-control ventilation) or flow-cycled (pressure-support ventilation). The ventilator is triggered when the patient makes an inspiratory effort. The methods of patient triggering (either reduction in airway pressure or baseline airflow) are similar to those used in invasive ventilation. For details regarding mechanical ventilation modes, see the previous discussion of invasive mechanical ventilation. Because of the additional inspiratory support, BiPAP is probably superior to CPAP alone when respiratory muscle fatigue is present.

Advantages of Facial vs. Nasal Masks in Noninvasive Mechanical Ventilation

Facial Mask	Nasal Mask
• Less air leak in mouth-breathers	• Less dead space: 10mlvs. 250 mL
• More effective in acute respiratory failure	• Less claustrophobia
	• Vomiting less hazardous
	• Oral intake possible with mask in place
	• Speaking easier with mask in place BI-LEVEL
	• Sputum expectoration easier

Ventilator Settings

During **CPAP,** a single positive airway pressure is applied; during **BiPAP**, an expiratory positive airway pressure (EPAP) and an inspiratory positive airway pressure (IPAP) are chosen. These settings should be titrated to attain certain specified endpoints.

Complications

NIMV is characterized by a lower risk of complications than invasive mechanical ventilation.

- The most common adverse events in patients undergoing NIMV are facial skin necrosis, gastric distention, and conjunctivitis.
- Facial skin necrosis can be prevented by avoiding overzealous tightening of the straps and accepting a small air leak and by placement of a wound dressing over the bridge of the nose.
- Gastric distention is less likely if peak mask pressure is kept below 30 cm H2O.

Routine placement of nasogastric tubes for gastric decompression are not considered necessary.

Manipulation of the mask to direct air leakage inferiorly toward the mouth rather than superiorly toward the eyes reduces the risk of conjunctivitis.

Discontinuation of Noninvasive Mechanical Ventilation

The general criteria for initiating discontinuation of NIMV are identical to those for invasive mechanical ventilation. To summarize, the underlying process initiating respiratory failure should be sufficiently improved, the patient should be otherwise medically stable, and oxygenation should be adequate on an FIO2 of 0.5 or less and 5 cm H2O or less of expiratory pressure (CPAP or EPAP). When these criteria are fulfilled, spontaneous breathing trials should be initiated. These are easier to accomplish with NIMV, since the mask can be simply removed and replaced as needed. This results in a true assessment of the patient's ability to breathe spontaneously. The confounding effects of the endotracheal tube and ventilator circuit on respiratory mechanics are avoided, as are the risks of re-intubation if the trial fails. If a patient has difficulty, the time without ventilator support can be progressively increased on a daily basis or the level of support can be progressively reduced.

What are risks of mechanical ventilation?

Problems that can develop from using a ventilator include:

■**Infections**—The ET or tracheal tube allows germs (bacteria) to get into the lungs more easily. This can cause an infection like pneumonia. Pneumonia can be a serious problem and may mean a person has to stay on the machine longer. Pneumonia can damage the lungs. People who are very sick can be more prone to infection. Pneumonia can often be treated with antibiotic medicines.

■**Collapsed lung (pneumothorax)** — sometimes, a part of the lung that is weak can become too full of air and start to leak. The leak lets air get into the empty space between the lung and the chest wall. Air in this space takes up room so the lung starts to collapse. If this air leak happens, the air needs to be removed from this space. Doctors can place a different kind of tube (chest tube) into the chest between the ribs to drain out the extra air. The tube allows the lung to re-expand and seal the leak. The chest tube usually has to stay in for some time to make sure the leak has stopped and get all the extra air out. Rarely, a sudden collapse of the lung can cause death.

■**Lung damage**— The pressure of putting air into the lungs with a ventilator can damage the lungs. Doctors try to keep this risk at a minimum by using the lowest amount of pressure that is needed. Very high levels of oxygen may be harmful to the lungs as well. Doctors only give as much oxygen as it takes to make sure the body is getting enough to supply vital organs. Sometimes it is hard to reduce this risk when the lungs are damaged. This damage can sometimes heal if a person is able to recover from the serious illness.

■**Side effects of medications**— At times sedation medicines can build up and the patient may remain in a deep sleep for hours to days, even after the medicine is stopped. The doctors and nurses try to adjust the right amount of medication for a patient. Different patients will react to each medicine differently. If muscle paralysis is needed, at times the muscles are weak for a while after it is stopped. This will get better over time.

■**Maintenance of Life**— For patients who are very sick, at times the ventilator only postpones death. Not every patient improves just because they use a ventilator. It is hard to predict or know for sure if a person will recover with treatment. Sometimes the doctors feel very sure the ventilator will help and the patient will recover. Other times, the doctors can only give a rough idea of the chances that a person will survive. Doctors may have to ask the patient (or next of kin) if the ventilator should be continued if the patient is not recovering or is getting worse. While patients can die even though they are hooked up to a ventilator, sometimes the ventilator seems to prolong the dying process.

ASSESSMENT AND PREPARATION

Assessment

1. Perform hand hygiene before patient contact.
2. Verify the correct patient using two identifiers.
3. Assess for the following before initiating ventilator support:
    a. Signs and symptoms of respiratory insufficiency or failure (e.g., hypercapnia secondary to hypoventilation, hypoxemia secondary to impaired gas exchange)
    b. Decreased oxygen saturation
    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

Preparation

1. Ensure that the patient and family understand pre-procedure teaching. Answer questions as they arise, and reinforce information as needed.
2. Pre-medicate the patient as needed and as ordered.
3. Ensure that the patient is positioned with the head of the bed elevated a minimum of 30 degrees, unless contraindicated.

EXPECTED OUTCOMES

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

UNEXPECTED OUTCOMES

- Unacceptable pH, $PaCO_2$, or PaO_2 levels
- Hemodynamic instability
- Pulmonary barotrauma
- Inadvertent extubation
- Malpositioned ET tube
- Health care–associated lung infection
- Respiratory muscle fatigue

DOCUMENTATION

- Patient and family education
- Consent (as per hospital protocol)
- Indication, date, and time ventilatory assistance was instituted
- Ventilator settings, including the following: FIO_2, mode of ventilation, VT, respiratory frequency (total and mandatory), PEEP level, I:E ratio or Ti, PIP, dynamic lung compliance, and static lung compliance
- ABG values
- SaO_2 readings
- Patient's response
- Hemodynamic values
- Vital signs
- Unexpected outcomes and nursing interventions
- VAP Checklists

CONCLUSION

Respiratory failure is common in critical illness, and mechanical ventilation is necessary in most patients. Careful monitoring of physical examination findings, pulse oximetry, ABG analysis, airway pressures, and tidal volume are necessary to avoid potential ventilator-induced harm to the patient. When used carefully, mechanical ventilation is a life-saving intervention that bridges the period of acute illness, providing support until the patient regains the ability to breathe spontaneously.

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

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