

Mechanical Ventilation for the Adult

3 Contact Hours

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Acknowledgements

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Purpose and Objectives

The purpose of Mechanical Ventilation for the Adult is to review the pulmonary system, indications for intubation, intubation, mechanical ventilation, complications, care of the patient on the ventilator, and extubation. It is important for healthcare providers who care for patients requiring mechanical ventilation understand how to properly care for the patient.

After successful completion of this course, you will be able to:

1. State the major components of ventilation
2. Review and understand ventilator definitions and terminology
3. Describe modes of ventilation
4. Understand the goals of ventilation
5. Understand ventilator parameters
6. Recognize common causes of alarms
7. State four complications from mechanical ventilation with two interventions or treatments
8. Review the weaning process
9. List the steps needed for extubation

Glossary

Ambu bag: Also known as a bag valve mask (BVM), manual resuscitation bag (MRB) or manual self-inflating resuscitation bag.

A/C (Assist control): A type of positive pressure ventilator setting that delivers a preset volume of gas at a set rate. If the patient initiates a breath on their own, the ventilator will assist in delivering the preset volume. The ventilator will deliver a breath every time the patient breaths so if the patient has a lot of spontaneous breaths this setting might not be indicated since the patient can hyperventilate resulting in a decreased CO₂ (Wilkins, Stoller, & Kacmarek, 2009).

Bagging (the patient): Providing manual ventilations with a BVM.

BiPAP: Bi-Level Positive Airway Pressure, commonly known as BiPAP uses noninvasive ventilation support that combines positive support ventilation (PSV) and positive end expiratory pressure (PEEP). BiPAP is used in an attempt to avoid intubation. It is also used in patients with sleep apnea (Wilkins, Stoller, & Kacmarek, 2009).

Biting the tube: The patient is biting the endotracheal tube essentially occluding their own airway. A commercial bite block or oral airway should be inserted orally to prevent hypoxia or damage to the endotracheal tube.

Bucking the vent: The patient is agitated and fighting against the breaths the ventilator is delivering.

BVM: Bag Valve Mask is also known as the manual resuscitation bag (MRB) or ambu bag. It connects to an oxygen source and can deliver breaths using a face mask or via adapter that attaches directly to an endotracheal tube or tracheostomy tube.

CO₂ detector: Also known as end tidal CO₂ (carbon dioxide); a CO₂ detector is used to measure the amount of CO₂ at end exhalation and is used immediately after intubation to help determine if the endotracheal tube has been successfully inserted into the trachea.

Compliance: Represents the ease of inflation and lung expansion (Wilkins, Stoller, & Kacmarek, 2009).

CPAP: Continuous positive airway pressure is a spontaneous breathing mode on the ventilator that is similar to PEEP. The application of continuous positive pressure decreases the work of breathing by

decreasing resistance (Wilkins, Stoller, & Kacmarek, 2009).

Dead-space ventilation: Reduced perfusion to an area of the lung. Occurs when alveoli do not have adequate blood supply for gas exchange to occur. May result from a pulmonary emboli and pulmonary infarction (Courey & Hyzy, 2013).

Expiratory Reserve Volume: maximum volume of gas that can be exhaled from the end-expiratory position. (Courey & Hyzy, 2013)

Fighting the tube: The patient is restless or agitated and is manipulating the tube by excessive swallowing or moving the tube around with the tongue or throat muscles. The patient will usually require sedation to prevent the possibility of trauma or accidental self-extubation.

FiO₂: Fractionated inspired oxygen, the amount of oxygen delivered by a ventilator.

Functional Residual Capacity: Volume of gas remaining in the lungs at resting expiratory level (Courey & Hyzy, 2013).

High Frequency ventilation (HFV): Can be referred to as jet ventilation. Type of ventilation that can be used for patients at risk for pneumothorax since it delivers a small amount of gas at a high rate (usually between 60-100 breaths per minute). HFV will minimize the risk for decreasing the patients cardiac output and can be used for neonates (Courey & Hyzy, 2013).

Hypercapnia: Arterial blood gas value of PaCO₂ greater than 50mm Hg.

Hypoxia: A decrease in tissue oxygenation measured by a low PaO₂ or blood flow. There are several classifications that include: hypoxic, circulatory, anemic and histotoxic.

Hypoxemia: Measured by arterial blood gases. Hypoxemia is defined as an arterial blood gas value PaO₂ of less than 60mmHg, represents low blood oxygen level and low hemoglobin saturation.

Hyperventilate (hyperventilating): Provide additional breaths, often with 100% O₂ prior to suctioning. Hyperventilating a patient with a head injury to decrease CO₂ was a common practice in the past, now controversial and only performed per physician order.

Inspiratory Capacity: Maximum volume of gas expired from resting expiratory level (Courey & Hyzy, 2013).

Inspiratory Reserve Volume: Maximum volume of gas that can be inhaled after a tidal breath is taken (Courey & Hyzy, 2013).

Macintosh blade: A curved laryngoscope blade used for intubation that exposes the glottis opening by advancing into the space between the base of the tongue and the epiglottis (the vallecula) (Chulay & Burns, 2010).

Miller blade: A straight laryngoscope blade recommended for use in patients with short necks and obese patients since the trachea may be located more anteriorly. The tip of the blade extends below the epiglottis to help lift and expose the opening (Chulay & Burns, 2010).

Mist in the tube: Condensation in the endotracheal tube consistent with respiration.

Nasal trumpet: Also known as a nasal or nasopharyngeal airway.

Noncompliant: The lungs are not elastic, feel stiff. See compliance.

Oral airway: Or oropharyngeal airway, often used in semi-conscious patients to prevent a relaxed tongue from occluding the airway. Often used post surgery and can be used as a bite block to prevent a patient from biting on an endotracheal tube when a commercial bite block is not available.

PEEP: Positive end expiratory pressure is another type of positive pressure that is used by the ventilator for patients that are breathing spontaneously on their own. PEEP is used to improve oxygenation in conjunction with another ventilator setting such as SIMV, assist control or control

ventilation (Wilkins, Stoller, & Kacmarek, 2009).

Residual Volume: volume of gas remaining in the lungs at end of a maximal expiration (Courey & Hyzy, 2013).

Sellick Maneuver: Also known as cricoid pressure, is used to decrease gastric distention, pulmonary aspiration and to aid in visualizing the cords during intubation. It consists of applying downward firm pressure on the cricoid ring. Once the Sellick maneuver is initiated it must be continued until the intubation has been completed (Chulay & Burns, 2010).

Settings: Refers to the ventilator settings.

Shunting: Reduced ventilation to an area of the lung. Unoxygenated blood moves from the right side of the heart to the left side of the heart and into systemic circulation (Wilkins, Stoller, & Kacmarek, 2009).

Silent Unit: A combination of shunting and dead-space ventilation. Occurs when little or no ventilation and perfusion are present. IE: pneumothorax (Courey & Hyzy, 2013).

SIMV: Synchronous intermittent mandatory ventilation provides a set respiratory rate and volume of gas for each breath. The ventilator delivers a breath when the patient has not initiated a breath spontaneously within a preset time. This allows the patient to breath spontaneously. This mode is often used during the weaning process (Wilkins, Stoller, & Kacmarek, 2009).

Sniffing position: A favorable position to insert an endotracheal tube. The patient is lying supine with the shoulders squared off and the head slightly tipped back as though sniffing through the nares.

Stiff: Refers to noncompliant lungs while using an ambu bag- the lungs should feel elastic without resistance when manually ventilated.

Tidal Volume (TV or VT): Volume of gas that is inhaled and exhaled during each respiratory cycle (Courey & Hyzy, 2013).

Total Lung Capacity: Volume of gas contained in the lung at the end of a maximal inspiration (Courey & Hyzy, 2013).

Vital Capacity: Maximum volume of gas expired after a maximum inspiration (Courey & Hyzy, 2013).

V/Q ratio: The relationship between ventilation and perfusion.

Introduction

A nurse receives a report that a patient is in the emergency department in septic shock from pneumonia. The patient has an oxygen saturation of 82% on 100% non-rebreather. The critical care nurse starts preparing the room for the admission and possible intubation. Respiratory emergencies require immediate intervention.

It is important to know how to care for the patient on the ventilator, but it is equally important to understand the indications for intubation and the indications for extubation. Although it is unlikely anyone besides those working in an advanced practice role will ever be required to perform an emergency tracheostomy or intubate a patient, it will be very beneficial for patient safety and professional nursing practice to develop an awareness of the skills required to mechanically ventilate the patient.

A healthcare provider is responsible for implementing safe, effective and appropriate airway management until an advanced airway can be placed. The “before,” “during,” and “after” mechanical ventilation will be reviewed in this course.

Physiologic Anatomy of the Pulmonary System

The pulmonary system's purpose is to provide gas exchange. Oxygen and carbon dioxide (CO₂) are exchanged between the atmosphere and alveoli, between the alveoli and pulmonary capillary blood, and between the systemic capillary blood and all the cells of the body (Alspach, 2006). Effective respiration requires gas exchange in the lungs (external respiration) and in the tissues (internal respiration). The processes for adequate oxygenation and acid-base balance are ventilation, pulmonary perfusion, and diffusion.

There are four basic steps in the gas exchange process:

1. **Ventilation:** Process of moving air.
2. **Diffusion:** Process by which alveolar air gasses are moved across the alveolar-capillary membrane to the pulmonary capillary bed and vice versa.
3. **Transport of gases into circulation:** Approximately 97% of oxygen is transported in chemical combination with hemoglobin (Hgb) in the erythrocyte and 3% is carried dissolved in the plasma. PaO₂ is a measurement of the oxygen carried in the plasma.
4. **Diffusion between systemic capillary bed and body tissue cells:** Diffusion of O₂ and CO₂ in the systemic capillaries, interstitial fluid, and cells.

(For more information about the pulmonary system, take the RN.Com course titled RN.com's Assessment Series: Focused Pulmonary Assessment.)

Assessing the Respiratory System

Patients with respiratory issues should have a thorough exam of their respiratory system. The healthcare provider should review:

- Inspection of the chest
- Percussion of the chest
- Auscultation of breath sounds
- Analyzing respiratory rate & interpretation of pulse oximetry (instant feedback on oxygenation)
- Interpretation of end-tidal CO₂ monitoring
- Interpretation of ABG

Quick Review of End-tidal CO₂ (EtCO₂) Monitoring

Monitoring EtCO₂ is done in the intensive care setting. Most healthcare professionals are familiar with checking EtCO₂ after intubation with the use of a colorimetric device. This is a pH sensitive colored paper strip that changes color in response to different concentrations of CO₂. This indicator verifies correct placement of the endotracheal tube.

With new American Heart Association (2010) guidelines, EtCO₂ capnography has become standard of care during a Code to evaluate the effectiveness of compressions and used as a tool to evaluate when return of spontaneous circulation (ROSC) occurs. EtCO₂ monitoring has become part of many hospital's policy and procedure for procedural sedation to monitor for hypoventilation.

More frequently, hospitals are using capnography (EtCO₂ monitoring) to monitor for adequacy of mechanical ventilation and to evaluate the patient's progress when weaning off mechanical ventilation.

EtCO₂

What is CO₂? Carbon dioxide (CO₂) is a by-product of cellular metabolism and is transported via the venous blood to the lungs where it is eliminated during exhalation.

What is EtCO₂ or Pet CO₂? End-tidal CO₂ represents the maximum carbon dioxide (CO₂) concentration at the end of each exhaled breath.

When there are fluctuations in the EtCO₂, what does it mean? Fluctuations in EtCO₂ are due to one of three components:

- **Metabolism** (how effectively CO₂ is being produced by cellular metabolism)
- **Circulation or perfusion** (how effectively CO₂ is being transported through the vascular system)
- **Ventilation** (how effectively CO₂ is being eliminated by the pulmonary system)

Colorimetric: When using a colorimetric indicator to confirm proper placement of the endotracheal tube, the practitioner observes that the device changes to GOLD. Many remember... "Good is GOLD; PURPLE pukey (meaning in the stomach)."

What are the CO₂ Numbers?

Normocapnia: Normal amount of CO₂ in blood. 35 – 40 mmHg

Hypocapnia: Decreased level of CO₂ in the blood.

Hypercapnia: Presence of abnormally high concentrations of CO₂ in the blood.

Test Yourself

What is the difference between pulse oximetry and capnography?

- A. There is no difference. They both tell us about oxygenation only.
- B. Capnography ONLY provides instantaneous feedback about oxygenation.
- C. Pulse oximetry informs the healthcare provider on perfusion.
- D. Pulse oximetry provides feedback on oxygenation while capnography provides information on ventilation, perfusion, and metabolism. – **Correct!**

Normal Blood Gas Values

It is important for nurses to be familiar with normal arterial blood gas values. Normal values are listed below.

Normal values	
pH	7.35 – 7.45
PaO ₂	80 – 100
PaCO ₂	35 – 45
HCO ₃	22 – 26
B.E.	± 2

Normal Blood Gas Values

pH - The normal pH of the body is slightly alkaline with a range of 7.35 to 7.45. Changes in the amount of hydrogen ions (H⁺) and bicarbonate (HCO₃) ions will shift the pH. When the lungs are unable to eliminate carbonic acid (in the form of CO₂), the pH of the body will shift and become increasingly acidotic. An increase of base (HCO₃) and/or a loss of acid (CO₂) will cause the body to become more alkaline (alkalotic).

PaCO₂ - The PaCO₂ is the respiratory component of the arterial blood gas. The normal value is 35-45 millimeters of mercury (mmHg). An increase in PaCO₂ indicates decreased ventilation of the alveoli. A decrease in PaCO₂ indicates hyperventilation (Kidd & Wagnor, 2001, pp.149).

HCO₃ - HCO₃ represents the metabolic or renal component of the ABG. The normal value is 22-26 mEq/L.

BE - BE (base excess) indirectly reflects the bicarbonate concentration in the body; however, it is not essential for basic interpretation of arterial blood gases. Normal BE is ±2mEq/L.

O₂ - Normal oxygenation status (of a healthy individual) reflects an oxygen level of 80-100 millimeters of mercury (mmHg).

Quick Review on Arterial Blood Gas (ABG)

When the pH is between 7.35 - 7.45 there is optimal cellular functioning.

A decrease in pH *below* 7.35 is termed acidemia and an increase in pH *above* 7.45 is termed alkalemia.

The bicarbonate (HCO₃) and carbon dioxide (CO₂) levels are the primary regulators in the balance between acids and bases.

HCO₃ is controlled by the kidneys and changes in HCO₃ excretion may take up to 24 hours. Normal HCO₃ levels are 22-26.

CO₂ levels is controlled by the lungs and changes in CO₂ can occur rapidly, within a minute, by increasing or decreasing respiration. Normal CO₂ levels are 35- 45.

ABG's

- Metabolic alkalosis- pH is >7.45 and HCO₃ >26mEq/L
- Metabolic acidosis- pH is <7.35 and HCO₃ <26mEq/L

- Respiratory alkalosis- pH is >7.45 and $\text{CO}_2 <35$
- Respiratory acidosis- pH is <7.35 and $\text{CO}_2 >45$

Remember:

A decreased pH (less than 7.35) always indicates acidosis.

An increased pH (greater than 7.45) always indicates alkalosis.

Interpretation of Blood Gas Values

Interpreting ABGs becomes more complex when the body begins to compensate for the deviation. If respiratory acidosis is present and the body begins to compensate metabolically, the blood gas results will reflect:

- pH < 7.35
- $\text{CO}_2 >45$
- $\text{HCO}_3 >26$

If metabolic alkalosis is present and the body begins to compensate through respirations, the blood gas result will reflect:

- pH > 7.45
- $\text{CO}_2 > 45$
- $\text{HCO}_3 > 26$

If a patient is becoming increasingly hypoxic despite individualized treatment based on their condition, the physician may decide that the patient requires advance airway adjuncts such as mechanical ventilation. Follow the hospital's policy and procedure and be prepared to assist with intubation.

For additional guidance on ABG interpretation, please see RN.com's course: Interpreting ABGs: The Basics.

Test Yourself

The following ABG is reported to the critical care nurse post-extubation:

pH 7.20

CO_2 55

HCO_3 24

What is the interpretation?

- A. Metabolic alkalemia
- B. Metabolic acidemia
- C. Respiratory alkalemia
- D. Respiratory acidosis – **Correct!**

The interpretation is respiratory acidosis since the pH is <7.35 and $\text{CO}_2 >45$

Indications for Mechanical Intubation

Deciding to Intubate

Prior to intubation the healthcare provider should determine the patient's wishes regarding intubation, from the patient, healthcare proxy, or advanced directives.

If a definite airway is not immediately clear, healthcare professionals should consider the following questions to determine the need for intubation:

1. Is there a failure of airway maintenance or protection?
2. Is there failure of oxygenation?
3. Is there failure of ventilation?

These will be discussed further.
(Brown, 2013)

Failure of Airway Maintenance or Protection

A thorough assessment of the patient should be completed to confirm or deny the patient's ability to maintain and protect their airway.

- If the patient can answer questions clearly, then they demonstrate airway patency, adequate ventilation, vocal cord function, and cerebral perfusion with oxygenated blood. If patient is not alert the patient is at risk of aspiration.
- Loss of airway protective reflexes mandates tracheal intubation. An absent gag reflex and a Glasgow Coma Scale (GCS) <8, increases the need for intubation.
- Is the patient able to swallow? Swallowing is a higher level of neurologic complexity. Inability to swallow with pooling secretions requires intubation.
- Inability to visualize oropharyngeal inlet because of obstruction will require the patient to be intubated. If the patient is needing basic airway maneuvers, oral devices, or nasopharyngeal devices, the patient probably needs intubation for airway protection.

(Brown, 2013).

Failure of Oxygenation

The inability to oxygenate mandates intubation. Tissues depend on oxygen for cellular respiration. Lack of oxygen to the tissue leads to ischemia (cell damage) and eventually infarction (cell death).

What does the hypoxic patient look like?

- **Restless**
- **Agitated**
- **Cyanotic**
- **Confusion**
- **Somnolent**
- **Obtunded**
- **Pulse oximetry decreasing**
- **Benefits from CPAP or BiPAP with noninvasive positive pressure ventilation (NIPPV). Some patients cannot tolerate the mask or are too ill to protect their airway. They will need intubation.**

(Brown, 2013)

Failure of Ventilation

Brown (2013) states that impaired ventilation from airway obstruction, muscular weakness, or drug-induced hypopnea will result in impaired CO₂ elimination. As reviewed previously, removal of

CO₂ depends on proper lung function and ventilation.

What does this patient look like?

- Capnography - increasing past the patient's baseline. Normal CO₂ is 35-45 mmHg. Patients with chronic ventilatory failure, like with chronic obstructive pulmonary disease, can tolerate a much higher CO₂.
- Benefits from CPAP or BiPAP with noninvasive positive pressure ventilation (NIPPV). Some patients cannot tolerate the mask or are too ill to protect their airway. They will need intubation.

Anticipated Need for Intubation

There are situations where there is controlled intubation when the disease progression would result in the compromise of their airway or inability to maintain oxygenation. Examples: burn victim with smoke inhalation or elderly patient with pneumonia and severe sepsis who is somnolent but arousable.

Indications for Mechanical Ventilation

Conditions/Disorders

Courey & Hyzy (2013) list common acute disorders which may require mechanical ventilation:

- Alveolar filling processes: (pneumonitis, noncardiogenic pulmonary edema, ARDS, cardiogenic pulmonary edema, pulmonary hemorrhage, tumor, alveolar proteinosis, intravascular volume overload of any cause)
- Pulmonary vascular disease (pulmonary thromboembolism, amniotic fluid embolism, tumor emboli)
- Diseases causing airway obstruction: central (tumor, laryngeal angioedema, tracheal stenosis)
- Diseases causing airway obstruction: distal (acute exacerbation of chronic obstructive pulmonary disease & acute, severe asthma)
- Hypoventilation: decreased central drive (general anesthesia & drug overdose)
- Hypoventilation: peripheral nervous system/respirator muscle dysfunction (amyotrophic lateral sclerosis, cervical quadriplegia, Guillain-Barre syndrome, myasthenia gravis, tetanus, tick bite, ciguatera poisoning, toxins, muscular dystrophy, myotonic dystrophy, myositis)
- Hypoventilation: chest wall and pleural disease (kyphoscoliosis, trauma, massive pleural effusion, pneumothorax)
- Increased ventilatory demand: (severe sepsis, septic shock, severe metabolic acidosis)

Indications for Mechanical Ventilation

Respiratory Abnormalities

There are clinical assessments, loss of ventilatory reserve, and refractory hypoxemia that may suggest mechanical ventilation.

Clinical Assessment: Apnea, stridor, severely depressed mental status, flail chest, inability to clear respiratory secretions, trauma to mandible, larynx, or trachea.

Loss of Ventilatory Reserve: Respiratory rate >35 breaths/min, tidal volume <5 mL/kg, vital capacity <10 ml/kg, negative inspiratory force weaker than -25 cm H₂O, minute ventilation <10L/min, and rise in PaCO₂ >10 mmHg.

Refractory Hypoxemia: Alveolar-arterial gradient >450 , $\text{PaO}_2/\text{PAO}_2 <0.15$, and PaO_2 with supplemental $\text{O}_2 <55\text{mmHg}$.

Objectives of Mechanical Ventilation

Brown (2013) and Slutsky (1993) stated that there are physiologic and clinical objectives with mechanical ventilation.

Physiologic Objectives:

1. Support pulmonary gas exchange based on alveolar ventilation and arterial oxygenation
2. Reduce the metabolic cost of breathing by unloading the ventilatory muscles
3. Minimize ventilator-induced lung injury

Clinical Objectives:

1. Reverse hypoxemia
2. Reverse acute respiratory acidosis
3. Relieve respiratory distress
4. Prevent or reverse atelectasis
5. Reverse ventilatory muscle fatigue
6. Permit secretions and/or neuromuscular blockage
7. Decrease systemic or myocardial oxygen consumption
8. Stabilize the chest wall

Basic Goals of Ventilation

- A goal of mechanical ventilation is try to not use them. If the patient will tolerate, try BiPAP or CPAP. These will be briefly discussed.
- Other goals of mechanical ventilation is to help the patient ventilate and oxygenate.
- The final goal of mechanical ventilation is to wean and extubate before any complications.

CPAP & BiPAP

Quick review of non-invasive modes of ventilation with use of a mask:

Bilevel Positive Airway Pressure (BiPAP):

- Provides oxygenation and ventilation
- A method of applying an inspiratory and expiratory pressure that can be used to provide non-invasive ventilation
- Noninvasive ventilatory assist device that utilizes a spontaneous breathing mode
- Allows separate regulation of inspiratory positive airway pressure (IPAP) and expiratory positive airway pressure

(Hyzy, 2013)

Continuous Positive Airway Pressure (CPAP):

- Provides oxygenation

- Designed to elevate end-expiratory pressure to above atmospheric pressure to increase lung volume and oxygenation. All breaths are spontaneous
- Can be used with intubated and nonintubated patients via mask
- Pressure, above atmospheric, maintained in the airways throughout the respiratory cycle during spontaneous breathing

(Hyzy, 2013)

Test Yourself

Goals of mechanical ventilation include which of the following?

- A. Airway protection
- B. Maintaining optimal blood gas exchange
- C. Both A & B – **Correct!**
- D. Neither A or B

Review of Artificial Airways: ETT

What are Endotracheal Tubes (ETTs)?

- These are tubes inserted by a trained professional into the patient's trachea through the oral or nasal route. Oral intubation is preferred and more common since nasal intubation is associated with increased risk of ventilator associated pneumonia and sinus infections.
- ETTs have a radiopaque line on all tubes to aid in determining placement via chest x-ray.
- Common adult ETT sizes are 7.0 – 9.0 mm.
- ETT can be left in place for up to several weeks, but tracheostomy is often considered following 10 – 14 days of intubation.

Review of Artificial Airways: Tracheostomy

What is the Tracheostomy Tube (often called trach)?

- Considered when assisted or controlled ventilation is needed for an extended period of time.
- In general, are better tolerated than the ETT in terms of comfort.
- Uncuffed tubes are commonly used in children and adults with laryngectomies and are sometimes used during decannulation or weaning.
- Cuffed tubes are typically used when a patient is receiving artificial ventilation and to prevent or limit aspiration of oral or gastric secretions.
- Keep an extra tracheostomy tube and tube obturator at the bedside in case the tube must be reinserted emergently.

Complications of Artificial Airways

Endotracheal Tube (oral & nasal)

- Laryngeal and tracheal damage
- Aspiration
- Infection; Sinusitis
- Discomfort
- Mucous membrane disruption; Nosebleed
- Tooth damage and/or dislodgement

Tracheostomy Tube

- Hemorrhage from erosion of the innominate artery
- Tracheal stenosis, malacia or perforation
- Laryngeal nerve injury
- Aspiration
- Infection

Intubation Box or Intubation Kit

Most healthcare facilities utilize a respiratory therapist (RT) and/or a specially trained registered nurse (RN) to assist with intubation; however, there may be times when you might be called upon to help.

If your facility has a rapid response team, they will come prepared with a cardiac monitor, pulse oximeter and an intubation kit that contains all the necessary equipment. Medications may or may not be part of the intubation kit.

The contents of an intubation kit typically include:

- Assorted adult sizes of endotracheal tubes from size 5.5mm to 9mm (using the largest tube possible will decrease airway resistance and facilitate suctioning)
- Endotracheal blade and handle: Straight blade (Miller) or curved blade (Macintosh)
- Extra light bulb and batteries for the laryngoscope
- Flexible stylet
- Water soluble lubricant
- 10mL syringe
- End tidal CO₂ detector
- BVM
- Commercial tube holder

Preparing for Intubation: Positioning & Bagging

- Prior to intubation, a team member should be bagging (ventilating) the patient with 100% oxygen (O₂).
- Another team member should be monitoring the patient's vital signs (including pulse oximetry), ensuring IV access and overall patient status.
- The wall suction should be turned on high and a Yankeur suction device attached and ready for use (it is convenient to place this by the patient's head).
- The patient's head of the bed should be flat with the pillow removed. The patient should be lying supine in good anatomical position with the shoulders square and the head in the sniffing position (the patient's neck is flexed slightly forward and the head is extended up and back in order to open a partially obstructed upper airway). The physician will likely need the bed elevated to facilitate tube placement. He or she might ask you to place a small rolled up towel or folded blanket under the shoulders or neck; this will also help to facilitate tube placement.

Preparing for Intubation: Positioning & Bagging

- The respiratory department usually maintains and stores the ventilators and will bring one to the unit when needed. The ventilator should arrive with all the necessary tubing. It is likely the unit will

stock any sterile water or saline that is needed.

- The physician will decide which size endotracheal tube (also referred to as ET tube or ETT) is best suited for the patient. Oral intubation is the preferred method with the exception of certain conditions in which case the physician will perform nasal intubation. Selecting the size of the tube is generally determined by a patient's size. An average adult female can usually accommodate a tube size of 7mm to 8mm. Males or larger females might require an 8mm to 9mm tube. A small female might require a 6.5mm tube. The smaller the internal diameter of the tube, the greater the resistance and work related to breathing (AACN, 2006, p. 121).
- Facilitate the procedure by placing a bedside table with all necessary equipment at the patient's head of the bed or in the location preferred by the healthcare provider placing the advanced airway. Since intubation is a procedure that should be performed rapidly, placing the equipment so that it is easily accessible to the physician will directly benefit the patient's ventilation status.
- Ensure that personal protective equipment is readily available for all team members. This includes face shield mask or protective eye wear.

(Chulay & Burns, 2010)

Rapid Sequence Intubation

Caro (2013) states that rapid sequence intubation is the standard of care in emergency airway management for intubations not anticipated to be difficult. This procedure standardizes the intubation process and allows healthcare workers to become familiar with and prepare for intubations.

Medications that are frequently used include:

- **Midazolam:** Sedation or amnesic.
- **Ketamine:** Sedative.
- **Propofol:** Hypnotic.
- **Lidocaine:** Given to help counteract a possible increase in intracranial pressure (ICP).
- **Etomidate:** Sedative/hypnotic agent.
- **Vecuronium:** Administer this nondepolarizing muscle relaxant two to three minutes prior to paralyzing the patient to block fasciculations.
- **Succinylcholine:** Neuromuscular blocking agent that can cause major muscle fasciculations that can cause increased ICP, rhabdomyolysis, hyperkalemia and muscle pain. Fasciculations should be prevented by administering a small dose of nondepolarizing muscle relaxant such as Vecuronium two to three minutes prior to paralyzing the patient.
- **Atropine:** Decreases vagal stimulation from the administration of neuromuscular blocking agents such as succinylcholine and from laryngoscopy.

Intubation

- Intubation is done by a trained and credentialed healthcare professional. The RN should monitor vital signs and deliver sedation, pain medications, and paralytics (if needed).
- The MD might ask you to apply cricoid pressure (also known as the Sellick maneuver). To provide cricoid pressure, place gentle pressure with your thumb or fingers to the Adams apple area. This will facilitate intubation by helping to visualize the vocal cords.
- During the intubation process the physician will use the laryngoscope to visualize and insert the endotracheal tube through the vocal cords and into the trachea via the upper airway. Optimal placement is usually two to four centimeters above the carina (Alspach, 2006).
- A successful intubation should not require more than a few seconds. Inflate the cuff. After the ETT

is in place, assess for bilateral chest excursion during inspiration and expiration. Auscultate both sides of the chest and the abdomen.

- If the physician encounters difficulty with the placement, ventilation should not be interrupted for longer than ten to thirty seconds. If the physician is unable to intubate the patient, the endotracheal tube should be removed and the patient should be ventilated with 100% oxygen via the BVM for a minimum of three to five minutes prior to another attempt (Alspach, 2006).
- After intubation, confirm correct placement by physical examination, auscultation of bilateral breath sounds and by colorimetric ETCO₂ or capnography. Properly document this information.
- Use an exhaled CO₂ detector or monitor to detect lung versus esophagus placement.
- Secure the tube in place using a commercial device or tape.
- Obtain a portable chest X-ray, with head of bed elevated to 30° unless contraindicated, to establish correct tube placement after the initial insertion.
- OGT/NGT placement to decompress stomach and prepare for possible enteral nutrition.

Cuff Pressures

The respiratory therapist and trained healthcare providers will assess and document cuff pressure as per policy or hospital standards.

- The cuff pressure is to be maintained at 25 to 30 cm H₂O or 18 to 25 mm Hg.
- Cuff pressure is to be measured between positive pressure breaths.
- In the event the cuff pressure exceeds 25 mm Hg or 30 cm H₂O, notify the physician. This may lead to tracheal ischemia, necrosis and erosion where the cuff contacts the tracheal mucosa.

(Chulay & Burns, 2010)

Nursing Care Considerations for the Intubated Patient

When caring for an intubated patient there are standards of care that need to be maintained for safe practice:

- Identify the centimeter marking of the ETT at the patient's lip and document every shift.
- All mechanically ventilated patients will be assessed routinely for the safety need of soft wrist restraints. The goal is to avoid restraints if possible.
- Head of bed elevated at 30° or greater unless practitioner orders otherwise.
 - Provide frequent mouth care: mouth care every 2 hours, toothbrush utilization every 8 hours.
 - Endotracheal cuff pressures maintained between 25 to 30 cm H₂O or 20 to 25 mm Hg.
- Check for placement of ETT after adjustments.
- Continuous analgesia should be strongly considered for patients receiving mechanical ventilation. All mechanically ventilated patients receiving sedation should be assessed for appropriateness of sedation wake up and readiness to wean.
- Maintain standard precautions and utilize appropriate PPE. Wear face shields for any procedure which may cause the release of fluids (suctioning, tracheostomy care, etc.).
- General observations at the bedside every hour to assure proper ventilation and oxygenation per nursing standard of care.

Nursing Care Considerations for the Intubated Patient

- Monitor lung sounds, ETT placement, and cuff leaks regularly.
- Assess ventilator settings, alarms, and patient's ability to synchronize breathing with the ventilator.
- Gloves and hand washing should be used for every contact with the ventilator.

- Monitor patient for increased heart rate, mental status change, respiratory rate, diaphoresis, or other signs and symptoms of increased work of breathing.
- Use a dry erase board, pen and paper, or open letter board for communication if appropriate.
- Patient should be kept nil by mouth (NPO) while intubated. This includes ice chips.
- Move ETT from one side of the mouth to the other side of the mouth at least daily. Follow your hospital's policy and procedure.
- Suction according to patient need.
- RN will reposition and turn the patient at least every 2 hours unless contraindicated or ordered by practitioner.
- Continuous monitoring of EKG and oxygen saturation.
- Maintain equipment at the patient's bedside: complete suction setup, 10 mL syringe for cuff inflation/deflation, Bag-Mask-Ventilation (BMV) System, tracheostomy tube of same size as indicated and one size smaller (for tracheostomy patients), and oral care.
- For tracheostomy patients, the nurse will provide care to clean the tracheostomy tube and stoma site; change the securing device, and remove the inner cannula and clean if appropriate as per nursing standard of care.
- All mechanically ventilated patients receiving sedation will be assessed for appropriateness of sedation wake up and readiness to wean.
- Maintain standard precautions and utilize appropriate PPE. Wear face shields for any procedure which may cause the release of fluids (suctioning, tracheostomy care, etc.).
- General observations at the bedside every hour to assure proper ventilation and oxygenation per nursing standard of care.
- Monitor lung sounds, ETT placement, and cuff leaks regularly.
- Assess ventilator settings, alarms, and patient's ability to synchronize breathing with the ventilator.

Test Yourself

Repositioning of the ETT from one side of the mouth to the other should be done appropriately every 24 hours or more frequently if necessary.

- A. True – **Correct!**
- B. False

Ventilator Basics

A ventilator is simply a box with numbers that can deliver between 21-100% of oxygen, depending on the setting selected. Most brands of mechanical ventilators perform similarly, although some are more advanced with graphics, whereas others may be more user-friendly and simpler to use.

Always familiarize yourself with the ventilator brand used in your clinical setting and make sure you are comfortable with the controls and settings.

Ventilator Etiquette

- Always keep the ventilator within view.
- Do not close doors as that will decrease the sound of the alarms. Some hospitals have the ventilator alarms saved into their call bells so there will be an alarm on the door. Some hospitals have ventilator alarms signaled to mobile phones. The nurse should always make sure she or he can hear alarms and should always respond.
- Electrical needs: Ventilators are to be plugged into an emergency electrical outlet.

Standard Modes of Mechanical Ventilation

After intubation the healthcare provider will need to order basic settings. There will be six modes of ventilation discussed. They are broken down into two sections: volume limited ventilation and pressure limited ventilation. Volume limited ventilation (volume control or volume cycled) require the clinician to set the peak flow, flow pattern, tidal volume, respiratory rate, positive end expiratory pressure (PEEP), and fraction of inspired oxygen (FiO₂). The inspiratory phase ends when the “set volume” is reached. Pressure limited ventilation (pressure cycled) requires the clinician to set the inspiratory pressure level, I:E ratio (inspiratory: expiratory), respiratory rate, PEEP, and FiO₂. The inspiratory phase ends when the “set pressure” is reached.

Volume Limited Ventilation:

- Assist Control (AC)
- Synchronized Intermittent Mandatory Ventilation (SIMV)

Pressure Limited Ventilation:

- Pressure Support Ventilation (PSV)
- Pressure Regulated Volume Control (PRVC)
- Bilevel
- Proportional Assist Ventilation (PAV)

Refer to your individual hospital’s ventilator and policies. Some hospitals use CMV instead of AC. Some hospitals use terms like CPAP instead of PSV. The basic modes of ventilation is discussed. There are some advanced modes of ventilation that will not be discussed.

Did You Know?

The main difference between volume limited ventilation and pressure limited ventilation is the determinant that ends each breath.

Volume Limited Ventilation: Inspiration ends when the “set” **tidal volume** is reached.

Pressure Limited Ventilation: Inspiration ends when the “set” **pressure** is reached.

Assist Control

The clinician determines the minimal minute ventilation by setting the respiratory rate and tidal volume. The ventilator delivers a preset respiratory rate & preset tidal volume regardless of lung resistance and compliance. There is a set backup respiratory rate, but the patient may breathe at a rate above the set rate. When the patient takes an extra breath the set tidal volume will be delivered.

Vent Settings Ordered

- **Mode:** AC
- **RR:** 16
- **TV:** 450 mL
- **FiO₂:** 40%
- **Peep:** 5

If the patient breathes at 20 each of the additional 4 breaths per minute will deliver 450mL of tidal volume.

(Hyzy, 2013)

Synchronized Intermittent Mandatory Ventilation

- SIMV is synchronized intermittent mandatory ventilation.
- A ventilatory mode that applies breaths at a set rate but permits the patient to breathe between the set breaths at their own tidal volume and peak flow.
- The ventilator attempts to synchronize the mandatory breaths with the patient initiated breaths.
- Breaths may be initiated by the patient but are not delivered by the ventilator.
- Patients are able to breathe spontaneously at the depth and desired rate until next mandatory breath from ventilator is delivered.

(Hyzy, 2013)

Spontaneous tidal volume are not set, they are completely generated by the patient.

Test Yourself

A patient is intubated, which ventilator setting will give the patient a “set” tidal volume even when the patient initiates their own breath.

- A. Assist Control – **Correct!**
- B. SIMV

Pressure Support Ventilation (PSV)

- Pressure-targeted, flow-cycled mode of ventilation. Designed to elevate end-expiratory pressure to above atmospheric pressure to increase lung volume and oxygenation. All breaths are spontaneous.
- Each breath is triggered by the patient since there is no set respiratory rate.
- Used in conjunction with SIMV to improve patient tolerance and decrease the work of spontaneous breaths. Also used as a stand-alone ventilatory support for weaning patients from the ventilator or during a stabilization period.
- Pressure support is an additional pressure that is added to help spontaneous breathing. Setting pressure support helps to augment spontaneous breaths.
- Patients that have shallow spontaneous tidal volumes will have increased volumes with the addition of pressure support.
- PSV helps to overcome the resistance of the ET tube and helps to make spontaneous breathing feel normal.

(Hyzy, 2013)

Since the work of breathing is inversely proportionate to the pressure support level, the work of breathing can be reduced for the patient by increasing the level of pressure support on the ventilator.

Pressure Control Ventilation or Pressure-Regulated Volume Control

- Ventilator delivers preset pressure, respiratory rate, and inspiratory time. This mode uses a set pressure to obtain a desired tidal volume.
- Used when lungs are non-compliant with high airway pressures and poor oxygenation. The lungs are inflated only to a set pressure, once the pressure level is achieved the breath or inspiration stops despite the obtained tidal volume.
- Setting a pressure to obtain a tidal volume, limiting the amount of pressure delivered to the lungs.
- There is little variance in the amount of pressure that the patient receives to obtain the desired tidal

volume.

- Peak airway pressure is maintained at a constant level without much fluctuation.
- Tidal volumes will vary depending on the patient.
- This is a lung protective strategy mode (ARDS patients).

(Hyzy, 2013)

Tidal volume is NOT set, the PRESSURE is set

Bi-Level & Proportional Assist Ventilation

Bi-Level:

- A mixed mode of ventilation that combines the attributes of mandatory and spontaneous breathing. Mandatory breaths are pressure-controlled and spontaneous breaths are pressure-supported.
- Bi-Level ventilation uses two set pressures to deliver tidal volumes: Peep High & Peep Low.
- The breath is held at Peep High for a set time and then returns to Peep Low.
- In this mode patients can breathe spontaneously at both pressure levels.

(Hyzy, 2013)

Proportional Assist Ventilation (PAV):

- Adjusts ventilatory support level based on patient demand to improve patient-ventilator synchrony.
- PAV is a form of synchronized partial ventilatory assistance with the characteristic that the ventilator generates pressure in proportion to the patient's instantaneous effort. The more the patient pulls, the more pressure the machine generates.

(Hyzy, 2013)

Criteria for Determining Ventilator Settings

After the physician or healthcare provider determines the mode of ventilation, there are ventilator settings that also need to be ordered. They are determined by the clinician using the following criteria:

- Patient's weight
- Patient's level of hypoxia and/or hypercapnia
- Mode of ventilation to be used

Modes of Ventilation

FiO₂

- Fractional inspired oxygen or the percent of oxygen in the inspired gas
- The oxygen concentration

(Hyzy, 2013)

Tidal Volume

- V_t -Tidal Volume is the volume of gas that moves in and out of the lungs with each normal breath
- Tidal volume can be set and the patient can also have spontaneous tidal volumes or breaths
- Ventilators often indicate spontaneous vs. delivered tidal volumes.

(Hyzy, 2013)

Peak Flow

- Velocity of gas at its fastest point.
- Used to help determine the patients inspiratory to expiratory ratio.
- The easiest rule of thumb to follow is that a patient requires a peak flow roughly four times that of the minute ventilation (if the MV is 15 liters, the patient requires a PF of >60 liters).

(Hyzy, 2013)

Respiratory Rate

- Breaths per minute (BPM): The rate of breaths delivered to the patient
- Respiratory Rate can be set and can also be spontaneous.
- In all modes, patients have the ability to take spontaneous breaths. We do not completely lock patients out so that they cannot breathe if they need to breath. True Control of ventilation is only accomplished by completely sedating and paralyzing the patient
- The total respiratory rate is displayed on the ventilator section of the ventilator. To know the spontaneous rate, take the total number of breaths and subtract the set breaths.

(Hyzy, 2013)

Peep

- Positive End-Expiratory Pressure (PEEP):
- Positive End Expiratory Pressure – amount of pressure left in the alveoli at the end of exhalation which increases the functional residual capacity (volume in lungs at the end of exhalation)
- Used in conjunctions with ventilator modes to help stabilize alveolar lung volume and improve oxygenation.
- The application of positive pressure to the airways during expiration may keep alveoli open and prevent closure.
- In general we use peep to increase a patient's oxygenation level. PEEP helps to keep the lungs inflated at the end of exhalation. Which allows more time for oxygenation and ventilation to occur. It prevents closure of the small airways and terminal alveoli, maintaining functional residual capacity and improving hypoxemia.
- Low levels of PEEP are good, higher levels indicate trouble
- Most patients are set on 5 of peep as a standard.
- Peep can cause a drop on B/P

(Hyzy, 2013)

Pressure Support

- Used alone or added to SIMV, pressure support provides a small amount of pressure during inspiration to help the patient draw in a spontaneous breath.
- Pressure support makes it easier for the patient to overcome the resistance of the ET tube and is often used during weaning because it reduces the work of breathing.
- It's not necessary during AC ventilation because in that setting, the ventilator supports all of the breaths.

(Woodruff, 2005); (Hyzy, 2013)

I:E

- Inspiratory and expiratory ratio determines how much time is given for inspiration and how much time is given for expiration.
- For ventilated patients, we generally like the I:E ratios to be at least 1:2. Which mean 1 second to inhale and 2 seconds to exhale. This allows the patient more time to exhale and can help to prevent Auto Peep or breath stacking.

(Hyzy, 2013)

PIP

- PIP is peak inspiratory pressure which is the amount of pressure that is generated by air entering the lungs during a ventilator generated inspiration.
- The maximum pressure that occurs during ventilation and is measured at end expiration.
- The amount of pressure needed to inflate the lungs to deliver, or achieve the desired tidal volume.
- It is important to monitor PIP's; over distention of the lungs cause damage to the lung tissue and can lead to ARDS.

(Hyzy, 2013)

Minute Ventilation (Volume)

- VE - Minute Ventilation (Exhaled).
 - Volume of gas that moves in and out of the lungs for the duration of 1 minute.
- Minute volume is the respiratory rate x the tidal volume.
- Some ventilators use a minute volume setting instead of programming both a respiratory rate and tidal volume.
- Example: Tidal volume of 600mls and a respiratory rate of 10. Multiple 600 by 10 and this number is the minute ventilation. It equals 6000 mL/min or 6L/min.

(Hyzy, 2013)

Other Ventilator Terms

- **Auto PEEP:** PEEP that is a result of obstructed airways or insufficient time to complete exhalation.
- **N.I.F. (Negative Inspiratory Force):** The amount of negative pressure or vacuum that can be generated during inspiration.
- **VC or Vital Capacity:** Volume of gas that can be exhaled from the lungs following a maximum inhalation. This can be forced or passive.
- **Sensitivity:** The ease for the patient to initiate or trigger a breath.

(Hyzy, 2013)

Ventilator and Gas Exchange

- Oxygenation is primarily a function of FiO₂ and PEEP.
 - Increasing the FiO₂ or PEEP will increase oxygen supply in the hypoxic patient.
 - Decreasing the FiO₂ or PEEP will decrease oxygen supply.
- CO₂ is primarily a function of respiratory rate and tidal volume.
 - Increasing the respiratory rate or the tidal volume will cause a decrease in PCO₂ and classically raise the pH.
 - Decreasing the respiratory rate or the tidal volume will cause an increase in PCO₂ and classically lower the pH.

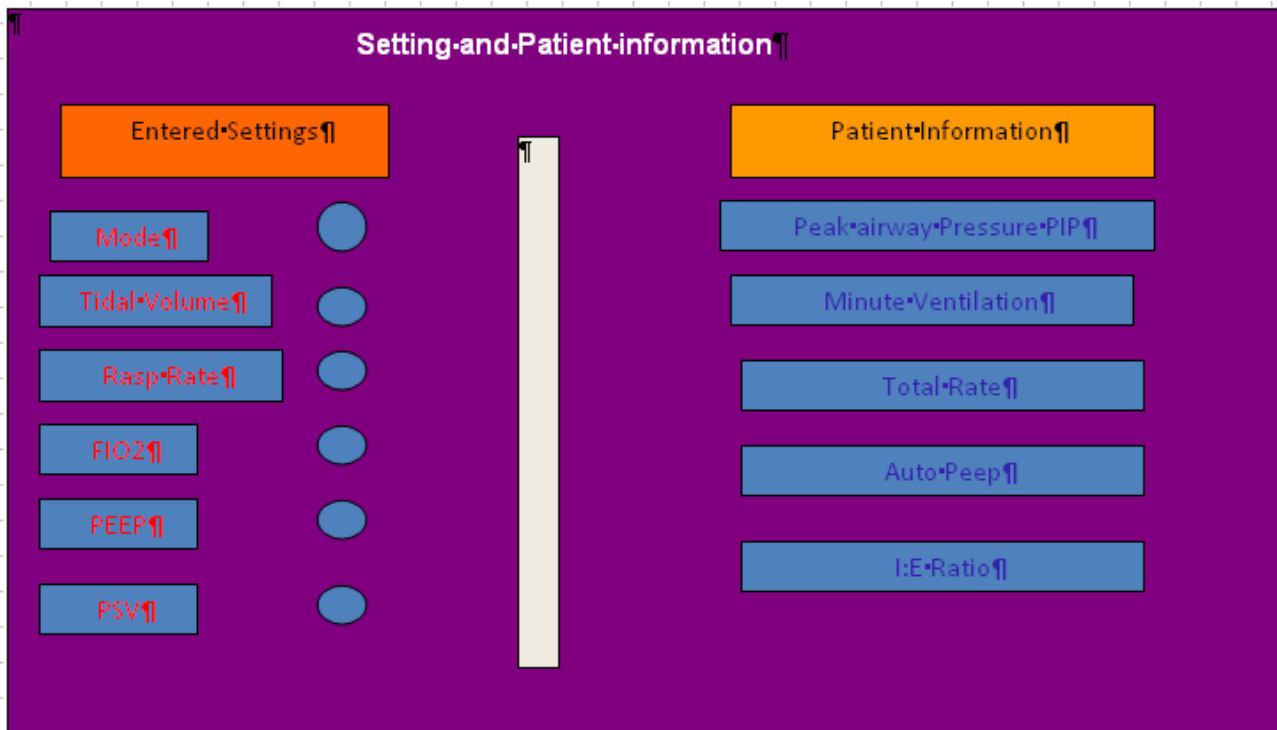
(Chulay & Burns, 2010)

Test Yourself

Increasing the FiO₂ or PEEP will increase oxygen supply in the hypoxic patient.

- A. True – **Correct!**
- B. False

Ventilator Settings



Types of Mechanical Ventilators

The negative pressure ventilator (previously called “iron lung”) has been replaced with the use of positive pressure ventilators. The negative pressure ventilator decreased intrathoracic pressure by applying negative pressure to the chest wall. Typically used for long-term noninvasive support when muscle strength is inadequate to support unassisted, spontaneous breathing. A further description about positive cycled ventilators will be discussed. The two types of positive pressure ventilators are: volume cycled and pressure cycled ventilators:

Volume Cycled Ventilators:

The volume cycled ventilator delivers a preset volume of gas (tidal volume) during inspiration.

Pressure Cycled Ventilators:

The pressure cycled ventilator terminates inspiration once a preset pressure is reached, at which time the patient exhales passively.

Sedation of Ventilated Patients

If a patient is in distress post-intubation, the patient may need analgesics, anxiolytics, and/or anti-psychotics.

- The physician should prescribe pain medications such as fentanyl, Dilaudid, and morphine. They can be given IV push. If it is uncontrolled, a fentanyl drip is most commonly given with periodic boluses for breakthrough pain.
- For anxiety and agitation, midazolam is given IV push. Again, if uncontrolled, a midazolam drip can be given with periodic boluses for increased anxiety or agitation.
- For increased delirium, as evidence by CAM-ICU positive (a positive score on the CAM-ICU which is a delirium monitoring instrument often used in ICUs), delirium should be controlled by Haldol or Zyprexa. Monitor patient for QTc prolongation.

(Hou & Baez, 2013)

Complications of Mechanical Ventilation

There are risks of complications when using mechanical ventilation. The following types of complications will be discussed in further detail:

- Cardiac
- Pulmonary
- Fluid balance
- Infection
- Gastrointestinal
- Neurological

Complications of Mechanical Ventilation: Cardiac

- Intrapleural and intrathoracic pressures can decrease venous return which results in a decreased cardiac output. PEEP level greater than 20 cm of H₂O may increase the severity. The healthcare provider can see changes in the hemodynamics like pulse changes, decreased urine output, and decreased blood pressure. Treatment involves: fluids to increase preload, adjustment of tidal volumes, titration of PEEP, and avoidance of auto-PEEP.
- Another cardiac complication from mechanical ventilation is dysrhythmias from hypoxemia and pH abnormalities. This is why patients on a ventilator require constant cardiac monitoring.
- Another complication includes deep vein thrombosis (DVT) from laying in bed. Ventilated patients should be prophylactically treated with anticoagulants such as Heparin or Lovenox injections and compression stockings.

(Alspach, 2006)

Complications of Mechanical Ventilation: Pulmonary

Mechanical ventilation can lead to complications such as: barotrauma, volutrauma, atelectasis, tracheal damage, oxygenation toxicity, patient-ventilator dysynchrony, Auto-PEEP, inability to wean, hypercapnia, and hypocapnia.

- **Barotrauma:** (Pneumothorax, subcutaneous emphysema) occurs when a high-pressure gradient between the alveolus and the adjacent vascular sheath causes the overdistended alveolus to rupture. Gas is forced into the interstitial tissue of the underlying perivascular sheath. Damage to the pulmonary system due to alveolar rupture from excessive airway pressures or over distention of alveolar.
- **Volutrauma:** Alveolar damage that results from high pressures resulting from large-volume ventilation in patients with acute respiratory distress syndrome. Volutrauma is different from barotrauma. Volutrauma results in alveolar fractures and flooding.
- **Atelectasis:** This is the collapse of lung parenchyma from occlusion of air passage, with reabsorption of gas distal to occlusion. The cause is from obstruction and possible lack of deep inflations in patients with small tidal volumes. It is diagnosed by diminished breath sounds or bronchial breath sounds, rales, or crackles, chest x-ray, and decreasing compliance. We can prevent this by use of adequate tidal volumes, humidity, tracheal suctioning, chest physical therapy, and repositioning.
- **Tracheal Damage:** The cause of tracheal damage is excessive cuff pressures due to overinflation or reduced tracheal blood flow causing ischemia. This can be avoided by proper monitoring of intracuff pressures or volumes.

- **Oxygen Toxicity:** Excessive oxygenation occurs from impaired surfactant activity, progressive capillary congestion, fibrosis, edema, and thickening of interstitial space. This can be prevented by careful monitoring of blood gases and the use of the lowest FiO₂ possible for adequate oxygenation (PaO₂ ≥ 60 mm Hg and SaO₂ ≥ 90%).
- **Patient-Ventilator Dysynchrony:** This is difficulty synchronizing the patient's ventilatory pattern to a particular mode of ventilation. May result in increase work of breathing, anxiety and development of auto-PEEP as a result of insufficient expiratory time. Check patient and ventilator settings. Do not assume the patient will adjust to the ventilator. Also, provide calm reassurance and analgesia and/or sedatives as appropriate.
- **Auto-PEEP:** Auto PEEP occurs when a delivered breath is incompletely exhaled before the onset of the next inspiration. This gas trapping increases overall lung volume, inadvertently raising end-expiratory pressure in the alveoli.
- **Inability to Wean:** This can occur in any patient, particularly those with COPD, cystic fibrosis, debilitation, malnutrition, and musculoskeletal disorders. Mechanical ventilation eases the work of breathing for these patients, making the transition off the ventilator (weaning) difficult.
- **Hypercapnia:** This is respiratory acidosis. It is caused by the inadequate ventilation leading to acute retention of CO₂ and decreased pH. This is corrected by improving alveolar ventilation and treating the underlying cause.
- **Hypocapnia:** This is respiratory alkalosis. It is caused by hyperventilation which increased elimination of CO₂ and increased pH. The treatment is to decrease the respiratory rate, decrease the vital volume if inappropriately high, and add mechanical dead space.

(Alspach, 2006)

Complications of Mechanical Ventilation: Fluid Balance

Fluid retention and dehydration are both complications from mechanical ventilation.

- Fluid retention is due to the overhydration by airway humidification and decreased urinary output because of possible ADH effects. Symptoms of fluid retention include: weight gain, intake greater than output, decreased compliance, and increased bronchial secretions.
- Dehydration is related to decreased enteral and parenteral intake in relation to urinary and/or gastrointestinal output, and overdiuresis. Signs of dehydration include decrease skin turgor, intake less than combined outputs, decreased body weight, hemoconcentration of urine, and thick secretions.

(Alspach, 2006)

Insensible losses average 300-500 mL/day and these losses can increase with fever.

Complications of Mechanical Ventilation: Infection

In general, patients on mechanical ventilator are at risk for infections. They are often the vulnerable population. These patients often have central lines and Foley catheters. They can be improperly positioned so that aspiration is possible. Frequent suctioning, ventilator equipment, and aerosols can contribute to contamination from bacteria.

- Ventilator-Acquire Pneumonia (VAP) is defined as a hospital-acquired pneumonia in patients who have been mechanically ventilated for at least 48 hours. The aspiration of bacteria in the oropharynx and lower respiratory tract may be the leading cause. Other causes include bacterial colonization of the oral cavity.
- Presence of an ETT bypasses upper respiratory tract defense mechanisms of cough and

mucociliary clearance action.

- Contaminated secretions pool above the ETT cuff and leak into the lower respiratory tract.
- Supine positioning, the presence of a nasogastric tube or reflux of bacteria from the stomach contribute to oropharyngeal colonization.

- How to Prevent VAP:

- Elevate head of bed at least 30 degrees
- Maintain optimal tube cuff pressure
- Routinely verify tube placement
- Follow mouth care protocol
- Handwashing

(Alspach, 2006), (Hyzy, 2013)

Test Yourself

Pathogenic etiology of VAP includes:

- A. Bacterial colonization of the oral cavity.
- B. Aspiration of contaminated secretions.
- C. All of the above. – **Correct!**

Complications of Mechanical Ventilation: Gastrointestinal

GI Complications: Peptic ulcers may develop as a result of physiologic pressures and stress.

Peptic Ulcer Disease (PUD) Prophylaxis:

- Routine auscultation of bowel sounds.
- Stress ulcer reduction should be addressed pharmacologically by the physician: antacids or histamine antagonists.
- Hemoccult or Gastrocult and pH stomach aspirate and stools.
- Report evidence of distention or ileus immediately.
- The need for nutritional support should be addressed.

(Alspach, 2006)

Complications of Mechanical Ventilation: Neurological

Due to the use of sedatives, narcotics, and paralytics which are sometimes needed for the mechanically ventilated patient, there is sometimes neurological complication such as: agitation, distress, delirium, somnolence.

Nursing Considerations:

- Patients may be over or under sedated.
- Ongoing assessment using validated sedation scales such as the Riker Scale or Richmond Agitation Sedation Scales (RASS). The nurse should titrate sedatives to goal of therapy.
- Perform daily wake up from continuous sedation/paralytic.
- Ongoing assessment using validated delirium scale such as the Confusion Assessment Method for the Intensive Care Unit [CAM-ICU].

Test Yourself

Patients receiving mechanical ventilation do not need to be assessed for DVT and PUD prophylaxis.

- A. True
- B. False – **Correct!**

Ventilator Alarms

Proper response and knowledge of ventilator alarms is imperative when working with intubated patients. All ventilator alarms should be responded to promptly and patient assessed. Most ventilators have different alarms for warning (yellow alarm) and immediate action needed (red alarm).

- When there is an alarm, always treat your patient first and the ventilator second! Look at the patient and assess vital signs.
- Review the ventilator display to review the type of alarm.
- If necessary, ventilate patient with manual resuscitation bag and call a Respiratory Therapist for assistance.

Alarms will be reviewed in more detail.

Types of Alarms

HIGH PRESSURE LIMIT: High pressure limit is reached before volume is delivered.

Interventions:

- Assess ETT for kinks, reposition, and use a bite block; check for kinks or condensation in ventilator tubing.
- Assess oxygenation status, vital signs, breath sounds and suction airway as needed.
- Bronchodilators may be ordered to reduce bronchospasm.
- Assess the patient for pain, anxiety and synchrony with the ventilator; provide emotional support; sedative may be required (nursing before narcotics).
- Notify the physician and respiratory therapist with deterioration in patient status and/or unable to troubleshoot the cause of alarm.

LOW INSPIRATORY PRESSURE: Not developing set pressure to deliver volume from circuit leak, disconnect, or change in compliance and resistance within the system.

Interventions:

- Check for a disconnect.
- Check the ETT for placement and cuff leak.
- Assess the patient for air leakage from the mouth or around the tube.
- Notify the physician and respiratory therapist with deterioration in patient status and/or unable to troubleshoot the cause of alarm.

LOW PEEP: Pressure below set peep level.

Interventions:

- Causes same as low inspiratory pressure
- Incorrectly set peep

LOW MINUTE VOLUME OR LOW TIDAL VOLUME: Patient is not exhaling at least 80% of mandatory or normal volume.

Interventions:

- Leak in circuit
- Disconnect
- High pressure limit reached

Troubleshooting Alarms

APNEA: Ventilator does not sense a breath during set delay period.

- Over sedation, or neurologic changes.
- Cardiopulmonary arrest.
- Assess the need for change in ventilator mode.
- Alarm interval synchrony.
- Rate increase.
- Remove from the vent and AMBU breath for the patient as needed.

HIGH RESPIRATORY RATE: Respiratory rate higher than set limit.

- Change respiratory rate limits, mode of ventilation, or sedate patient.

LOW O2 INLET PRESSURE: Loss of oxygen pressure.

- Call respiratory therapy. Monitor patient and bag patient if needed.

EXHALATION VALVE OPEN: Ventilator failure.

- Call respiratory therapy for new ventilator.
- Monitor patient; remove patient from ventilator and bag, if needed.

LOW BATTERY or NO AC POWER: Battery for audible alarms weak.

- Plug in ventilator. If problem does not resolve, call respiratory therapy for new ventilator.
- Stay with patient and remove from ventilator and bag, if needed.

HEATER ALARM: Overheated humidifier.

- Call Respiratory Therapy to exchange water container or adjust settings.

Suctioning

When a patient is intubated they cannot clear their secretions by themselves. Clinical indicators of the need for suctioning include: coughing, visible secretions, increase in ventilator airway pressures, respiratory distress, decrease in arterial oxygen levels or SPO₂, decreased breath sounds, adventitious sounds during chest auscultation, and assessment of airway patency. The use of an in-line suction catheter aids in quickly suctioning the patient. When needing to suction a patient, maintain standard precautions. Then explain the procedure to patient.

1. Press 100% suction button on the ventilator. Follow hospital policy. Some hospitals have the practitioner deliver 3 manual inspirations while others have the practitioner wait 2 minutes.
2. Suction the patient with the in-line suction catheter. Each attempt should last less than 10 seconds at less than 120 mm Hg of pressure. During the suction monitor the patient's hemodynamic status.
3. Assess the need for further suctioning (e.g., auscultate, audible congestion, copious amounts of secretions, etc.).
4. Determine if SPO₂ have returned to baseline within 5 minutes of suctioning. If not, continue to deliver 100% O₂ until baseline levels have returned.
5. Repeat suction process if necessary.
6. Document procedure, patient response, and sputum character.

(Chulay & Burns, 2010)

Weaning from Mechanical Ventilation

When the underlying disease process that necessitated mechanical ventilation has significantly improved or fully resolved, weaning procedures should begin. Studies indicate that protocols that wean sedation along with the ventilator spend less time on the ventilator, less time in the ICU, and less time in the hospital (Girard, Kress, & Fuchs, 2008).

- Consider weaning from the ventilator when:
 - Patient is able to protect own airway.
 - Patient is hemodynamically stable.
 - Patient is able to follow simple commands.
 - Underlying pulmonary disorder or illness that led to mechanical ventilation has sufficiently resolved or has stabilized.
- Unnecessary delays in weaning from the mechanical ventilator increase the likelihood of complications such as:
 - Ventilator-induced lung injury.
 - Pneumonia.
 - Discomfort.
 - Increase hospitalization costs.

There are two parts that need to be done prior to extubation: readiness testing and weaning. These should be done on an awake patient.

Sedation Wake Up or Daily Wake-Up

As long as it is not contraindicated (e.g.: patient with open abdomen sedated and paralyzed or hemodynamically unstable), patients should have a sedation vacation or daily wake-up. It is performed by nursing staff and respiratory therapy. Together, they turn off sedation and do a spontaneous weaning trial screen such as the Rapid Spontaneous Breathing Index (RSBI).

How is it done?

Sedation is titrated down until the patient is able to perform three of the following four actions:

- Open the eyes in response to a voice
- Use the eyes to follow the investigator on request
- Squeeze a hand on request
- Stick out the tongue on request

Assessment of Readiness

Most hospitals assessment of readiness to wean includes just three or four criteria for most short-term ventilator patients.

1. ABG's within normal limits on minimal to moderate support ($FiO_2 < \text{or} = .50$; $mv < \text{or} = 10L/min$, $PEEP < \text{or} = 5 \text{ cm H}_2O$)
2. Negative inspiratory pressure $< \text{or} = -20 \text{ cm H}_2O$
3. Spontaneous $V_t \geq 5mL/kg$
4. Vital Capacity $\geq 10mL/kg$
5. Respiratory Rate < 30 breaths/min
6. Spontaneous rapid-shallow breathing index (RSBI) < 100 to 105

(Chulay & Burns, 2010)

Readiness Testing: Rapid Shallow Breathing Index (RSBI)

- Studies indicate that the ratio of respiratory frequency divided by tidal volume in liters is the best predictor of a patient's readiness to breathe successfully off the ventilator (Epstein, 2013). The ratio is called rapid shallow breathing index (RSBI). Clinically accepted standard in assessing the readiness of a patient to be liberated from mechanical ventilation.
 - A RSBI is monitored during and recorded at the end of the spontaneous breathing trial (SBT).
 - RSBI < 80, extremely likely to be weaned
 - RSBI 80-105, an even chance to be weaned
 - RSBI > 105, unlikely to be weaned

Test Yourself

Patient is getting a RSBI done to evaluate whether or not he could be extubated. He is on 0 PEEP and 5cm H₂O PSV for 1 minute. His minute ventilation (VE) is 10L/min. 20 breaths per minute. What is his RSBI?

Answer: 40

Is this patient ready to wean off the ventilator?

Answer: Yes

There are websites that quickly do the math for you! [Click here](#).

Strategies to Facilitate Weaning

Chulay and Burns (2010) list seven strategies to facilitate weaning:

1. Explain the weaning process to the patient and family and maintain open communication throughout weaning.
2. Position to maximize ventilatory effort (sitting upright in bed or chair).
3. Administer analgesics to relieve pain and sedatives to control anxiety, if appropriate.
4. Remain with the patient during the weaning trial and/or provide a highly vigilant presence.
5. Frequently assess the patient's response to the weaning trial.
6. Avoid unnecessary physical exertion, painful procedures, and/or transports during the weaning trial.
7. Maximize the physical environment to be conducive to weaning (e.g.: temperature, noise, and distractions).

Common Weaning Methods

The following are common weaning methods:

1. **Spontaneous Breathing Trial (SBT) on Continuous Positive Airway Pressure (CPAP) or T-piece.** CPAP is the use of the ventilator to allow spontaneous breathing periods without mandated breaths. T-piece involves removing the patient from the ventilator and attaching an oxygen source to the ETT with a "T" piece. There is no ventilatory support with this device, the patient is breathing spontaneously.
 - Generally lasts 30 minutes to 120 minutes
 - Some prefer low levels of pressure support
2. **Pressure Support Ventilation (PSV).** Patients can spontaneously breathe on the ventilator with a

small amount of ventilator support.

3. **Synchronized Intermittent Mandatory Ventilation (SIMV).** This one of the most popular methods of weaning. It is when the therapist progressively decreases the number of mandated breaths delivered by the ventilator; therefore, the patient performs more of the work of breathing by increasing spontaneous breathing.

(Chulay & Burns, 2010)

Weaning Intolerance

Weaning intolerance is the need to return to ventilatory support. It can be indicated by:

- Increased respiratory rate, heart rate or blood pressure
- Shallow breaths or decreasing spontaneous tidal volumes
- Dyspnea
- Accessory muscles use
- Decreased LOC
- Diaphoresis
- Fatigue or pain
- Anxiety
- Deterioration in PaO₂, PaCO₂, SpO₂ or end-tidal CO₂

(Chulay & Burns, 2010).

Planned Extubation

After the patient is assessed as ready to wean and successfully weans, the next step is extubation. A qualified nurse, doctor, or respiratory therapy may extubate a patient with an order if an anesthesiologist or a qualified practitioner is available in-house for re-intubation, if needed. The procedure is extubation is:

- Maintain standard precautions.
- Explain procedure to patient and family. Explain what to expect and need to cough.
- Medicate for pain, if indicated.
- Set-up appropriate method for O₂ delivery.
- Position patient to 30-45 degree head of bed elevation to improve diaphragmatic function.
- Pre-oxygenate with 100% O₂ for a minimum of 30-60 seconds.
- Suction patient's secretions from ETT, oral and nasopharynx.
- Allow a few minutes for the patient to rest after suctioning then remove tape or Velcro strap from the ETT.
- Using a syringe, deflate the ETT cuff and auscultate for air movement around the cuff.
- Remove the tube slowly with an outward motion. After extubation, encourage the patient to take deep breaths and apply oxygen.
- Monitor patient post-extubation including: bronchospasm, tracheal damage, and aspiration.
- Monitor for stridor. Inspiratory stridor occurs from glottic and subglottic edema and may develop immediately or take several hours.
- Document procedure.

(Chulay & Burns, 2010)

Unplanned Extubation

If a patient accidentally removes their airway, purposefully removes their airway, or someone dislodges an airway, there are three immediate steps that should be taken:

1. Apply 100% O₂ and assess the patient's ability to breathe.
2. Immediately notify the responsible practitioner and respiratory therapist.
3. Constantly assess patient for stridor, immediately notifying anesthesia and responsible practitioner if stridor presents.

(Chulay & Burns, 2010).

Conclusion

When patients have difficulty ventilating or oxygenating, mechanical ventilation may be necessary. Managing a patient's respiratory status and pulmonary needs are the first steps in preventing a respiratory arrest. But if necessary, mechanical ventilation may be needed; therefore, it is important for practitioners to be familiar with the intubation process, management of the advanced airway, the modes of ventilation, care of the intubated patient including complications, and proper steps to extubated.

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Note: All dosages given are for adults unless otherwise stated. The information on medications contained in this course is not meant to be prescriptive or all-encompassing. You are encouraged to consult with physicians and pharmacists about all medication issues for your patients.

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