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Adult Ventilation Management

7.9 Nursing Contact Hours

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Objectives

At the conclusion of this self-learning packet the reader should be able to:

1. Define mechanical ventilation.
2. Identify three clinical situations in which mechanical ventilation may be used.
3. Describe the role of the respiratory therapist in the management of mechanically ventilated patients.
4. List six types of artificial airways and the indications for each one.
5. Describe the nurse's responsibilities before, during, and after intubation.
6. Identify three alternative means of communication for patients with artificial airways.
7. Describe three different ventilator settings.
8. Describe three different ventilator modes.
9. List three potential causes for a high-pressure alarm.
10. List two nursing interventions for a high respiratory rate alarm.
11. List three types of non-invasive mechanical ventilation.
12. Describe proper nursing care of an endotracheal tube.
13. Describe proper nursing care of a tracheostomy tube.
14. Describe the correct procedure for sterile suctioning.
15. Identify two indications for sedating and pharmacologically paralyzing a mechanically ventilated patient.
16. Define train-of-four and describe the correct procedure for testing.
17. Identify four parameters that must be monitored while patients are mechanically ventilated.
18. Identify five nursing interventions for a patient who is accidentally extubated.
19. Define ventilator weaning.
20. Compare and contrast two different weaning methods.
21. Identify three criteria that indicate when the patient is ready to be extubated.
22. Describe proper post-extubation nursing care.

You're charting at the ICU nurses station when you hear the code siren sound. You run to room 220 and find that Mr. Hill, a 68-year-old man admitted yesterday for acute respiratory failure, has respiratory arrested. One nurse is trying to ventilate Mr. Hill with a manual resuscitation bag, but she's having a hard time keeping his airway open and bagging at the same time. You hear the air rushing out around the mask, and you don't see his chest rising. Another nurse is trying to find the endotracheal tubes in the crash cart. A nursing assistant is attempting to shove a backboard under Mr. Hill, in case chest compressions are needed. A third nurse is charting furiously on the code record. In the midst of the chaos, no one else notices that Mr. Hill isn't receiving adequate ventilation. You grab the mask with both hands to ensure a tight seal and tilt his head back to open the airway. The nurse who is bagging looks relieved when you both see his chest rise and hear a "whoosh" enter his lungs.

Most of us have been certified in Basic Life Support for a long time. Airway, breathing, and circulation are second nature, but sometimes we have to be reminded of the importance, and the order, of the ABCs. This article will focus on the airway and breathing components. Most of the discussion will be on initiating, managing, and weaning mechanical ventilation, but we'll also review the various types of airways and the indications for each one. Along the way, we'll follow Mr. Hill through his hospital stay. Hopefully, your expert nursing care will help him recover enough to go home!

Airway Management & Mechanical Ventilation Basics

The goal of airway management is to ensure that the patient has a patent airway through which effective ventilation can take place. An obstructed airway causes the body to be deprived of oxygen and, if ventilation isn't reestablished, causes brain death within minutes. When a patient is critically ill and requires an artificial airway and mechanical ventilation, it is the responsibility of the healthcare professionals caring for the patient to ensure that the airway is secure, and that it's as close to the patient's natural airway as possible. This means mechanically performing physiological functions such as humidifying inspired air and removing secretions.

Mechanical ventilation is used when a patient is unable to breathe adequately on his or her own. The ventilator can either completely take over respiratory function, or it can be used to support the patient's own respiratory efforts.

Indications for Mechanical Ventilation
The patient experiencing respiratory failure or arrest is the first type of patient most of us think of when we hear "mechanical ventilation." The code scenario described above is a classic clinical situation; if the patient survives the code, we know he will be transferred to the ICU on a ventilator. Similarly, any patient experiencing respiratory distress with impaired gas exchange or increased work of breathing is likely to be intubated and mechanically ventilated, hopefully before he or she reaches the point of respiratory arrest.

Mechanical ventilation can also be used in other situations. For example, relieving the work involved with breathing decreases myocardial and systemic oxygen consumption. This is

particularly beneficial for patients who have both respiratory and cardiac failure. The increased work of breathing resulting from respiratory distress or fatigue puts extra stress on the heart, which can lead to a cardiac event. A diminished work of breathing also decreases intracranial pressure, thus mechanical ventilation is often used in patients with brain injuries.

In some cases, it's advantageous for a patient to be heavily sedated or even pharmacologically paralyzed. Patients with brain injuries may be placed in a barbiturate coma in order to decrease the metabolism and use of oxygen in the brain. This facilitates healing and reduces the risk of further ischemic brain injury. Likewise, patients who are admitted after ingesting drugs or alcohol, or who are experiencing drug or alcohol withdrawal, may be violent and a safety risk to themselves and others. They may be pharmacologically sedated and paralyzed during this time, especially if they are hospitalized for another physical problem or injury that could be exacerbated by their behavior, such as myocardial infarction, trauma, or after surgery.

Finally, mechanical ventilation may be used to provide stability of the chest wall after trauma or surgery if movement or coughing would disrupt broken bones or surgical incisions. In this case, the patient would likely be heavily sedated and pharmacologically paralyzed to inhibit any spontaneous movement.

Role of Registered Nurse
Nurses are constantly present at the patient's bedside, so they are the primary healthcare professionals responsible for monitoring the patient's respiratory status. They are expected to keep an eye on any equipment required by the patient, including ventilators and monitoring equipment, and to respond to monitor alarms. The nurse is also responsible for notifying the respiratory therapist when mechanical problems occur with the ventilator, and when there are new physician orders that call for changes in the settings or the alarm parameters.

The nurse is responsible for documenting frequent respiratory assessments. This usually means documenting ventilator settings and spontaneous respiratory parameters every hour, with a full respiratory assessment, including lung sounds, at least every four hours. The nurse also performs suctioning and provides oral and site care around the artificial airway. There is often a great deal of teaching and reassuring that must be done, both for the patient (if alert) and family; the nurse is in a prime position to address those needs.

Role of Respiratory Therapist
The respiratory therapist (RT) is generally responsible for setting up the ventilator, doing the daily check, changing ventilator settings based on physician's orders, and performing general ventilator maintenance.

The RT is also responsible for assessing the patient's respiratory status and performing suctioning. RTs usually round on their assigned patients every two hours to document the ventilator settings and the patient's spontaneous respiratory parameters. The RT and nurse must communicate so each knows when the patient was last suctioned. The RT is also responsible for performing weaning criteria on patients who may be extubated and communicating the results to the nurse.

Artificial Airways

There are a number of different artificial airways; each one has its own criteria for use based on the clinical circumstances. The artificial airways that you see most often relate to the unit you work in. If you're in the ER, you'll see the temporary airways frequently; if in ICU, you'll see endotracheal tubes (ETT) and tracheostomies; if in long-term care, you'll see a lot of tracheostomies; and if in the OR, you'll see a little of everything. We'll start with the temporary airways, which should only be used for a few hours, and progress to those that can be used for longer time periods.

Combitube
A combitube is often used by paramedics in field resuscitation. It contains two lumens, one that intubates the esophagus, and one that intubates the trachea. The combitube is easy to insert quickly, and it eliminates the risk of intubating the esophagus rather than the trachea. The manual resuscitation bag is attached to the lumen that inflates the lungs, and the esophageal balloon is inflated to decrease the risk of aspiration. The combitube should only be used for emergency intubation, and should be replaced with an ETT as soon as possible.

Laryngeal Mask Airway
A laryngeal mask airway (LMA) is used for emergent intubation or in situations where ETT intubation has failed. The LMA looks like an ETT with an inflatable, silicone rubber collar at the bottom end. This collar surrounds and covers the supraglottic area, providing a continuous upper airway. The LMA does not protect the patient from aspiration, thus it can only be used as a short-term measure until another type of airway is established. An advantage of the LMA is that it maintains an open airway, while allowing ETT intubation to be done through it. This is particularly beneficial in patients in whom previous ETT intubation attempts have failed.

Oropharyngeal
The goal of an oropharyngeal airway is to keep the tongue from obstructing the upper pharynx. It will cause an alert patient to gag, thus it should only be used in an unconscious patient with a diminished gag reflex.

Before inserting the airway, explain the procedure to the patient (even though they're unconscious) and use universal precautions as necessary. Place the patient in the supine position, if possible; suction the mouth; and remove any dentures. To estimate the appropriate size, hold the airway next to the patient's upper jaw, with the front even with the patient's teeth. The end of the airway should reach the angle of the jaws. In general, a small airway is used for children, a medium for average-sized adults, and a large for large adults. Size is important since an airway that's too large can contribute to the obstruction and cause the patient to gag, vomit, and aspirate, whereas an airway that's too small may push the tongue further back into the oropharynx.

The airway is inserted into the mouth upside down, then rotated 180° as it is placed over the tongue. Care should be taken to avoid scraping the palate or exerting pressure on the upper teeth. The airway should be rotated down slightly as it approaches the posterial wall of the oropharynx, so it follows the natural curvature of the oral cavity. It's recommended that oropharyngeal airways not be taped in place. Complications of oropharyngeal airway insertion

include oral trauma, obstruction of the airway, laryngospasm, gagging, and vomiting. After insertion, the patient's lungs should be auscultated, and the patient placed on his or her side to decrease the risk of aspiration.

Most patients don't have an oropharyngeal airway in place for long periods of time, since they will either be intubated if they continue to have a compromised airway, or else will recover to the point of not needing it. However, here are some tips for those instances when you may have to care for a patient with an oropharyngeal airway.

- The position of the airway in the patient's mouth and breath sounds should be assessed frequently.
- The oral cavity should be suctioned as needed.
- Mouth care should be done every two to four hours and as needed. Mouth care can be done with a moistened swab.
- If the airway is coated with secretions, it can be removed and cleaned if the patient's respiratory status is stable. Remove the airway by pulling it out and downward, following the curvature of the mouth. Immediately insert a clean airway before cleaning the soiled one with hydrogen peroxide and water. This airway can be kept for future use with the same patient. If the patient has the oropharyngeal airway as a long-term measure, the airway should be cleaned and replaced at least once every eight hours.

Nasopharyngeal
The function of a nasopharyngeal airway is similar to that of the oropharyngeal, except that it's lubricated and inserted through a nostril into the posterior pharynx. Conscious patients tolerate this better than the oropharyngeal airway. Another benefit of a nasopharyngeal airway is that it provides easy access for sterile suctioning of the patient's pharynx and trachea.

Before inserting the airway, explain the procedure to the patient and position him or her in the supine position, if possible. Nasopharyngeal airways are available in sizes from #28 to #34 French. To select the correct size, hold the airway next to the patient's cheek and compare the diameter of the airway to the diameter of the nostril. The airway diameter must be slightly smaller. The airway should also be slightly longer than the distance from the tip of the nose to the edge of the jaw.

Lubricate the airway with water-soluble lubricant and insert it into the selected nostril. Gently slide it along the floor of the nose while pushing the tip of the nose up with your nondominant hand. Once inserted, it should follow the natural curvature of the nasopharynx. If you encounter resistance, carefully twist the airway as you insert it, but don't force it. If there's still resistance, try the other nostril or use a smaller airway.

If you can feel air moving through the airway opening, it's placed properly. You should also be able to see the tip of the airway behind the uvula when you look into the patient's mouth. Lung sounds should also be auscultated. Complications of nasopharyngeal airway insertion include trauma to the nares, airway obstruction, laryngospasm, gagging, and vomiting.

Some patients may have a nasopharyngeal airway in place for a few days. Care of the airway is similar to that of an oropharyngeal airway. The airway should be removed once every eight hours. Explain the procedure to the patient and use universal precautions. If you encounter resistance while removing the airway, apply water-soluble lubricant around the nares and the

nasal end of the tube, then gently rotate the tube until it can be removed. Immediately insert another nasopharyngeal airway into the patient's other nostril, unless contraindicated. Then clean the soiled tube with hydrogen peroxide and water, and store it for future use with the same patient. Assess the patient's nares for irritation and ulceration.

Endotracheal Tube

The endotracheal tube (ETT) is the most common artificial airway used for short-term (up to three weeks) airway management or mechanical ventilation. Insertion of an ETT is indicated for airway maintenance, secretion control, oxygenation and ventilation, and administration of emergency medications during cardiopulmonary arrest. The tube may be inserted either nasally or orally; however, the oral route is preferred during emergency placement because insertion is easier and a larger-diameter tube can be used. The nasal route is used if the patient has a jaw fracture, a history of recent oral surgery, or trauma to the mouth or lower face. This route also provides greater patient comfort. Nasal intubation is contraindicated if the patient has a nasal obstruction, a fractured nose, sinusitis, or a bleeding disorder. Extreme caution should be used if the patient has a basal skull fracture.

ETTs are available in a variety of sizes, based on the inner diameter. For adults, this generally includes tubes with an inner diameter of 6 mm to 8.5 mm. It's recommended that at least a size 7 tube be used in adults to decrease the work of breathing when the patient is weaning from the ventilator. Breathing spontaneously through an ETT has been compared to breathing through a straw. Obviously, a smaller tube may have to be used for nasal intubation, but most patients can tolerate tube sizes between 6 and 7.5 for this.

The process of intubation and nursing care of the patient with an ETT will be addressed later.

Tracheostomy Tube

A tracheostomy (trach) tube is the preferred artificial airway for patients requiring long-term mechanical ventilation (longer than three weeks). It's also indicated for other conditions, such as upper airway obstruction or malformation, failed or repeated intubations, complications from endotracheal intubations, glottic incompetence, sleep apnea, or chronic inability to clear secretions. Resistance to airflow is less with a trach tube than an ETT because it is wider, shorter, and less curved. This reduces the work of breathing for the patient, and allows easy removal of secretions. Some trach tubes also allow eating and talking (if the patient's respiratory status is stable), and are more comfortable than an ETT. Trach tubes come in the same sizes as ETTs, based on the inner diameter. Most adults require a size 7, 7.5, or 8.

Trach tubes are made of either disposable plastic or metal. Plastic tubes are generally changed two times per week, and are thrown away after one-time use. Metal tubes are left in place for longer periods of time, and are reinserted after cleaning. Trach tubes can be either single-lumen or double-lumen tubes. Single-lumen tubes have a cuff around the tube that is inflated with air to hold it in place, and an obturator, which is used during tube insertion. Double-lumen tubes contain the same components as the single-lumens, along with an additional inner cannula that can be removed. Many inner cannulas are disposable and are simply thrown away and replaced once every eight hours. Cannulas that are not disposable can be reinserted after removal for cleaning. Single-lumen tubes have a larger internal diameter that is less restrictive to airflow, which reduces the work of breathing for the patient. Double-lumen tubes are safer for patients with copious secretions because the inner cannula can be quickly removed if it

becomes obstructed. Removing the cannula essentially converts the double-lumen tube to a single-lumen. Disposable, plastic trach tubes have an adaptor on the outer end that can connect to a manual resuscitation bag, providing for easy manual ventilation in the event of respiratory arrest. The adaptor also fits with ventilator tubing, making it simple to mechanically ventilate a patient with a trach who is experiencing respiratory distress.

Tracheostomy tubes are inserted either surgically or percutaneously. Complications of insertion include hemorrhage, pneumothorax, laryngeal nerve injury, pneumomediastinum, tracheoesophageal fistula (opening between trachea and esophagus), and cardiopulmonary arrest. Wound infection, subcutaneous emphysema (air in subcutaneous tissue), tube obstruction, and tube displacement may also occur. Long-term complications include tracheal stenosis (narrowing), tracheoesophageal fistula (opening between the trachea and esophagus), tracheoinnominate artery fistula (opening between trachea and innominate artery, causing hemorrhage), and tracheocutaneous fistula (opening between trachea and skin).

Nursing care of the patient with a trach tube will be addressed later.

Finally, if the patient is being ventilated with a manual resuscitation bag without an artificial airway in place, there are some important points to remember. First, there is no limit to the length of time that a patient can be manually ventilated, <u>as long as the procedure is done correctly</u>. "Bagging" seems such a simple procedure, but many healthcare professionals do it incorrectly. The following are guidelines to keep in mind.

- Tilt the patient's head back to open the airway, unless neck injury is present. In this case, use a jaw thrust.
- It takes two people to perform manual resuscitation correctly: one to keep the airway open and the mask tightly sealed, and one to squeeze the bag.
- The patient's chest should rise with each squeeze of the bag.
- Ensure that 100% oxygen is hooked up to the resuscitation bag.
- Condensation in the mask indicates ventilation is taking place in the lungs.
- Listen for lung sounds or tracheal sounds of air entering the lungs.
- If the patient has dentures, ventilation may be easier to perform if the dentures are left in.
- If the patient has any spontaneous breaths, manual breaths should be coordinated with the patient's own breaths.

Here's a review of the advantages and disadvantages of each artificial airway.

	Combitube	LMA
Advantages	• Easy to insert quickly. • Don't have to worry about accidentally intubating esophagus. • Balloon prevents aspiration.	• Easy to insert quickly. • Allows ETT intubation through it, while maintaining an open airway.
Disadvantages	• Can only be used for a few hours.	• Does not prevent aspiration. • Can only be used short term until another airway is established.

	Oropharyngeal	Nasopharyngeal
Advantages	• Prevents tongue from obstructing pharynx. • May prevent the need for intubation in patients who are temporarily unable to maintain their airway (i.e., drug overdose).	• Same as oropharyngeal. • Tolerated by conscious patients with an intact gag reflex. • Can be left in place for a few days. • Provides route for sterile suctioning of airway.
Disadvantages	• Causes conscious patients to gag, thus can only be used in unconscious patients with a diminished gag reflex.	• Nares must be closely monitored for skin breakdown if used for a few days.

	Endotracheal Tube	Tracheostomy
Advantages	• Can be used for up to three weeks. • Provides route for sterile suctioning of airway. • Some emergency medications can be given via the ETT ("NAVEL"= Narcan, atropine, Versed, epinephrine, lidocaine) • Can be inserted either nasally or orally (oral route generally preferred unless patient had jaw trauma or surgery).	• Can be used long-term; up to years. • More comfortable for patient. • Allows speaking and eating if respiratory status is stable. • Patients can be taught how to care for their tracheostomy at home. • Stoma can be plugged, but kept patent if needed.
Disadvantages	• Patients may need sedation and/or wrist restraints to prevent accidental removal. • Patients may feel like they're breathing through a straw. • Patients not able to speak.	• Requires surgical procedure to insert. • Long-term use can cause fistulas between trachea and skin, esophagus, or innominate artery.

Nursing Interventions Related To ETT Intubation

Endotracheal intubation is usually done under stressful conditions; the patient is either experiencing significant respiratory distress, or has already respiratory arrested. It's helpful for you to know what your responsibilities are prior to the event occurring, in order to minimize stress and provide the best outcome for the patient. Your responsibilities differ based on the type of unit you work in. If you work in a critical care environment, are ACLS certified, and/or are part of a code team, you'll have a large role in the intubation. If you work in the emergency department, you know that things often happen more quickly than in the rest of the hospital. You may not have time to prepare much, or the patient may arrive with a Combitube or ETT from the field. If you work in a different area from these, you'll primarily be expected to gather equipment and medications, monitor the patient during the intubation, and document on the code record.

Note: As nurses gain experience, they can often predict when a patient is going to need intubation and mechanical ventilation. They may gather the intubation equipment hours before the patient actually needs it and keep it near the room "to ward off evil spirits." (Nurses can be a superstitious lot! Sometimes it actually works.) Nurses who have this ability, and who are assertive in notifying the physician, are a great asset in improving the patient's outcome.

Of course, the first step in intubation is recognizing that the patient needs it and notifying the respiratory therapist and the staff member who intubates patients in your practice setting. This is usually an anesthesiologist, a Certified Registered Nurse Anesthetist (CRNA), a medical resident, or another physician. Prior to intubation, all necessary equipment and medications should be at the bedside. It saves time if you know who will be doing the intubation, and what their personal preferences are. Most hospitals have intubation trays or kits that are part of the code cart. The entire tray should be brought to the room, so that extra equipment is available. Murphy's Law always prevails in these situations, and you'll appreciate having back-up equipment! You should have a laryngoscope with both Macintosh (curved like a <u>Macintosh</u> apple) and Miller (straight like the "l" in <u>Miller</u>) blades. Make sure that the battery in the laryngoscope handle and the light bulbs in all of the blades are working.

Here's a list of some of the other things you should have ready.

EQUIPMENT	MEDICATIONS	PATIENT HISTORY
Various sizes of ETT tubes (6 to 8.5)	Sedative (i.e., Versed)	Medical history/reason for admit
Tape or device to secure ETT tube	Paralytic (i.e., succinylcholine)	Events leading to intubation
Bite block	Pain medication (i.e., morphine)	Vital signs
Sterile gloves		Breath sounds
Suction – sterile and Yankauer		Allergies
Saline		If on anticoagulants
Stethoscope		Labs (electrolytes, ABGs)
CO_2 detector to confirm placement		Latest chest x-ray result
Cardiac monitor/pulse oximeter		Presence of dentures (remove them)
		Last oral intake

If you have been caring for the patient, it's vital that you know the history and the events leading up to the intubation. Here's an important bit of trivia: succinylcholine (Anectine) is a depolarizing neuromuscular blocker that's often used to paralyze the patient prior to intubating. However, the prolonged depolarization causes potassium to leave the muscle cells, raising the serum potassium level by 0.5-1.0 mEq/L. If your patient is already hyperkalemic, it's important that this drug not be used. (A perfect example of why you should know your patient's latest lab values.)

Anything you can do to prepare the room ahead of time is also helpful. This may include removing the head of the bed, pulling the bed away from the wall, removing extra equipment (such as unused orthopedic trapeze), and asking visitors to step out of the room.

While the physician is intubating the patient, you'll be responsible for monitoring and documenting vital signs, administering medications, and preparing equipment. Sterile suction should be set up and ready for use as soon as the ETT is placed. Often, suctioning of mucus or aspirate is all that's needed to restore spontaneous breathing after a respiratory arrest.

After intubation, you should have a stethoscope ready to listen for bilateral breath sounds. Many institutions also use CO_2 detectors to confirm that the ETT is in the lungs, and not the esophagus. (However, this is not a foolproof method of confirmation, since it can detect CO_2 in the esophagus of a patient who recently drank a carbonated beverage.) A chest x-ray is necessary to confirm the position of the ETT. There are centimeter markings along the length of the tube; the depth of the ETT in most adults should be between 20-22 centimeters. On the chest x-ray, the end of the ETT should be approximately two finger widths above the carina. You should have tape or an ETT holder ready to secure the tube, as well as wrist restraints for the patient, in order to prevent accidental removal of the tube.

Case Study

Remember Mr. Hill? We left him in the middle of a respiratory arrest, but fortunately, you and your coworker have been successfully manually ventilating (bagging) him until now. (You can bag this long in real life. Just don't give the patient any long-acting paralytics!)

Joe, RN, CRNA arrives to intubate Mr. Hill. The RT arrives at the same time and takes over bagging. Mr. Hill's cardiac rhythm has remained sinus tachycardia with a pulse. You realize that you're the most experienced nurse in the room and that the other three nurses are looking at you, so you step in to assist Joe with the intubation.

1. List seven things that you should get ready.
   - A. Assemble laryngoscope handle and blade (ask Joe which blade he wants and make sure light bulb is working).
   - B. Ask Joe what size ETT he plans to use and have it ready (inflate/deflate balloon to check for leaks, but keep the tube sterile).
   - C. Have a sedative and paralytic at the bedside (i.e., Versed and succinylcholine-delegate someone to find out the patient's last potassium).
   - D. Have tape ready for securing the ETT.
   - E. Have a stethoscope and CO_2 detector ready for confirming placement.
   - F. Have sterile suction ready to use as soon as the ETT is inserted.
   - G. Delegate someone to monitor the cardiac monitor and pulse oximeter.

The intubation goes smoothly. Breath sounds are present bilaterally and the CO_2 detector indicates the ETT is in the lungs.

2. Which other diagnostic test should be done to confirm the position of the ETT?

   Answer:
   Chest x-ray.

Joe orders initial ventilator settings until the pulmonologist can be called, and the RT sets up the ventilator. Mr. Hill's vital signs are stable, and he's still sedated from the Versed given prior to intubation.

Alternative Methods of Communication For Patients With Artificial Airways

Patients who are mechanically ventilated are often heavily sedated to prevent them from "bucking" the ventilator or feeling discomfort while breathing through the ETT. (Remember that this has been compared to breathing through a straw.) However, some patients may be alert, especially during weaning when they must be able to follow commands. The ETT prevents speech because it passes through the vocal cords; this may increase anxiety if the patient thinks no one will know if he or she is having trouble breathing. Caregivers must enter the room (so the patient can see them) frequently to reassure the patient that he or she is being carefully monitored. Alternative means of communication should be used as well, to ensure the patient feels that his or her needs are being acknowledged and met.

Some patients may be able to mouth words well enough for caregivers to read their lips around the ETT. However, this takes great patience on the part of both the caregivers and the patient. Having the patient write notes and draw pictures is another option, but this also requires time and patience. The patient may have to use their nondominant hand because of IVs and arterial lines, they may not have their glasses on, or they may be positioned awkwardly in the bed, all of which result in illegible writing and frustration. Communication boards can be a terrific alternative. These are posters that usually have large-type letters and numbers on one side, and pictures of typical patient requests on the other side. The pictures include items such as medication, pain, nurse, doctor, family, call light, TV, reposition, and water. Some patients may be able to spell out words using the side with the letters. These boards are usually large enough to be seen without glasses, and they can be kept in the patient's room for family to use. (The only problem is finding one on your unit when you need one. They seem to always be missing!)

Stable patients with a trach can have a capped, fenestrated trach tube inserted that allows speech. This tube has an opening in the posterior wall that allows the patient to breathe through the upper airway when the tube is capped. The cuff must be deflated to allow airflow around the tube, and the patient should be closely monitored for respiratory distress. A special valve can be attached to the tube instead of a cap (Passey-Muir or Montgomery valve), which allows the patient to inhale through the tracheostomy tube, but requires exhalation through the upper airway, enabling speech. There are also tracheostomy tubes that have speaking ports attached. Oxygen is delivered through a port above the inflated cuff, while occluding the speaking port with a finger causes airflow to move through the upper airway and vocal cords.

Ventilators

There are two general kinds of ventilators: negative pressure and positive pressure.

Negative Pressure

The original ventilators used negative pressure to remove and replace gas from the ventilator chamber. Examples of these include the iron lung, the Drinker respirator, and the chest shell. Rather than connecting to an artificial airway, these ventilators enclosed the body from the outside. As gas was pulled out of the ventilator chamber, the resulting negative pressure

caused the chest wall to expand, which pulled gas into the lungs. The cessation of the negative pressure caused the chest wall to fall and exhalation to occur. While it's an advantage that these ventilators didn't require insertion of an artificial airway, they were noisy and made nursing care difficult. These ventilators are no longer commonly used in the critical care environment.

Positive Pressure

Positive pressure ventilation was a result of the polio epidemic in 1955, when the demand for mechanical ventilation exceeded the available number of negative pressure ventilators. There was such a shortage in Sweden that medical students worked in 8-hour shifts, manually ventilating polio patients. The Emerson Company in Boston developed the positive pressure ventilator, which was first used at Massachusetts General Hospital. It was an immediate success, and launched a new era of intensive care medicine.

Positive pressure ventilators require an artificial airway (endotracheal or tracheostomy tube), and use positive pressure to force oxygen into a patient's lungs. Inspiration can be triggered either by the patient or the machine. There are four types of positive pressure ventilators: volume cycled, pressure cycled, flow cycled, and time cycled.

Volume-cycled ventilators are designed to deliver a preset tidal volume, then, allow passive expiration. This is ideal for patients with bronchospasm since the same tidal volume is delivered regardless of the amount of airway resistance. This type of ventilator is the most commonly used in critical care environments.

Pressure-cycled ventilators deliver gases at preset pressure, then, allow passive expiration. The benefit of this is a decreased risk of lung damage from high inspiratory pressures. The disadvantage of these ventilators is that the patient may not receive the complete tidal volume if he or she has poor lung compliance and increased airway resistance. This type of ventilation is usually used for short-term therapy (less than 24 hours). Some ventilators have the capability to provide both volume-cycled and pressure-cycled ventilation. These combination ventilators are also commonly used in critical care environments.

Flow-cycled ventilators deliver a breath until a preset flow rate is achieved during inspiration. Time-cycled ventilators deliver a breath over a preset time period. These aren't used as much as the volume-cycled and pressure-cycled ventilators.

Operation and Maintenance

Many ventilators are now computerized and have a user-friendly control panel. To activate various modes, settings, and alarms, the appropriate key need only be pressed. There are windows on the face panel that show the current settings and the alarm parameters. Some ventilators have dials instead of computerized keys; for example, the smaller, portable ventilators used for transporting patients.

Ventilators are electrical equipment and must be plugged in. They do have battery back-up, but this isn't designed for long term use. It should be ensured they are plugged into an outlet that will receive generator power if there is an electrical outage. Ventilators are a method of life-support; if the ventilator stops working, the patient's life may be in jeopardy. There should be a

manual resuscitation bag at the bedside of every patient receiving mechanical ventilation, so they can be manually ventilated, if needed.

When mechanical ventilation is initiated, the ventilator goes through a self-test to ensure that it's working properly. The ventilator tubing should be changed every 24 hours and another self-test run afterwards. The bacteria filters should be checked for occlusions or tears, and the water traps and filter should be checked for condensation or contaminants. These should be emptied and cleaned every 24 hours and as needed.

Ventilator Settings

Ventilator settings are ordered by the physician and are individualized for each patient. Ventilators are designed to monitor many components of the patient's respiratory status. Various alarms and parameters can be set to warn healthcare providers that the patient is having difficulty with the settings.

Respiratory Rate (RR)
The respiratory rate is the number of breaths the ventilator delivers to the patient each minute. The rate chosen depends on the tidal volume, the type of pulmonary pathology, and the patient's target $PaCO_2$. The respiratory rate parameters are set above and below this number and the alarm will then sound if the patient's actual rate is outside of the desired range.

(The following are guidelines.) For patients with obstructive lung disease, the rate should be set at 6-8 breaths/minute to avoid the development of auto-PEEP and hyperventilation, or "blowing off CO_2". Patients with obstructive lung disease often adapt to a higher $PaCO_2$, so lowering it back to the "normal" range of 35-45 mm Hg may not be beneficial. Patients with restrictive lung disease usually tolerate a range of 12-20 breaths/minute. Patients with normal pulmonary mechanics can tolerate a rate of 8-12 breaths/minute. The patient should be monitored on the initial rate setting and adjustments made as necessary.

Tidal Volume (V_T)
The tidal volume is the volume of gas the ventilator delivers to the patient with each breath. The usual setting is 5-15 cc/kg, based on compliance, resistance, and type of pathology. Patients with normal lungs can tolerate a tidal volume of 12-15 cc/kg, whereas patients with restrictive lung disease may need a tidal volume of 5-8 cc/kg. The tidal volume parameters are set above and below the desired number, and the alarm will sound if the patient's actual tidal volume is outside of the desired range. This is especially helpful if the patient is breathing spontaneously between ventilator-delivered breaths, since the patient's own tidal volume can be compared with the tidal volume delivered by the ventilator.

Fractional Inspired Oxygen (FIO_2)
The fractional inspired oxygen is the amount of oxygen delivered to the patient. It can range from 21% (room air) to 100%. It's recommended that the FIO_2 be set at 1.0 (100%) upon the initiation of mechanical ventilation to allow the patient to get used to the ventilator without experiencing hypoxia. However, 100% oxygen should not be used continuously for long periods of time because of the risk of oxygen toxicity. Oxygen toxicity causes structural changes at the alveolar-capillary membrane, pulmonary edema, atelectasis, and decreased PaO_2. Once the

patient is stabilized, the FIO_2 can be weaned down based on pulse oximetry and arterial blood gas values. The FIO_2 should only be as high as is necessary to keep the PaO_2 in the desired range.

Most ventilators have a temporary 100% oxygen setting that delivers 100% oxygen for only a few breaths. This should always be used prior to and after suctioning; during bronchoscopy, chest physiotherapy, or other stressful procedures; and during patient transport.

Inspiratory:Expiratory (I:E) Ratio
The I:E ratio is usually set at 1:2 or 1:1.5 to approximate the normal physiology of inspiration and expiration. Occasionally, a longer inspiratory than expiratory time is desired to allow more time to oxygenate the patient's lungs. This is called inverse ratio ventilation, and will be discussed later.

Pressure Limit
The pressure limit regulates the amount of pressure the volume-cycled ventilator can generate to deliver the preset tidal volume. Because high pressures can cause lung injury, it's recommended that the plateau pressure not exceed 35 cm H_2O. If this limit is reached, the ventilator stops delivering the breath and alarms. This may be an indication that the patient's airway is obstructed with mucus, in which case, the high pressure is usually resolved with suctioning. It can also be caused by the patient coughing, biting on the ETT, breathing against the ventilator, or by a kink in the ventilator tubing.

Flow rate
The flow rate is the speed with which the tidal volume is delivered. The usual setting is 40-100 liters per minute.

Sensitivity/Trigger
The sensitivity determines the amount of effort required by the patient to initiate inspiration. It can be set to be triggered by pressure or flow. Flow triggering is a better setting for patients who can breathe spontaneously because it reduces the work of breathing.

Sigh
The ventilator can be programmed to deliver an occasional sigh with a larger tidal volume. The use of frequent sighs was popular during the 1970s because it was thought that it prevented collapse of the alveoli (atelectasis), which can result from the patient constantly inspiring the same volume of gas. However, recently there has been concern that the increased pressure produced in the alveoli may heighten the risk of the alveoli rupturing and causing pneumothorax.

Ventilator Settings

The following is a summary of the settings that nurses deal with the most.

SETTING	FUNCTION	USUAL PARAMETERS
Respiratory Rate (RR)	Number of breaths delivered by the ventilator per minute	Usually 4-20 breaths per minute
Tidal Volume (V_T)	Volume of gas delivered during each ventilator breath	Usually 5-15 cc/kg
Fractional Inspired Oxygen (FIO_2)	Amount of oxygen delivered by ventilator to patient	21% to 100%; usually set to keep $PaO_2 > 60$ mmHg or $SaO_2 > 90\%$
Inspiratory:Expiratory (I:E) Ratio	Length of inspiration compared to length of expiration	Usually 1:2 or 1:1.5 unless inverse ratio ventilation is required
Pressure Limit	Maximum amount of pressure the ventilator can use to deliver breath	10-20 cm H_2O above peak inspiratory pressure; maximum is 35 cm H_2O

Ventilator Modes

Mode refers to how the machine will ventilate the patient in relation to the patient's own respiratory efforts. There is a mode for nearly every patient situation, plus many can be used in conjunction with each other.

Control Ventilation (CV)
CV delivers the preset volume or pressure regardless of the patient's own inspiratory efforts. This mode is used for patients who are unable to initiate a breath. If it is used with spontaneously breathing patients, they must be sedated and/or pharmacologically paralyzed so they don't breathe out of synchrony with the ventilator.

Assist-Control Ventilation (A/C)
A/C delivers the preset volume or pressure in response to the patient's own inspiratory effort, but will initiate the breath if the patient does not do so within the set amount of time. This means that any inspiratory attempt by the patient triggers a ventilator breath. The patient may need to be sedated to limit the number of spontaneous breaths since hyperventilation can occur. This mode is used for patients who can inititate a breath but who have weakened respiratory muscles.

Synchronous Intermittent Mandatory Ventilation (SIMV)
SIMV was developed as a result of the problem of high respiratory rates associated with A/C. SIMV delivers the preset volume or pressure and rate while allowing the patient to breathe spontaneously in between ventilator breaths. Each ventilator breath is delivered in synchrony with the patient's breaths, yet the patient is allowed to completely control the spontaneous breaths. SIMV is used as a primary mode of ventilation, as well as a weaning mode. (During weaning, the preset rate is gradually reduced, allowing the patient to slowly regain breathing on his or her own.) The disadvantage of this mode is that it may increase the work of breathing and respiratory muscle fatigue.

Pressure Support Ventilation (PSV)
PSV is preset pressure that augments the patient's spontaneous inspiratory effort and decreases the work of breathing. The patient completely controls the respiratory rate and tidal volume. PSV is used for patients with a stable respiratory status and is often used with SIMV to overcome the resistance of breathing through ventilator circuits and tubing.

Positive End Expiratory Pressure (PEEP)
PEEP is positive pressure that is applied by the ventilator at the end of expiration. This mode does not deliver breaths, but is used as an adjunct to CV, A/C, and SIMV to improve oxygenation by opening collapsed alveoli at the end of expiration. Complications from the increased pressure can include decreased cardiac output, pneumothorax, and increased intracranial pressure.

Constant Positive Airway Pressure (CPAP)
CPAP is similar to PEEP except that it works only for patients who are breathing spontaneously. The effect of both is comparable to inflating a balloon and not letting it completely deflate before inflating it again. The second inflation is easier to perform because resistance is decreased. CPAP can also be administered using a mask and CPAP machine for patients who do not require mechanical ventilation, but who need respiratory support; for example, patients with sleep apnea.

Independent Lung Ventilation (ILV)
This method is used to ventilate each lung separately in patients with unilateral lung disease or with a different disease process in each lung. It requires a double-lumen endotracheal tube and two ventilators. Sedation and pharmacological paralysis are used to facilitate optimal ventilation and increased comfort for the patient.

High Frequency Ventilation (HFV)
HFV delivers a small amount of gas at a rapid rate (as much as 60-100 breaths per minute.) This is used when conventional mechanical ventilation would compromise hemodynamic stability, during short-term procedures, or for patients who are at high risk for pneumothorax. Sedation and pharmacological paralysis are required.

Inverse Ratio Ventilation (IRV)
The normal inspiratory:expiratory ratio is 1:2 but this is reversed during IRV to 2:1 or greater (the maximum is 4:1). This mode is used for patients who are still hypoxic even with the use of PEEP. The longer inspiratory time increases the amount of air in the lungs at the end of expiration (the functional residual capacity) and improves oxygenation by reexpanding collapsed alveoli. The shorter expiratory time prevents the alveoli from collapsing again. Sedation and pharmacological paralysis are required since it's very uncomfortable for the patient.

Ventilator Modes

MODE	FUNCTION	CLINICAL USE
Control Ventilation (CV)	Delivers preset volume or pressure regardless of patient's own inspiratory efforts	Usually used for patients who are apneic
Assist-Control Ventilation (A/C)	Delivers breath in response to patient effort and if patient fails to do so within preset amount of time	Usually used for spontaneously breathing patients with weakened respiratory muscles
Synchronous Intermittent Mandatory Ventilation (SIMV)	Ventilator breaths are synchronized with patient's respiratory effort	Usually used to wean patients from mechanical ventilation
Pressure Support Ventilation (PSV)	Preset pressure that augments the patient's inspiratory effort and decreases the work of breathing	Often used with SIMV during weaning
Positive End Expiratory Pressure (PEEP)	Positive pressure applied at the end of expiration	Used with CV, A/C, and SIMV to improve oxygenation by opening collapsed alveoli
Constant Positive Airway Pressure (CPAP)	Similar to PEEP but used only with spontaneously breathing patients	Maintains constant positive pressure in airways so resistance is decreased
Independent Lung Ventilation (ILV)	Ventilates each lung separately; requires two ventilators and sedation/paralysis	Used for patients with unilateral lung disease or different disease process in each lung
High Frequency Ventilation (HFV)	Delivers small amounts of gas at a rapid rate (60-100 breaths/minute); requires sedation/paralysis	Used for hemodynamic instability, during short-term procedures, or if patient is at risk for pneumothorax
Inverse Ratio Ventilation (IRV)	I:E ratio is reversed to allow longer inspiration; requires sedation/paralysis	Improves oxygenation in patients who are still hypoxic even with PEEP; keeps alveoli from collapsing

Alarms and Common Causes

As mentioned earlier, the ventilator is designed to monitor many aspects of the patient's respiratory status, and there are many different alarms that can be set to warn healthcare providers that the patient isn't tolerating the mode or settings. The following are common ventilator alarms and their most frequent causes.

High Pressure Limit	Low Pressure	High Respiratory Rate	Low Exhaled Volume
• Secretions in ETT/airway or condensation in tubing • Kink in vent tubing • Patient biting on ETT • Patient coughing, gagging, or trying to talk • Increased airway pressure from bronchospasm or pneumothorax	• Vent tubing not connected • Displaced ETT or trach tube	• Patient anxiety or pain • Secretions in ETT/airway • Hypoxia • Hypercapnia	• Vent tubing not connected • Leak in cuff or inadequate cuff seal • Occurrence of another alarm preventing full delivery of breath

Case Study

Mr. Hill has been on the ventilator for 24 hours. You volunteered to care for him today, since you know him from the intubation yesterday. The settings ordered by the pulmonologist after intubation were as follows: A/C, rate 14, V_T 700, FIO_2 60%. Since 0700, Mr. Hill has been assisting the ventilator with a respiratory rate of 24. (The time is now 1100.)

1.   Describe the ventilator settings.

   Answer:
   The ventilator delivers 14 breaths per minute, each with a tidal volume of 700 ml. The A/C mode delivers the breaths in response to Mr. Hill's own respiratory effort, but will initiate the breath if he doesn't within the set amount of time. (He's currently breathing above the vent setting.) The oxygen concentration is 60%.

You notice that Mr. Hill's pulse oximetry has been consistently documented as 100% since intubation. You also notice that his respiratory rate is quite high and that he's fidgety, doesn't follow commands, and doesn't maintain eye contact when you talk to him. He hasn't had any sedation since he was intubated.

2.   Which lab test should you check to find out what his true ventilatory status is?

   Answer:
   Arterial blood gas (ABG) - which he should have had done with his morning labs. If not, check with the pulmonologist about getting one.

3.   Which two parameters on the ABG will give you a quick overview of Mr. Hill's status?

   Answer:
   $PaCO_2$ (which affects the pH) and PaO_2. With his high respiratory rate, Mr. Hill is at risk for hypocapnia from "blowing off CO_2." If the PaO_2 is adequate, the FIO_2 could be decreased, since his oxygen saturation has been consistently 100%.

4.   What are some possible causes of Mr. Hill's increased respiratory rate? (Give the corresponding nursing interventions as well.)

   Answer:
   - Secretions - suction through the ETT, as well as his mouth.
   - Anxiety or pain - Mr. Hill hasn't received any sedation since he was intubated. At this point, he should at least have a prn order for sedation, if not a continuous IV infusion.
   - The vent settings may not be appropriate – check the ABGs and notify the pulmonologist.

Mr. Hill didn't have an ABG done this morning, so you obtain an order from the pulmonologist to get one now (1130). When it comes back, the $PaCO_2$ is 28, the pH is 7.48, and the PaO_2 is 120 (normals: $PaCO_2$ 35-45 mm Hg, pH 7.35-7.45 mm Hg, PaO_2 80-100 mm Hg).

5. Based on the ABG, the pulmonologist changes the vent settings to SIMV, rate 10, PS 10, FIO_2 40%. The V_T remains 700. How will these new settings help Mr. Hill?

Answer:
SIMV will deliver 10 breaths with the full tidal volume each minute, but in synchrony with Mr. Hill's spontaneous breaths. This mode is not triggered to deliver a breath each time Mr. Hill inhales, and the tidal volume of his spontaneous breaths is under his control. Pressure support decreases the work of breathing that results from breathing through the ventilator circuits and tubing. The PaO_2 was higher than desired, indicating that the FIO_2 could be decreased. We need to be careful to prevent oxygen toxicity.

The pulmonologist also orders midazolam (Versed) 1-2 mg every hour prn for sedation.

Noninvasive Forms of Mechanical Ventilation

Some patients need ventilatory support, but may not require an artificial airway. Candidates for noninvasive positive pressure ventilation (NIPPV) include patients who don't have oxygenation problems, who are able to manage their secretions, and who don't have an upper airway obstruction. A prime example is a patient with sleep apnea who only requires ventilatory assistance during sleep. The following are the most common types of NIPPV.

CPAP
Continuous Positive Airway Pressure (CPAP) was mentioned above as a spontaneous breathing mode that can be delivered by a ventilator through an ETT or tracheostomy. CPAP can also be delivered through either a nasal mask or a full face mask. There are pros and cons to each of these. Full face masks minimize air leaks, but they are more claustrophobic, and they must be removed for the patient to speak or expectorate secretions. Also, a smaller air leak leads to greater pressure buildup and gastric distention. Nasal masks are less claustrophic and don't have to be removed to speak or expectorate, but they usually have large air leaks. A customized mouthpiece with a lip seal may be used for chronic CPAP application. This is the ideal delivery method, since the seal is maintained even when the facial muscles are relaxed. A separate CPAP machine is used to deliver noninvasive CPAP rather than the ICU ventilator.

As mentioned above, CPAP maintains constant airway pressure. Remember that the effect is like blowing up a balloon and not letting it completely deflate before blowing it up again. Resistance and the work of breathing are decreased.

BiPAP

Bilevel Positive Airway Pressure (BiPAP) is similar to CPAP, and in practice, the two are often confused. BiPAP maintains positive airway pressure during both inspiration and expiration. The two levels are referred to as inspiratory positive airway pressure (IPAP) and expiratory positive airway pressure (EPAP). The machine cycles between IPAP and EPAP either in response to the patient's respiratory efforts, or at a specific time determined by the respiratory rate and inspiratory time settings. The benefits of IPAP include increased tidal volume and minute ventilation, decreased $PaCO_2$ level, relief of dyspnea, and reduced use of accessory muscles. Benefits of EPAP include increased functional residual capacity, resulting in an increased PaO_2 level.

BiPap is usually delivered through a nasal mask, allowing exhalation through the mouth.

IPPB

Intermittent Positive Pressure Breathing (IPPB) is used in some institutions to assist patients to take deeper breaths, especially after surgery or for a short time after mechanical ventilation has been discontinued. The IPPB machine is a pressure-cycled ventilator that delivers compressed gas under positive pressure into the patient's airway. It's triggered when the patient inhales, but it allows passive expiration. The specific pressure and volume used are ordered by the physician for each patient. Usually, 10-20 breaths are given every 1-2 hours for 24 hours. Benefits of IPPB include prevention of atelectasis, promotion of full-lung expansion, improved oxygenation, and administration of nebulized medications.

Nursing Care of the Mechanically Ventilated Patient

Nursing Care of the Endotracheal Tube (ETT)

ETT management consists of ensuring a patent airway, suctioning pulmonary and oral secretions, and providing frequent oral and/or nasal care. If the patient is restless or agitated, any activities that involve loosening the straps that hold the ETT in place should be rescheduled for when the patient is calm or after a sedative has been given. Otherwise, the ETT may be inadvertently removed.

A primary portion of ETT management is suctioning down the tube every two hours or as needed. This is a sterile procedure. The color and amount of any sputum return should be noted since the ETT provides a direct connection to the lungs, making these patients highly susceptible to infection. The oral cavity should also be suctioned as these patients often have difficulty swallowing saliva.

The patient must also be monitored for skin breakdown in either the oral or nasal cavity, depending on where the ETT is located. Thorough oral care should be provided every eight hours and as needed. If the patient has a bite block to prevent them from biting on the tube, it must be removed and cleaned or replaced every eight hours. The tube should be repositioned so that it is not continuously exerting pressure in the same area. If the tube is taped to the patient's face, the tape must be removed and replaced on the opposite side of the face at least once per day and as needed.

The ETT has a cuff that is inflated with air to hold the tube in place in the trachea. The amount of air in the cuff should be checked every eight hours to ensure that the cuff is not exerting too much pressure on the trachea walls. This is often done by the respiratory therapist but may be done by the nurse.

Any needed supplies for endotracheal tube care should be at the bedside prior to beginning the procedure. This includes a sterile suction kit; a bottle of sterile 0.9% sodium chloride; sterile gloves; a clean bite block, if necessary; and tape torn into appropriately sized pieces. It's recommended that another healthcare professional firmly hold the ETT in place during any activity that requires loosening the straps that hold the tube. The patient should also be preoxygenated with 100% oxygen prior to suctioning.

After ETT care, the patient's respiratory status should be reassessed. The insertion point (in centimeters) of the ETT should be confirmed to be the same as prior to the procedure, unless the purpose of the procedure was to change the depth of the tube.

Nursing Care of the Tracheostomy Tube

Tracheostomy (trach) care should be done every eight hours and involves cleaning around the incision, as well as replacing the inner cannula if the patient has a double-lumen tube. After the site heals, the entire trach tube is replaced once or twice per week, depending on the physician's order. The goals of tracheostomy care are to maintain the patency of the airway, prevent breakdown of the skin surrounding the site, and prevent infection.

Extra precautions should be taken when performing site care during the first few days after the tracheostomy is surgically created. The site is prone to bleeding and is sensitive to movements of the tube. It's recommended that another healthcare professional securely hold the tube while site care is performed. Tracheostomy care should not be done while the patient is restless or agitated, since this increases the chance that the tube may be pulled out and the airway lost.

Trach care begins with suctioning the patient's airway, both via the tracheostomy and orally. The patient should be preoxygenated with 100% oxygen prior to suctioning, and sterile technique must be used during the procedure. The gauze dressing is removed and the amount and color of drainage should be noted. Using sterile technique, the skin and external portion of the tube is cleaned with hydrogen peroxide. Cotton-tipped applicators should be used to clean close around the stoma. The condition of the skin and stoma should be noted. The area is then wiped with gauze dampened in 0.9% sodium chloride and a new dressing is applied.

If the patient has a disposable inner cannula, the old cannula can simply be removed and discarded. A new cannula is inserted using sterile technique. If the inner cannula isn't disposable, it must be cleaned with hydrogen peroxide, rinsed with 0.9% sodium chloride, and reinserted using sterile technique. The cannula should be tapped against the side of the sterile container to remove excess fluid; it shouldn't be completely dried since the film of saline facilitates reinsertion.

All supplies needed for tracheostomy care should be at the bedside prior to beginning the procedure. There are prepackaged kits available that contain gauze pads, cotton-tipped applicators, a tracheostomy dressing, and hydrogen peroxide. In addition, a container of 0.9% sodium chloride solution, a suction kit, and sterile gloves are needed. The velcro straps or ties that hold the tracheostomy tube in place may need to be replaced as well.

If the patient is agitated, a sedative should be given and the procedure rescheduled for a later time when he or she is calm. Pain medication should be offered, especially during the first few days after surgery when manipulating the incision can cause discomfort.

After tracheostomy care is finished, the soiled dressing and supplies should be discarded, either in the garbage or in a biohazard container if there is a large amount of blood. The patient may need to be suctioned again and his or her respiratory status should be reassessed. Again, pain medication should be offered, as appropriate.

Sterile suctioning
Suctioning consists of inserting a sterile suction catheter into the airway in order to remove secretions. This is an extremely important part of caring for a patient with an artificial airway since the normal reflex of coughing to expectorate secretions is not effective. The patient will experience respiratory distress if the tube is obstructed by sputum. Suctioning should be performed only when the patient needs it; however, the need should be assessed at least every two hours.

A number of studies have been done to determine ways to minimize the complications of suctioning. Sterile technique should be used to decrease the risk of infection. There are now closed suction systems available that are attached to the ventilator tubing on one end and to the artificial airway on the other. The catheter remains protected inside a sterile plastic sleeve and is changed every 24 hours. This system limits the amount of times the tubing must be disconnected from the airway, thus reducing exposure of the trachea to environmental contaminants.

Suctioning causes oxygen deprivation for the time that the suction is applied. Hypoxemia can be minimized by preoxygenating the patient with 100% oxygen prior to suctioning and between each pass of the suction catheter. This can be done by either pushing the 100% oxygen button on the ventilator or by using a manual resuscitation bag. The patient's pulse oximetry should be monitored while suctioning. The duration of each suction pass should be limited to ten seconds and the number of passes should be limited to three or less, if possible. This decreases hypoxemia and airway trauma. Studies have shown that using intermittent suction is no more beneficial than continuous suction.

Installation of a small amount of saline prior to suctioning was a common procedure in the past. It was thought that saline helped loosen and remove secretions; however, research has shown this to be a false assumption. On the contrary, saline installation has been shown to increase infection rates and to cause decreased oxygen levels for longer periods than suctioning without saline use. Therefore, saline installation should not be used routinely (Hess, 1996).

Sedation & Neuromuscular Blockade

As mentioned above, most patients require sedation in order to tolerate mechanical ventilation. It can be a frightening experience; not only do they have a very large tube in their throat, but they can't even control their own breathing. Patients who are mechanically ventilated for more than a few days may be used to it enough to remain calm and follow commands once they're aroused, but they still need frequent reassurance that they're being closely monitored and that their needs will be met.

Common Medications
Medications used during mechanical ventilation fall into four categories: sedatives, neuroleptics, analgesics, and paralytics.

Sedatives include benzodiazepines, barbiturates, and propofol. These drugs decrease anxiety and produce amnesia, but they don't relieve pain. Most of these drugs also have anticonvulsant effects without causing cardiac depression. The exceptions to this are midazolam (Versed) and propofol (Diprivan), which can cause cardiac depression.

The primary concerns related to use of sedatives during mechanical ventilation are that many have long half lives, and that drug levels can accumulate and cause prolonged effects in the critically ill and elderly. This is particularly true of the barbiturates, and may negatively impact weaning attempts. Midazolam (Versed) has the shortest half life of the benzodiazepines (1 hour), thus it is the most commonly used. The other benefit to benzodiazepines is that their effects can be reversed with flumazenil (Romazicon).

One precaution should be mentioned regarding midazolam (Versed). It tends to accumulate in the tissues if administered for longer than 48 hours, and can cause excessive sedation. This is especially true of obese patients because of the lipophilic properties of the drug and the high degree of lipid solubility. In obese patients, the ideal body weight should be used to calculate dosing, rather than the actual weight.

Propofol (Diprivan) is the sedative of choice for rapid induction of anesthesia in the ICU for minor invasive procedures. It has a rapid onset and a half-life of less than 30 minutes. However, it often causes hypotension and is very expensive.

Dexmedetomidine (Precedex) is a short-acting alpha agonist approved by the U.S. Food and Drug Administration in 1999 for use as an ICU sedative. It has anxiolytic, anesthetic, hypnotic, and analgesic properties, and can be given even during ventilator weaning. Patients receiving an IV infusion can be easily aroused, yet return to a hypnotic state when not stimulated. These properties make it an ideal drug for ventilator-dependent patients, but it's also very expensive.

The following is a summary of the most common sedatives given as a continuous infusion.

	Lorazepam	Midazolam	Propofol	Dexmedetomidine
Trade name	Ativan	Versed	Diprivan	Precedex
Onset of action	5-15 minutes	1-3 minutes	1 minute	Immediately
Half-life	6-15 hours	1 hour	< 30 minutes	1.5-3 hours
Loading Dose	0.05 mg/kg	0.03 mg/kg	0.5 mg/kg	1 mcg/kg
Infusion rate	0.5-5 mg/hr	1-20 mg/hr	0.5-3 mg/kg/hr	0.2-0.7 mcg/kg/hr

In addition to sedation, neuroleptics may be given to patients who are experiencing delirium or "ICU psychosis." This is common in critically ill patients who lose sense of time and events because of altered sleep patterns and a different daily schedule while they're hospitalized. Symptoms include disorganized thinking, audio and visual hallucinations, and disorientation. Sedatives and narcotics often worsen the delirium because they further alter sensory perception. The neuroleptic drug of choice is haloperidol (Haldol). It's usually given intravenously in 2-10 mg doses every 2 to 4 hours. Effects should be observed within 30-60 minutes. Haloperidol can prolong the QT interval on the EKG, and should be used cautiously in patients who are at risk for QT prolongation from other causes.

Analgesics should be prescribed for every patient receiving mechanical ventilation. Because sedatives reduce many of the emotional signs of pain, medical personnel may overlook the fact that the patient is still experiencing the physical component of pain. Intravenous narcotics are the analgesic of choice for this patient population because they exert their effect on the central nervous system, rather than only the peripheral pain receptors. Morphine is preferred unless the patient has cardiovascular instability. In this case, the patient may not tolerate the transient hypotension produced by morphine-related histamine release, so fentanyl (Sublimaze) or hydromorphone (Dilaudid) can be used instead.

If a patient receives large or continuous doses of narcotics, they must be monitored for the development of ileus. Tolerance of tube feedings and bowel movements should be assessed frequently.

Paralytic agents, or neuromuscular blocking agents (NMBs), are used to paralyze a patient in order to allow controlled mechanical ventilation. However, these drugs do not have any sedative or analgesic effects, so they **must always** be administered with other sedatives and narcotics. Imagine being fully awake and able to feel pain...but paralyzed!

There are two classes of NMBs: nondepolarizing (inhibit acetylcholine) and depolarizing (prolong depolarization of the postsynaptic receptors). The depolarizing agents have a short duration of action and are used for short-term paralysis during intubation. Succinylcholine (Anectine) is a depolarizing agent. The nondepolarizing agents produce prolonged paralysis and are used for controlled mechanical ventilation. Examples include cisatracurium (Nimbex), pancuronium (Pavulon), and vecuronium (Norcuron), among others.

Peripheral Nerve Stimulator
Patients who require long-term neuromuscular blockade must be closely monitored to prevent complications, such as prolonged skeletal muscle weakness. The patient's level of paralysis is assessed with a peripheral nerve stimulator (PNS). This is a device that delivers an electrical stimulus to a preselected nerve. Usually the ulnar nerve is used, although the facial, posterior

tibial, or peroneal nerves are also options. Pre-gelled electrodes (often the same as those used for cardiac monitoring) are attached to the patient's skin and the current is delivered through them.

The methods of testing the level of paralysis include single, tetanic, and train-of-four (TOF). TOF is the most common and involves delivering four consecutive electrical stimuli. When the ulnar nerve is used, the expected response is twitches of the thumb toward the hand. The number of twitches corresponds to the level of paralysis: four indicates 75% blockade; three twitches, 80%; two twitches, 85%; one twitch, 90%; and none indicates 100% blockade. Generally, the desired goal is one twitch, or 90% blockade.

It's very important to test the patient's baseline TOF prior to administering the NMB. The amount of electrical current delivered is controlled by the milliamp (mA) dial. Find the patient's baseline by starting at 10 mA and increasing by 10 mA until four strong twitches are achieved (most patients require approximately 30 milliamps), then double that number for testing TOF after administration of the NMB (usually close to 60 milliamps). The mA should never be set at less than 40 mA or greater than 100 mA for testing TOF while the patient is receiving the NMB. After initiation of the NMB, the TOF should be checked and recorded every 15-30 minutes until a steady state is achieved, then every two hours for the first 24 hours. If the infusion is continued longer than 24 hours, the TOF can be checked every four hours unless the NMB is being titrated.

Other factors can affect the results of the PNS. Poor skin contact with the electrodes, improper electrode placement, serum electrolyte imbalances, and edema can result in false twitch responses, leading to underestimation of the degree of paralysis, or no response, leading to overestimation of the degree of paralysis. False responses may lead to incorrect dosing of the paralytic agent, thus the PNS test should be correlated to observations of patient movement.

Connecting the PNS to the Patient

Critical Illness Polyneuropathy

One final note must be made related to the use of NMBs. Critical illness polyneuropathy is primary axonal degeneration of motor and sensory fibers, denervation atrophy of muscles, impaired tendon reflexes, and damaged muscle membranes resulting from long-term use of NMBs. Patients with diabetes or who are receiving large doses of steroids are especially at risk for polyneuropathy. Weakness can last for months and is not reversed by cholinesterase inhibitors. Prolonged nerve block without damage can occur in patients who are receiving large doses of steroids and in those with renal failure or sepsis, related to an inability to metabolize and excrete the NMBs. Patients often develop tolerance to the NMBs over the course of several days, and the dosing must be increased to have the desired effect, which increases the risk of polyneuropathy. In the ICU, it's recommended that NMBs only be used when sedatives and analgesics have failed to provide controlled ventilation, and that they not be used for more than 24 hours in patients with renal failure, sepsis, or on high doses of steroids.

Quiz

Identify the correct class of medication for each drug.

	Drug	Class
1.	midazolam (Versed)	sedative (benzodiazepine)
2.	cisatracurium (Nimbex)	paralytic (nondepolarizing)
3.	morphine	analgesic (narcotic)
4.	haloperidol (Haldol)	neuroleptic
5.	propofol (Diprivan)	sedative
6.	succinylcholine (Anectine)	paralytic (depolarizing)

Case Study

At 1330, Mr. Hill's wife asks for you at the nurses' station. She tells you that Mr. Hill seems very anxious, and that she's been holding his hands so he doesn't pull out the tube. You follow her to the room and find Mr. Hill with his legs hanging off the side of the bed and his hand on the ventilator tubing. His respiratory rate is 30 and the ventilator is alarming with almost every breath. Per the pulmonologist's order, you administered 2 mg of Versed at 1200 and 1300, but Mr. Hill's anxiety seems worse instead of better. He looks at you when you talk to him, but doesn't respond appropriately or follow commands. Another nurse helps you settle him in bed again and you ensure that his wrist restraints are secure before leaving the room to call the physician.

1. What do you anticipate the physician will order?

    Answer:
    A continuous Versed infusion and possibly neuromuscular blockade.

The physician orders a continuous Versed infusion of 1-10 mg/hr, titrated to effect, and a Nimbex infusion with TOF maintained at 90%.

2. The physician is ready to hang up the phone, but you think of one more crucial thing to ask him about the ventilator settings. What is it?

    Answer:
    The ventilator mode is currently SIMV, which is used with spontaneously breathing patients. However, the Nimbex infusion will paralyze Mr. Hill's diaphragm along with the rest of his body, thus the ventilator mode should be changed to completely take over respiratory function. The mode should be changed to control or assist-control ventilation.

3. Which infusion will you start first, the Versed or the Nimbex?

    Answer:
    Versed. Remember that NMBs do not have any sedative or analgesic properties. Always sedate the patient prior to administering a paralyzing agent.

4. How will you monitor the level of paralysis?

    Answer:
    Test train-of-four (TOF) with a peripheral nerve stimulator. Remember to test and record the baseline prior to starting the Nimbex. After the infusion is started, test TOF every 15 –30 minutes until steady state is achieved. Then it may be tested every two hours for the first 24 hours, unless the Nimbex is being titrated. The physician ordered 90% blockade, so the goal is one thumb twitch.

5.   How will you explain this change in events to Mr. Hill's wife and family?

Answer:
Keep the explanation simple but be sure to answer their questions. Keep in mind that the word "paralysis" may frighten them. Important points to include are: the paralysis is caused by medication and is reversible, the paralysis is only a temporary measure to help Mr. Hill breathe better with the ventilator, and his level of paralysis will be closely monitored with the PNS. Tell them that he is sedated, but encourage them to talk to him and touch him. Also reassure them that Mr. Hill's physical needs such as repositioning, oral care, and bathing will be taken care of by the staff.

Assessment Criteria

The respiratory status of patients who are mechanically ventilated must be frequently assessed. The following are some of the most important assessment categories.

Breath Sounds
Breath sounds should be assessed at least every four hours while patients are mechanically ventilated, and more frequently as needed. Both the anterior and posterior chest should be auscultated bilaterally. A good time to do this is when repositioning the patient every two hours, since you will have another staff member who can assist in holding the patient on his or her side while you listen to the back. The following is a review of abnormal breath sounds.

Lung Sound	Description	Cause
Crackles (rales)	Popping or crackling sound	Fluid in small airways/alveoli or collapsed airways snapping open on inspiration
Rhonchi	Course, low-pitched rumbling	Airflow over secretions or narrowing of large airways
Wheeze	High-pitched squeak or whistling	Airflow through narrowed small airways
Pleural friction rub	Creaking, leathery, course sound	Inflamed pleural surfaces rubbing together

Spontaneous Respiratory Rate and Tidal Volume
Even if a patient is mechanically ventilated, the spontaneous respiratory rate and tidal volume (the volume of air exhaled after a normal resting inhalation) can give some important clues about respiratory function. For example, if the spontaneous tidal volume is low the patient may not do well with weaning attempts. If the respiratory rate is high, particularly with weaning modes, it may indicate that the patient isn't tolerating the mode, needs suctioning, or that he or she is anxious or trying to communicate. This topic will be further addressed when we discuss weaning.

Pulse Oximetry
Usually patients who are mechanically ventilated have a continuous pulse oximeter to measure oxygen saturation (SpO_2). The machine detects the percent of hemoglobin that is fully saturated. Pulse oximetry is a useful monitoring tool, but it provides minimal indication of the patient's ventilatory or acid-base status. Thus, it should not take the place of arterial blood gases. Readings can also be affected by abnormal hemoglobins, vascular dyes, and poor perfusion. The pulse oximeter can't differentiate between normal and abnormal hemoglobins; thus, a patient with carbon monoxide poisoning could have a pulse oximetry reading of 100%, but may not be adequately oxygenated. However, pulse oximetry can be a helpful guide when titrating FIO_2: In general, a SpO_2 of 92% in white patients, and 95% in black patients indicates adequate oxygenation ($PaO_2 > 60$ mmHg).

(Capnography) End Tidal CO_2
Capnography, also called end tidal CO_2, is CO_2 measured at the end of exhalation. It's usually measured via the exhalation port on the ventilator tubing; the gas is analyzed by a sensor and the data are transferred to a display where a waveform (capnogram) is created, along with a number that closely approximates the $PaCO_2$. In a hemodynamically stable patient with a normal ventilation/perfusion relationship, the end tidal CO_2 (also called $PetCO_2$) is generally 1-5 mmHg less than the $PaCO_2$. The reliability of this number is decreased in patients with abnormal cardiopulmonary function.

The most useful function of end tidal CO_2 measurement is to confirm ETT placement in the lungs. There are disposable devices available that produce a color change when CO_2 is detected; these are often used to confirm placement after intubation. (If the ETT is in the esophagus, little CO_2 will be detected unless the patient consumed a carbonated beverage a short time before the intubation.) Some ICUs routinely monitor the $PetCO_2$ in adult, mechanically ventilated patients, but this practice has not been supported by research. There is wide variability in the relationship between $PaCO_2$ and $PetCO_2$ among patients; therefore, great care must be taken when predicting the $PaCO_2$. $PetCO_2$ should not take the place of arterial blood gases during ventilator weaning (Hess, 1996).

Arterial Blood Gases (ABG)
Arterial blood gas interpretation could be a whole separate program in itself; therefore, we'll just cover the basics here.

The following are the components of the ABG that are the most crucial for you, the nurse, to know. Follow along for a review of basic chemistry.

pH
- Normal pH of body fluids = 7.35-7.45
- Acid ➡ capable of releasing hydrogen (H^+) in a solution (increased H^+ = increased acidity = decreased pH)
- Base ➡ capable of accepting H^+ in a solution (decreased H^+ = increased alkalinity = increased pH)
- pH < 7.35 = acidosis
- pH > 7.45 = alkalosis

PaCO$_2$

- PaCO$_2$ is the partial pressure of dissolved CO$_2$ in blood.
- Most is excreted by the lungs, although some is excreted by the kidneys as HCO$_3$.
- Normal = 35-45 mmHg
- PaCO$_2$ is directly related to rate and depth of respiration. <u>It's a direct indicator of the effectiveness of ventilation.</u>
- As PaCO$_2$ rises, the blood becomes more acidic and pH drops.
- As PaCO$_2$ decreases, the blood becomes more alkaline and pH rises.
- If a change in PaCO$_2$ is the primary alteration, then a <u>respiratory</u> problem exists.

HCO$_3$

- Bicarbonate (HCO$_3$) is the primary buffer in the body and is able to take up and release H$^+$.
- Normal = 22-26 mmHg
- As HCO$_3$ rises, the blood becomes more alkaline and pH increases.
- As HCO$_3$ drops, the blood becomes more acidic and pH decreases.
- If a change in HCO$_3$ is the primary alteration, then a <u>metabolic</u> problem exists.

CO$_2$

- Considered a measure of bicarbonate concentration; includes total of bicarbonate and carbonic acid.
- Normal = 23-27 mEq/L
- Generally not used in deference to HCO$_3$ measurement.

Base Excess/Deficit

- Measures excess amount of acid or base present in blood. This is independent of changes in PaCO$_2$; therefore, it's a measure of <u>metabolic</u> acid-base balance.
- Increased HCO$_3$ = base excess (alkalosis)
- Decreased HCO$_3$ = base deficit (acidosis)

PaO$_2$

- The amount of oxygen dissolved in plasma (about 3% of total; the other 97% is bound to hemoglobin).
- Normal is 80-100 mmHg in healthy young people breathing room air at sea level; this decreases with age and altitude.
- Pa$_{O2}$ > 60 mmHg is considered acceptable in critically ill, mechanically ventilated adults.
- Adequacy of PaO$_2$ must be weighed against potential oxygen toxicity.

Quiz

Take some time to figure out the ABG results below. Determine which imbalance each result indicates: respiratory acidosis, metabolic acidosis, respiratory alkalosis, or metabolic alkalosis. (Don't worry, it's not graded!)

Answers:

1. pH 7.30, Pa_{CO2} 40, HCO_3 18

2. pH 7.48, Pa_{CO2} 30, HCO_3 24

3. pH 7.25, Pa_{CO2} 54, HCO_3 26

4. pH 7.50, Pa_{CO2} 42, HCO_3 33

1. Metabolic acidosis (pH ↓ , Pa_{CO2} ok, HCO_3 ↓)

2. Respiratory alkalosis (pH ↑ , Pa_{CO2} ↓ , HCO_3 ok)

3. Respiratory acidosis (pH ↓ , Pa_{CO2} ↑, HCO_3 ok)

4. Metabolic alkalosis (pH ↑, Pa_{CO2} ok, HCO_3 ↑)

Weaning & Extubation

The purpose of mechanical ventilation is to "breathe for the patient" until he or she is sufficiently recovered to breathe on his or her own. This process is usually a gradual one, and is referred to as weaning. During the ventilatory weaning process, the modes of mechanical ventilation are gradually changed to allow the patient to initiate more breaths while the ventilator provides fewer breaths.

Weaning should not be attempted until the patient's respiratory status is stable and he or she is arousable and able to follow commands. Sedatives/paralytics should be weaned off. If the patient is unstable or unarousable, attempting to wean may cause unnecessary physical stress and may delay recovery. Pulse oximetry and a cardiac monitor should be applied, if not already present. The patient should be suctioned prior to any weaning attempt. Keep in mind that patients may be anxious during this time. They may feel isolated and afraid no one will hear them if they have trouble. Always make sure that your weaning patient has a call light within reach and let him or her see you enter the room frequently.

Weaning is accomplished by decreasing the number of breaths supplied by the ventilator, as well as by changing the way in which those breaths are delivered to the patient. The process also depends on the reason why the patient initially required mechanical ventilation. For example, post-operative cardiac bypass patients are generally weaned within a few hours after surgery. However, a patient with extensive lung disease may require days or weeks to wean. There are also some patients who are never able to completely wean. (This includes patients with spinal cord injuries above the diaphragm). They require a tracheostomy and placement in a long-term ventilator care unit, unless they have family who are able to care for them at home. Some may be able to be off the ventilator during the day, but still need it at night.

One last thought. If you have a stable patient on the ventilator who prematurely extubates himself or herself, the physician may decide to wait to see if the patient tolerates breathing without the ventilator. If the patient can't tolerate it, he or she should be manually ventilated and reintubated as soon as possible.

Methods of weaning
There are three primary methods used to wean patients from the ventilator. These include T-piece/CPAP trials, Synchronized Intermittent Mandatory Ventilation (SIMV), and Pressure Support Ventilation (PSV). PSV is often used with SIMV to decrease the work of breathing. PSV augments the patient's spontaneous inspiration with a positive pressure "boost," which decreases the resistance created from breathing through ventilator tubing. The weaning method chosen depends on the patient's respiratory status and the length of time that he or she has been on the ventilator.

T-piece/CPAP trials
T-piece trials consist of alternating intervals of time on the ventilator with intervals of spontaneous breathing. To facilitate spontaneous breathing, the patient is removed from the ventilator and a T-shaped tube is attached to the endotracheal or tracheostomy tube. One end of this tubing is attached to an oxygen flowmeter and the other end is open; the amount of oxygen used is ordered by the physician. Patients with a T-piece don't have the ventilator as back-up if they can't breathe, so they must be monitored closely. If they tire out or their respiratory status becomes unstable, they should be reconnected to the ventilator. The goal of this method of weaning is to gradually increase the amount of time spent off the ventilator. Patients with tracheostomies may be weaned in a similar fashion with a trach collar. This is a mask-like device that delivers humidified oxygen. It fits loosely over the tracheostomy and is held in place by an elastic band around the neck.

Alternatively, CPAP may be used instead of a T-piece. With CPAP, the patient breathes spontaneously, but has the benefit of the ventilator alarms if he or she has difficulty. CPAP maintains constant positive pressure in the airways, which facilitates gas exchange in the alveoli.

SIMV
SIMV is a ventilator mode that delivers a preset number of breaths to the patient but coordinates them with the patient's spontaneous breaths. Thus, the ventilator may be set to deliver 12 breaths per minute, but the patient's respiratory rate may be 16 (12 ventilator breaths plus 4 patient-initiated breaths). The goal of SIMV weaning is to gradually decrease the number of breaths delivered by the ventilator, allowing the patient to take more breaths of his or her own. The ventilator rate is usually decreased by one to three breaths at a time and an arterial blood gas (ABG) is obtained 30 minutes after the change to assess the patient's respiratory status. The benefits of SIMV weaning are that the patient has the ventilator for back-up if he or she fails to take a breath and the ventilator alarms will sound if he or she is not tolerating weaning. However, the patient should still be closely monitored for signs of respiratory fatigue.

Pressure support

Weaning with pressure support alone consists of placing the patient on the pressure support mode at a level that allows the patient to achieve a spontaneous tidal volume of 10-12 ml/kg. As mentioned above, PSV gives a positive pressure "boost" that helps the patient overcome the work of breathing. During weaning, the level of PS is decreased by 3-5 cm H_2O as long as the patient maintains the desired tidal volume.

(CPAP, SIMV, and PSV were discussed in the section on ventilator modes.)

Weaning criteria
Weaning criteria are done when a patient seems ready to be extubated. These include a number of simple bedside pulmonary function tests that indicate whether the patient is likely to tolerate breathing without the ventilator or not.

Vital capacity (VC)
The vital capacity is the maximal amount of air that can be exhaled after a maximal inhalation. The patient's vital capacity should be at least 10-15 cc/kg.

Negative inspiratory force (NIF)
Negative inspiratory force is the ability to take a deep breath and to generate a cough strong enough to clear secretions. The patient's NIF should be at least –20 cm H_2O.

Tidal volume (V_T)
Tidal volume is the volume of air inspired and expired during a normal respiratory cycle. The patient's tidal volume should be at least 5 ml/kg during spontaneous respiration.

Minute volume (V_E)
Minute volume is the total volume of air inhaled and exhaled in one minute. The patient's minute volume should be less than 10 liters per minute. A greater amount indicates that the patient is working too hard to breathe spontaneously.

Respiratory rate (RR)
The respiratory rate is the number of breaths per minute. The patient's RR should be less than 25 breaths/minute.

Arterial blood gas (ABG)
An ABG should be done before the patient is extubated. The Pa_{O2} should be at least 50 mmHg on less than 50% oxygen and with no more than 5 cm H_2O PEEP.

Extubation
Both the nurse and the RT have a role in extubating the patient. The roles differ among institutions and individuals, but both should at least be in the patient's room at the time of extubation. In general, the RT is responsible for performing the weaning criteria; the nurse should obtain the ABG prior to the weaning criteria being done so the results aren't altered by the pulmonary function tests. The nurse then usually calls the results of the ABG and the weaning criteria to the physician.

Once the physician's order to extubate is received, the nurse and RT coordinate a time when they can both be in the patient's room. The RT is usually responsible for assembling the oxygen delivery system to be used after extubation; this includes a mask and humidification. The nurse should explain the procedure to the patient and prepare suction. The patient should be sitting up at least 45 degrees.

Prior to extubating, the patient should be suctioned both via the ETT and orally. All fasteners holding the ETT should be loosened and a sterile suction catheter should be inserted into the ETT and withdrawn as the tube is removed. (A second sterile suction catheter may be needed if the first is contaminated from oral suctioning.) The ETT should be removed in a steady, quick motion as the patient will likely cough and gag. It's helpful to have a towel draped across the patient's chest to set the soiled ETT on and to contain secretions.

The patient should be asked to cough and speak. Quite often, the patient's first request is for water because of a dry, sore throat. Generally, you can immediately swab the patient's mouth with an oral swab dipped in water. It may be best to wait for 30-60 minutes before offering ice chips, but this depends on how long the patient was intubated and on the physician's orders. If the patient is able to tolerate a few ice chips, it's usually best to not leave a full glass at the bedside. You'll likely come back to find it empty!

Post-Extubation Care

Humidified oxygen
Humidification of inspired air normally takes place in the upper respiratory tract. When this area is bypassed by an artificial airway, humidification must be performed outside the body. The use of supplemental oxygen requires humidification to prevent drying and irritation of the respiratory tract and to facilitate removal of secretions. There are humidification devices available that can be attached to oxygen flow meters.

Patients usually require oxygen delivered through a mask for a few hours after extubation. Encourage the patient to keep the mask on since the humidified oxygen will soothe his or her sore, dry throat.

Respiratory exercises
As nurses, we're all very familiar with coughing and deep breathing. Every extubated patient should be encouraged to do this as much as possible, along with incentive spirometry exercises. If family is present, include them in any teaching. Best of all, put them to work encouraging the patient to do the exercises. You may have to remind the patient to splint any chest or abdominal incisions in order to limit discomfort while coughing and deep breathing.

Some extubated patients may have Intermittent Positive Pressure Breathing (IPPB) ordered for the first 24 hours after extubation, rather than incentive spirometry. This was mentioned early in this program, but here it is again as a review.

IPPB is used in some institutions to assist patients to take deeper breaths, especially after surgery. The IPPB machine is a pressure-cycled ventilator that delivers compressed gas under positive pressure into the patient's airway. It's triggered when the patient inhales, but it allows passive expiration. The specific pressure and volume used are ordered for each patient by the physician. Usually, 10-20 breaths are given every 1-2 hours for 24 hours. Benefits of IPPB include prevention of atelectasis, promotion of full-lung expansion, improved oxygenation, and administration of nebulized medications.

Assessment and monitoring
The assessment and monitoring criteria are much the same as those discussed above for mechanically ventilated patients. Breath sounds, pulse oximetry, and vital signs should be assessed and recorded immediately upon extubation. Vital signs should be documented frequently for the first few hours after extubation (i.e., every 15 minutes x 1 hour, every 30 minutes x 1 hour, then every hour until stable, although this differs by institution and physician). Most physicians order an ABG to be done 30-60 minutes after extubation. Also, don't forget to ask the patient how his or her breathing feels, and be sure to leave the call light within reach.

Case Study

Mr. Hill was kept sedated and paralyzed for 2 days. Today, he is completely weaned off of both drugs and is calm, arousable, and able to follow most commands. The pulmonologist wants to start weaning Mr. Hill so he orders the following: SIMV, rate 10, PS 10, FIO_2 40%. Decrease the rate by 2 breaths every 2 hours, and decrease FIO_2 as tolerated.

1.   How will PS 10 assist Mr. Hill with the SIMV mode?

      Answer:
      Pressure support (PS) gives a positive pressure "boost" with each inhalation. This decreases the work of breathing through the ventilator tubing and circuits.

Six hours later, Mr. Hill is tolerating SIMV rate 4. You've also been able to decrease the FIO_2 to 30%. The pulmonologist orders an ABG and weaning criteria an hour after the last ventilator change.

The results of the ABG and weaning criteria are as follows.

ABG:		Weaning criteria:		
pH 7.42			Vital capacity	12 cc/kg
$PaCO_2$ 39			Negative inspiratory force	-30 cm H_2O
HCO_3 25			Tidal volume	8 ml/kg
PaO_2 88			Minute volume	8 liters
			Respiratory rate	15

2.   Is Mr. Hill ready to be extubated?

     Answer:
     Yes!

3.   What form of oxygen therapy will you administer to Mr. Hill once he's extubated?

     Answer:
     Humidified mask with oxygen at 30%. (The last FIO_2 setting he had while intubated.)

4.   How will you confirm that Mr. Hill's respiratory status is stable after he's extubated?

     Answer:
     Monitor pulse oximetry, vital signs, respiratory rate, and breath sounds, and ask Mr. Hill how he feels. Also, remember to check another ABG 30 minutes after extubation (or per physician order).

Congratulations!

Thanks to your expert nursing care, Mr. Hill is doing very well. His physician plans to transfer him to the step-down unit in a few days. Both Mr. and Mrs. Hill have said that you're a wonderful nurse. Today when you arrive for your shift, you find a plate of cookies from Mrs. Hill with a thank you card!

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EVALUATION

Adult Ventilation Management

The following questions are related to this educational program. Circle the number that best represents your rating of the program starting with question one (1) and using the following scale:

5	=	Excellent
4	=	Very good
3	=	More than adequate or good
2	=	Adequate or fair
1	=	Inadequate or poor

If you rate any of the statements "1" (inadequate or poor), please explain the reason for this rating. If you need more space use the back of the page.

		Excellent				Poor
A.	**Please indicate to what extent you achieved the following objectives:**					
1.	Define mechanical ventilation.	5	4	3	2	1
2.	Identify three clinical situations in which mechanical ventilation may be used.	5	4	3	2	1
3.	Describe the role of the respiratory therapist in the management of mechanically ventilated patients.	5	4	3	2	1
4.	List six types of artificial airways and the indications for each one.	5	4	3	2	1
5.	Describe the nurse's responsibilities before, during, and after intubation.	5	4	3	2	1
6.	Identify three alternative means of communication for patients with artificial airways.	5	4	3	2	1
7.	Describe three different ventilator settings.	5	4	3	2	1
8.	Describe three different ventilator modes.	5	4	3	2	1
9.	List three potential causes for a high-pressure alarm.	5	4	3	2	1
10.	List two nursing interventions for a high respiratory rate alarm.	5	4	3	2	1
11.	List three types of non-invasive mechanical ventilation.	5	4	3	2	1
12.	Describe proper nursing care of an endotracheal tube.	5	4	3	2	1
13	Describe proper nursing care of a tracheostomy tube.	5	4	3	2	1
14.	Describe the correct procedure for sterile suctioning.	5	4	3	2	1
15.	Identify two indications for sedating and pharmacologically paralyzing a mechanically ventilated patient.	5	4	3	2	1
16.	Define train-of-four and describe the correct procedure for testing.	5	4	3	2	1
17.	Identify four parameters that must be monitored while patients are mechanically ventilated.	5	4	3	2	1

18.	Identify five nursing interventions for a patient who is accidentally extubated.	5	4	3	2	1
19.	Define ventilator weaning.	5	4	3	2	1
20.	Compare and contrast two different weaning methods.	5	4	3	2	1
21.	Identify three criteria that indicate when the patient is ready to be extubated.	5	4	3	2	1
22.	Describe proper post-extubation nursing care.	5	4	3	2	1
B.	Rate the content as it relates to the program objectives.	5	4	3	2	1
C.	Rate the effectiveness of the teaching/learning methods used in this instructional packet.	5	4	3	2	1
D.	Rate your ability to use this in your work.	5	4	3	2	1
E.	Rate the relationship of the objectives to the overall purpose of the program.	5	4	3	2	1

F.　How much time did you spend on this independent study?　___　Hours

G.　Would you recommend this instructional packet to other colleagues?　Yes　　No

H.　What areas in your practice could be improved or enhanced with additional education and training?
_____
_____
_____

I.　Please give us your comments or suggestions on this course and its handouts:
_____
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With my signature I confirm that I am the person who completed this independent educational activity by reading the article and completing this self-evaluation.

Signature: _____ Date: _____

Name: _____

Address: _____

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Adult Ventilation Management
Post-Test

1. Mechanical ventilation is:
    A.   Chest compressions performed during cardiopulmonary arrest.
    B.   Use of a heart-lung machine during coronary artery bypass surgery.
    C.   Use of a machine to breathe for a patient who can't breathe on his or her own.
    D.   Use of an intra-aortic balloon pump for cardiogenic shock.

2. Which of the following is <u>not</u> an indication for mechanical ventilation?
    A.   Myocardial infarction (MI)
    B.   Respiratory failure
    C.   Provide stability of the chest wall after trauma or surgery.
    D.   Brain injury requiring a barbiturate-induced coma.

3. Who is generally responsible for general ventilator maintenance?
    A.   Nurse
    B.   Nursing assistant
    C.   Physician
    D.   Respiratory therapist

4. Which artificial airway intubates both the trachea and esophagus?
    A.   Laryngeal mask airway (LMA)
    B.   Combitube
    C.   Oropharyngeal airway
    D.   Tracheostomy tube

5. Which artificial airway is used for long-term airway management?
    A.   Tracheostomy tube
    B.   Nasopharyngeal airway
    C.   Endotracheal tube
    D.   Laryngeal mask airway (LMA)

6. Which lab value must the nurse know for a patient who may receive succinylcholine?
    A.   Sodium
    B. $PaCO_2$
    C.   Calcium
    D.   Potassium

7. Which of the following is <u>not</u> a method of confirming correct positioning of an endotracheal tube?
    A.   End tidal CO_2 detector
    B.   Asking patient to speak
    C.   Breath sounds
    D.   Chest x-ray

8.	Identify one way to assist a patient with an artificial airway to communicate:
	A.	Tell family to take the patient's glasses home.
	B.	Encourage patient to talk.
	C.	Use a communication board.
	D.	Teach the patient sign language.

9.	What is tidal volume?
	A.	The number of breaths per minute.
	B.	The amount of oxygen delivered with each breath.
	C.	The amount of pressure used to deliver a breath.
	D.	The volume of gas delivered in a single breath.

10.	Which of the following is a risk of long-term 100% oxygen?
	A.	Oxygen toxicity
	B.	Cerebral edema
	C.	Cyanosis
	D.	Hypercapnia

11.	How does Synchronized Intermittent Mandatory Ventilation (SIMV) differ from Assist Control
	(A/C) in relation to the patient's spontaneous breaths?
	A.	A/C allows the patient to control the tidal volume of spontaneous breaths.
	B.	SIMV allows the patient to control the tidal volume of spontaneous breaths.
	C.	A/C does not allow spontaneous breaths.
	D.	SIMV delivers the same tidal volume for both spontaneous and ventilator-initiated
		breaths.

12.	Describe the effect of Positive End Expiratory Pressure (PEEP):
	A.	It increases the work of breathing.
	B.	It allows the patient to cough more productively.
	C.	It opens collapsed alveoli at the end of expiration.
	D.	It decreases oxygenation.

13.	Which of the following will cause a high-pressure alarm?
	A.	Secretions
	B.	Disconnected ventilator tubing
	C.	Hypoxia
	D.	A cuff leak

14.	Which of the following could you do for a high respiratory rate alarm?
	A.	Turn off the Versed infusion.
	B.	Increase the respiratory rate alarm parameters.
	C.	Test Train-of-Four.
	D.	Assess the patient for pain and/or anxiety.

15.	List one indication for noninvasive mechanical ventilation:
	A.	Difficulty weaning from the ventilator
	B.	Sleep apnea
	C.	Upper airway tumor
	D.	Copious secretions

16. How often should the bite block be cleaned for a patient with an endotracheal tube?
    A.   Every 8 hours
    B.   Every 2 hours
    C.   Every 24 hours
    D.   Every 4 hours

17. Which of the following is not a goal of tracheostomy care?
    A.   Prevent infection.
    B.   Maintain airway patency.
    C.   Ensure that the patient can swallow.
    D.   Prevent skin breakdown.

18. Identify one way to decrease the complications associated with sterile suctioning:
    A.   Use only 50% oxygen before and after suctioning.
    B.   Suction routinely every hour.
    C.   Do not used a closed suction system.
    D.   Do not routinely instill saline prior to suctioning.

19. Identify one way to provide controlled ventilation for a patient who is consistently agitated:
    A.   Restrain the patient.
    B.   Administer continuous sedation and neuromuscular blockade.
    C.   Tell the patient to be calm.
    D.   Have a nursing assistant sit with the patient throughout the shift.

20. Which of the following indicates 90% blockade on the Train-of-Four method of testing level of neuromuscular blockade?
    A.   One twitch
    B.   Two twitches
    C.   Three twitches
    D.   Four twitches

21. If your patient has respiratory acidosis, which of the following will you see on the ABG?
    A.   Elevated HCO_3
    B.   Decreased PO_2
    C.   Increased PCO_2
    D.   Decreased HCO_3

22. If your patient accidentally extubated himself and is now having respiratory distress, what is the first thing you should do?
    A.   Try to reinsert the endotracheal tube.
    B.   Manually ventilate the patient with a manual resuscitation bag.
    C.   Document the pulse oximetry.
    D.   Obtain an ABG.

23. Define ventilator weaning:
    A.   Turning off the ventilator and letting the patient breathe spontaneously.
    B.   Changing to a noninvasive form of ventilation.
    C.   Increasing the tidal volume delivered by the ventilator.
    D.   Decreasing the number of ventilator breaths while allowing an increased number of spontaneous breaths.

24.   When using T-piece trials to wean, which of the following is true?
       A.   The patient alternates time on the ventilator with time breathing spontaneously.
       B.   The number of ventilator breaths is gradually decreased.
       C.   The patient has the benefit of the ventilator alarms while on the T-piece.
       D.   The T-piece gives a positive pressure "boost" to decrease the work of breathing.

25.   What should a patient's minimum spontaneous tidal volume be in order to be successfully
       weaned from the ventilator?
       A.   10 ml/kg
       B.   20 ml/kg
       C.   5ml/kg
       D.   7-10 ml/kg

26.   Which of the following is not a component of weaning criteria?
       A.   Negative inspiratory force
       B.   I:E ratio
       C.   Minute volume
       D.   Vital capacity

27.   What kind of oxygen administration system should be used for a patient immediately after
       extubation?
       A.   Nasal cannula
       B.   Venturi mask
       C.   Room air
       D.   Humidified mask

28.   Which of the following should be done to assess respiratory status after extubation?
       A.   ABG
       B.   Electrolyte panel
       C.   Monitor end tidal CO_2
       D.   Bronchoscopy

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Linking Learning to Performance

Name:	
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Phone:	Email:
Date Submitted:	

**ADULT VENTILATION MANAGEMENT
POSTTEST ANSWER SHEET**

Please use pencil or black pen. Always keep a copy of your answers for future reference.
Read ALL the choices carefully.

Question #	Answer	Question #	Answer
1.		15.	
2.		16.	
3.		17.	
4.		18.	
5.		19.	
6.		20.	
7.		21.	
8.		22.	
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11.		25.	
12.		26.	
13.		27.	
14.		28.	