Mechanical Ventilation

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Outlines

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- Types of ventilators
- Ventilator setting
- Modes
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- Weaning
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Definition

automatic machine designed to provide all or part of the work the body must produce to move gas into and out of the lung. The act of moving air into and out of the lung is called breathing or more formally ventilation.

- A mechanical ventilator is a positive- or negative-pressure breathing device that can maintain ventilation and oxygen delivery for a prolonged period.

- Mechanical Ventilation is ventilation of the lungs by artificial means usually by a ventilator. Once a patient's PaO_2 cannot be maintained by the basic methods of oxygen delivery systems, i.e. masks, cannula; endotracheal

Purposes of Mechanical Ventilation

Mechanical ventilation is instituted to:

- Maintain or improve ventilation, i.e. for adequate tissue oxygenation.
- Decrease the work of breathing and improve patient's comfort

Objectives of Mechanical Ventilation

- To decrease the work associated with breathing.
- Improve oxygenation and ventilation
- To reverse sever life-threatening hypoxemia.
- To reverse acute progressive respiratory acidosis
- To reversal respiratory muscle fatigue

Types of breathing

- **Mandatory breath:** are machine cycled in which patient is entirely passive and the ventilator perform the work of breathing
- **Assist breaths:-**like mandatory but triggered by the patient ,breathing work is thus partly by the ventilator and partly by the patient
- **Spontaneous breaths: -** are triggered limited and cycled by the patient who perform all the work of breathing.

Indications for Ventilator support

- impending or existing respiratory failure
- Drug Over dose of respiratory depressant drugs such as sedatives and narcotics.
- Apnea , Obstructive sleep apnea.
- Cerebrovascular accident & cerebral trauma.
- Acute respiratory distress syndrome (ARDS).
- Asthma.
- Acute exacerbation of COPD.
- Chest trauma, Spinal cord injury & Flail chest.
- Pneumothorax & Hemothorax.

- Post-cardiac/thoracic surgery.
- Severe neurologic/neuromuscular dysfunction.
- Head trauma.
- Patient comatose, GCS 8.
- Guillain-Barre syndrome & Myasthenia gravis.
- Severe pneumonia.
- Aspiration.
- Near drowning
- Smoke inhalation.

Criteria for Institution of Ventilatory Support:

Parameters	Ventilation indicated	Normal range
<u>Pulmonary function studies</u> Respiratory Rate (b/m)	> 35	10-20
Tidal volume (ml/kg body wt)	< 5	5-7
Vital capacity (ml/kg body wt)	< 15	65-75
Maximum Inspiratory force (cmH_2O)	≤ 20	75-100

Criteria for Institution of Ventilatory Support:

Parameters	Ventilation indicated	Normal range
Arterial blood gases:		
PH	< 7.25	7.35-7.45
PaO_2 (mmHg)	< 60	75-100
$PaCO_2$ (mmHg)	> 50	35-45

Types of ventilators

A ventilator can deliver gas under:

- **Positive pressure**
- **or by negative pressure exerted on the chest wall.**

1. Negative Pressure Ventilators

Iron Lung – Negative pressure ventilator

- Early negative-pressure ventilators were known as "iron lungs." The patient's body was encased in an iron cylinder and negative pressure was generated by a large piston to enlarge the thoracic cage. This caused alveolar pressures to fall, and a pressure gradient was formed so that air flowed into the lungs.
- The iron lung was used most frequently during the poliomyelitis epidemics of the 1930s and 1940s, but iron lungs are still occasionally used today. Intermittent short-term negative-pressure ventilation is sometimes used in patients with chronic diseases.

2. Positive Pressure Ventilators

*Ventilators are classified by their method of cycling from the inspiratory phase to the expiratory phase.

*That is to say according to how the inspiratory phase ends.

*The factor which terminates the inspiratory cycle reflect the machine type.

2. Positive Pressure Ventilators

- ***Positive Pressure Ventilation***. is the primary method used with acutely ill patients. During inspiration the ventilator pushes air into the lungs under positive pressure. Unlike spontaneous ventilation, intrathoracic pressure is raised during lung inflation rather than lowered. Expiration occurs passively as in normal expiration.

2. Positive Pressure Ventilators

- Modes of PPV are categorized into:
- **Volume ventilators**
- **Pressure ventilators**
- **High frequency ventilation**

Bear 1000– Positive Pressure Ventilator

Volume Ventilation:

in which inspiration is terminated after a preset volume has been delivered by the ventilator, i.e. the ventilator delivers a preset tidal volume (Vt), and inspiration stops when the preset tidal volume is achieved.

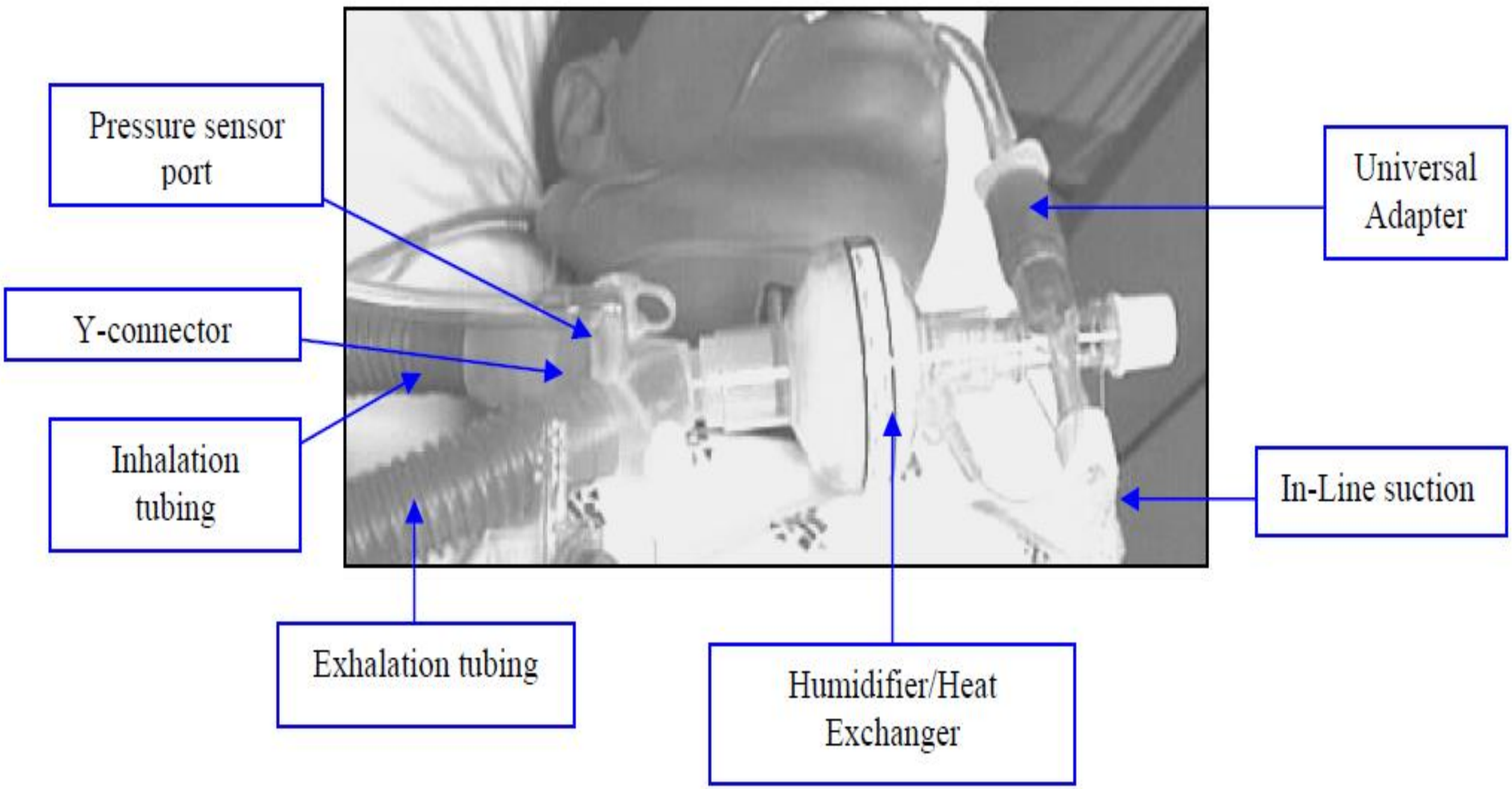
- Pressure Ventilation:

in which inspiration is terminated when a specific airway pressure has been reached, i.e. the ventilator delivers a preset pressure; once this pressure is achieved, end inspiration occurs.

- Time-cycled ventilator,:

in which inspiration is terminated when a preset inspiratory time, has elapsed. Time cycled machines are not used in adult critical care settings. They are used in pediatric intensive care areas.

Ventilator Circuits



Ventilator Modes

- **A ventilator mode is a description of how breaths are supplied to the patient. The mode describes how breaths are controlled (pressure or volume), and how the four phases of the respiratory cycle are managed.**

Mode of Ventilation of positive pressure ventilators:

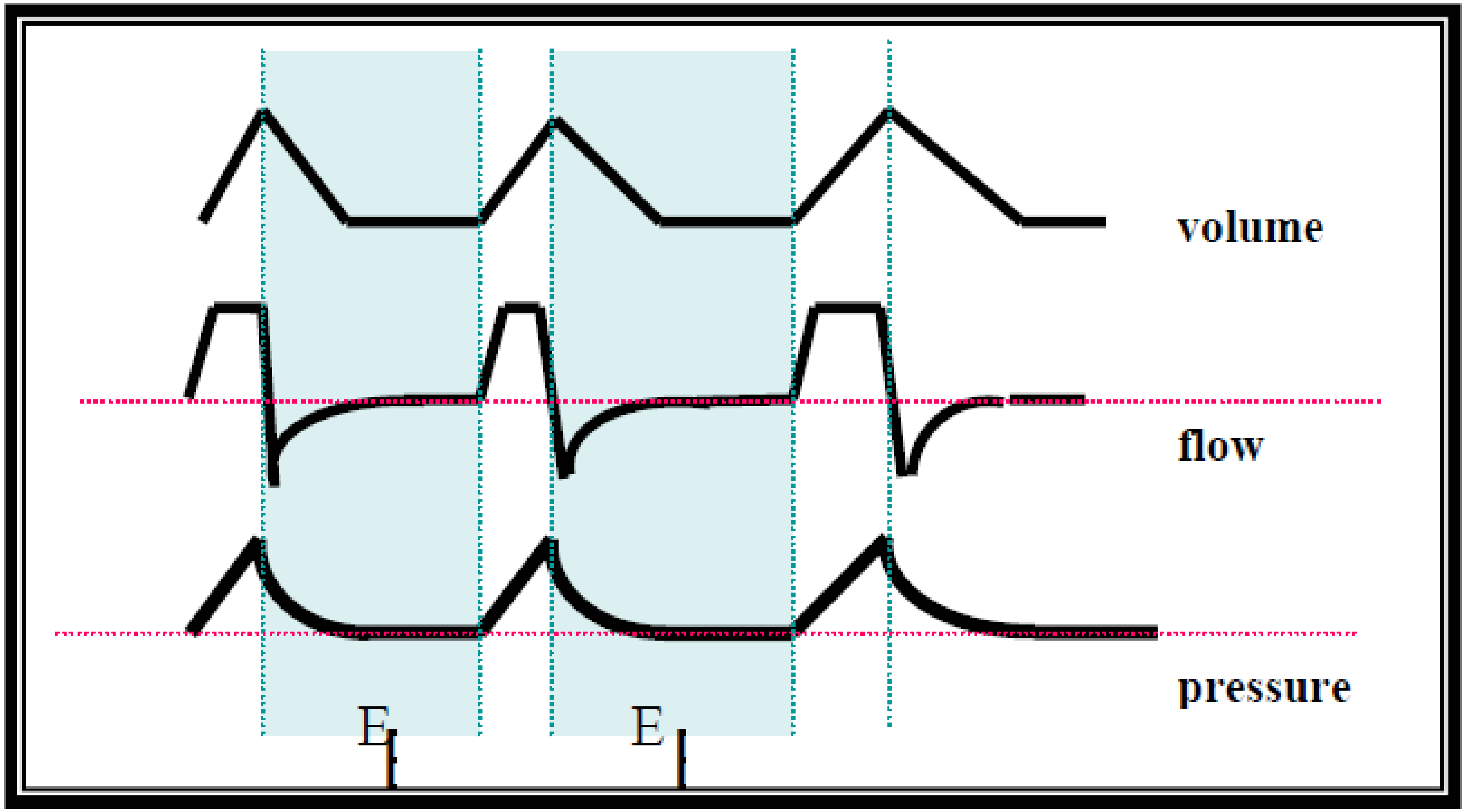
- 1) Volume modes
- 2) pressure modes

Volume modes

- **Controlled mandatory ventilation (CMV)**
- **Assist control ventilation (ACV)**
- **Synchronized intermittent mandatory ventilation (SIMV)**

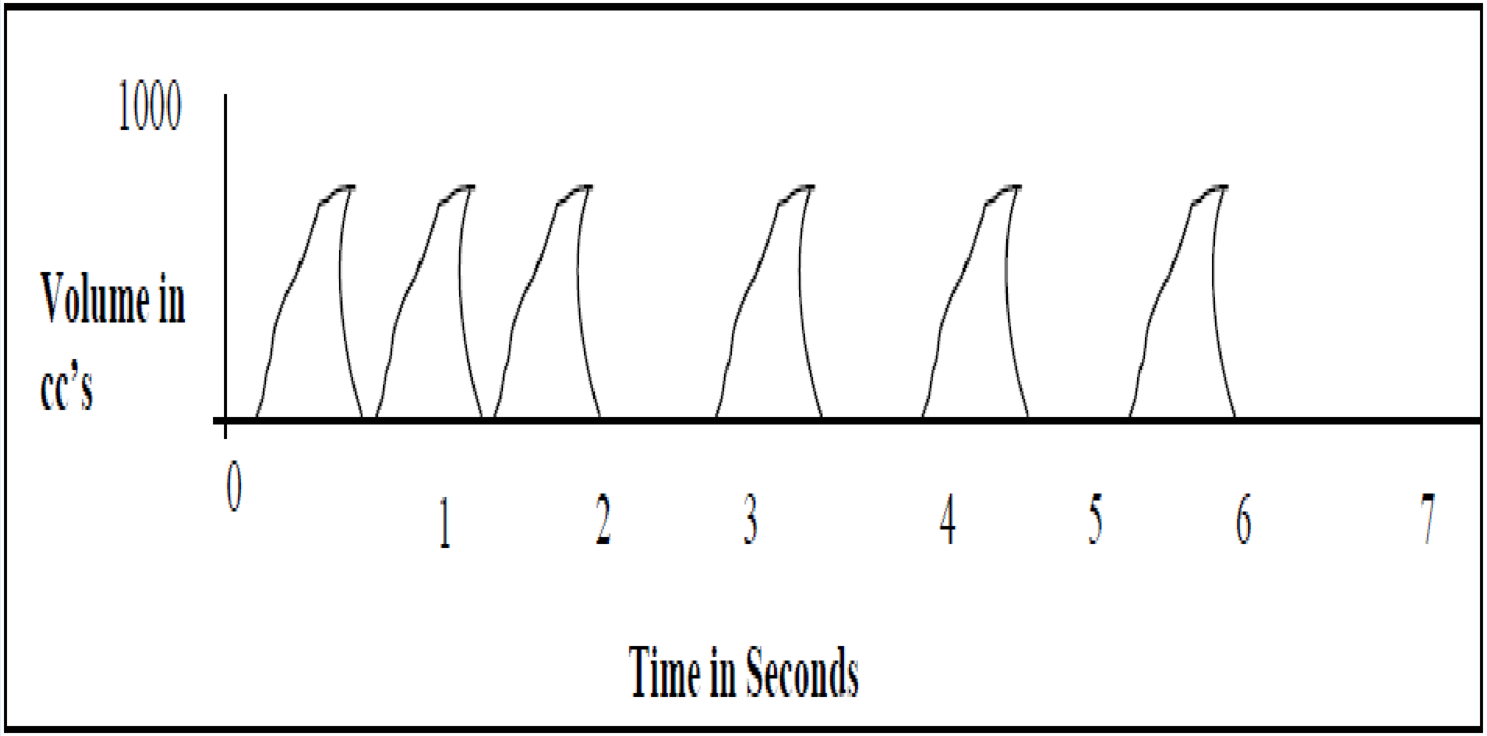
Controlled Mandatory Ventilation (CMV)

- CMV completely controls the patient’s ventilation. It “locks out” the patients own spontaneous efforts at breathing. The rate that is set on the ventilator is exactly what the patient receives and no more. This mode can be either pressure-controlled (PC-CMV) or volume-controlled (VC-CMV).


volume
flow
pressure
E
E

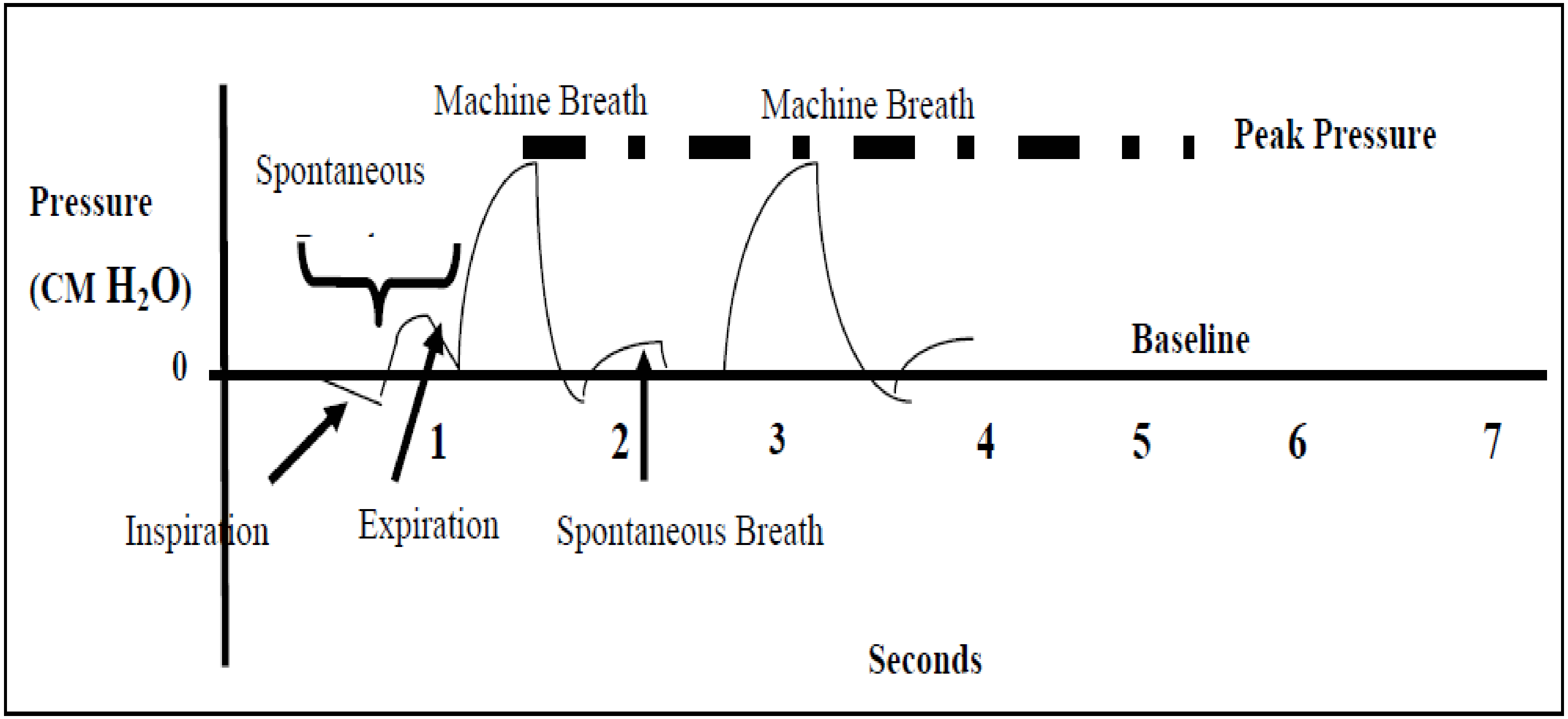
Assist Control (A/C) Ventilation

- The A/C mode is similar to CMV, but it allows the patient to trigger an assisted breath at any time.
- As with CMV, A/C ventilation can be pressure or volume controlled.
- the ventilator delivers a preset VT at a preset frequency.
- When the patient initiates a spontaneous breath, the ventilator senses a decrease in intrathoracic pressure and then delivers the preset VT
- ACV is used in patients with a variety of conditions, including neuromuscular disorders (e.g., Guillain- Barré syndrome), pulmonary edema, and acute respiratory failure.


1000
Volume in cc's
0
1
2
3
4
5
6
7
Time in Seconds

Synchronized Intermittent Mandatory Ventilation (IMV)

- **The ventilator delivers a preset VT at a preset frequency in synchrony with the patient's spontaneous breathing.**
- **Between ventilator delivered breaths, the patient is able to breathe spontaneously through the ventilator circuit.**
- **Thus the patient receives the preset FIO2 during the spontaneous breaths but self-regulates the rate and volume of those breaths.**



Machine Breath
Machine Breath
Peak Pressure
Spontaneous
Pressure
(CM H_2O)
Baseline
0
1
2
3
4
5
6
7
Inspiration
Expiration
Spontaneous Breath
Seconds

2) Pressure modes:

- A) Pressure Support (PSV)
- B) Pressure controlled ventilation (PCV)
- C) Continuous Positive Airway Pressure (CPAP)
- D) Positive end expiratory pressure (PEEP)

A) Pressure Support

- **PS provides pressure assistance to each *spontaneous* breath.**
- **positive pressure is applied to the airway only during inspiration and is used in conjunction with the patient's spontaneous respirations. The patient must be able to initiate a breath in this modality.**
- **A PS breath is supported, which means the supported breath is delivered under positive pressure but is triggered and cycled by the patient rather than the ventilator. PS reduces respiratory work of the patient by providing positive pressure during inspiration.**

- **The level of PSV should be set high enough to provide a tidal volume of 8 – 12 ml/kg and to maintain a total respiratory rate ≤ 20 breaths per minute.**
- **PSV is usually used with the SIMV mode and can also be used in combination with PEEP. PSV usually ranges from 10-30 cm H2O pressure.**

- **As the patient initiates a breath, the machine senses the spontaneous effort and supplies a rapid flow of gas at the initiation of the breath and variable flow throughout the breath. With PSV the patient determines inspiratory length, VT, and respiratory rate. VT depends on the pressure level and airway compliance.**
- **PSV is used with continuous ventilation and during weaning. PSV may also be used with SIMV during weaning.**

C) Continuous Positive Airway Pressure (CPAP)

- **The pressure in CPAP is delivered continuously during spontaneous breathing, thus preventing the patient’s airway pressure from falling to zero. For example, if CPAP is 5 cm H_2O, airway pressure during expiration is 5 cm H_2O. During inspiration, 1 to 2 cm H_2O of negative pressure is generated, thus reducing airway pressure to 3 or 4 cm H_2O.**

- **The patient receiving SIMV with PEEP receives CPAP when breathing spontaneously. CPAP is commonly used in the treatment of obstructive sleep apnea. CPAP can be administered noninvasively by a tight-fitting mask or an ET or tracheal tube. CPAP increases WOB because the patient must forcibly exhale against the CPAP.**

D) Bi-level Positive Airway Pressure

- **In addition to O2, bi-level positive airway pressure (Bi-PAP) provides two levels of positive pressure support: higher inspiratory positive airway pressure and lower expiratory positive airway pressure.**
- **It is a noninvasive modality and is delivered through a tight-fitting face mask, nasal mask, or nasal pillows. As with PSV delivered through an artificial airway, the patient must be able to spontaneously breathe and cooperate with this treatment.**
- **Bi-PAP is used for COPD patients with heart failure and acute respiratory failure and for patients with sleep apnea. Bi-PAP may also be used after extubation to prevent reintubation.**

Positive End-Expiratory Pressure

- **Is a ventilator maneuver in which positive pressure is applied to the airway during exhalation. Normally during exhalation, airway pressure drops to zero, and exhalation occurs passively. With PEEP, exhalation remains passive, but pressure falls to a preset level, often 3 to 20 cm H2O.**
- **Lung volume during expiration and between breaths is greater than normal with PEEP. This increases functional residual capacity (FRC) and often improves oxygenation with restoration of lung volume that normally remains at the end of passive exhalation.**
- **The mechanisms by which PEEP increases FRC and oxygenation include increased aeration of patent alveoli, aeration of previously collapsed alveoli, and prevention of alveolar collapse throughout the respiratory cycle.**

Common ventilator settings/ parameters/ controls

- **Fraction of inspired oxygen (FlO2):** The percent of oxygen concentration that the patient is receiving from the ventilator. (Between 21 % & 100%)
- **Tidal Volume (Vt):** Is the volume of gas delivered to a patient during a ventilator breath? i.e. the amount of air inspired and expired with each breath. (Usual volume selected is between 5 to 15 ml/ kg body weight

- **Respiratory Rate (f):** (Mandatory respiratory rate per minute) Is the number of breaths the ventilator will deliver/minute (12-14 b/m). Total respiratory rate equals patient rate plus ventilator rate.
- **Positive end expiratory pressure (PEEP)** Positive pressure applied at the end of expiration of ventilator breaths expiration to maintain alveolar recruitment during mandatory breath. Usual setting 5: 10 cm H2O

- **Pressure support (PS)** preset pressure delivered by ventilator to assess spontenous breath. Usual setting: 10-15 cm H_2O
- **I:E Ratio** (inspiration to expiration ratio): Is the ratio of inspiratory time to expiratory time during breath (Usually 1:2)
- **Minute Volume:** Is the volume of expired air in one minute (VT x f)
- **Sigh Volume**: Is a deep breath. A breath that has a greater volume than the tidal volume. It provides hyperinflation and prevents atelectasis. (Usual volume is 1.5 -2 times tidal volume, and usual rate is 4 to 5 times an hour).

Mechanical ventilation alarms and Interpreting

- ***High-pressure limit***
  - Secretions, coughing, or gagging
  - Patient fighting ventilator (ventilator asynchrony)
  - Condensate (water) in tubing
  - Kinked or compressed tubing (e.g., patient biting on endotracheal tube [ET] tube)
  - Increased resistance (e.g., bronchospasm)
  - Decreased compliance (e.g., pulmonary edema, pneumothorax)

- ***Low-pressure limit***
  - **Total or partial ventilator disconnect**
  - **Loss of airway (e.g., total or partial extubation)**
  - **ET tube or tracheotomy cuff leak (e.g., patient speaking, grunting)**
- ***Apnea***
  - **Respiratory arrest**
  - **Over-sedation**
  - **Change in patient condition**
  - **Loss of airway (e.g., total or partial extubation)**

- ***High tidal volume, minute ventilation, or respiratory rate***
  - **Pain, anxiety**
  - **Change in patient condition**
  - **Excess condensate in tubing (i.e., false reading)**
- ***Low tidal volume or minute ventilation***
  - **Change in patient's breathing efforts (e.g., rate and volume)**
  - **Patient disconnection, loose connection, or leak in circuit**
  - **ET tube or tracheotomy cuff leak (e.g., patient speaking, grunting)**
  - **Insufficient gas flow**
- ***Ventilator inoperative or low battery***
  - **Machine malfunction**
  - **Unplugged, power failure, or internal battery not charged**

Interventions for mechanical ventilation alarms

Low pressure alarm:

- **Reconnect the tube to the ventilator**
- **Check the tube placement; reposition if needed. If extubation or displacement has occurred, ventilate the patient manually and call the practitioner immediately.**
- **Make sure all connections are intact. Check for holes or leaks in the tubing and replace, if necessary. Check the humidification jar and replace, if cracked.**

High pressure alarm

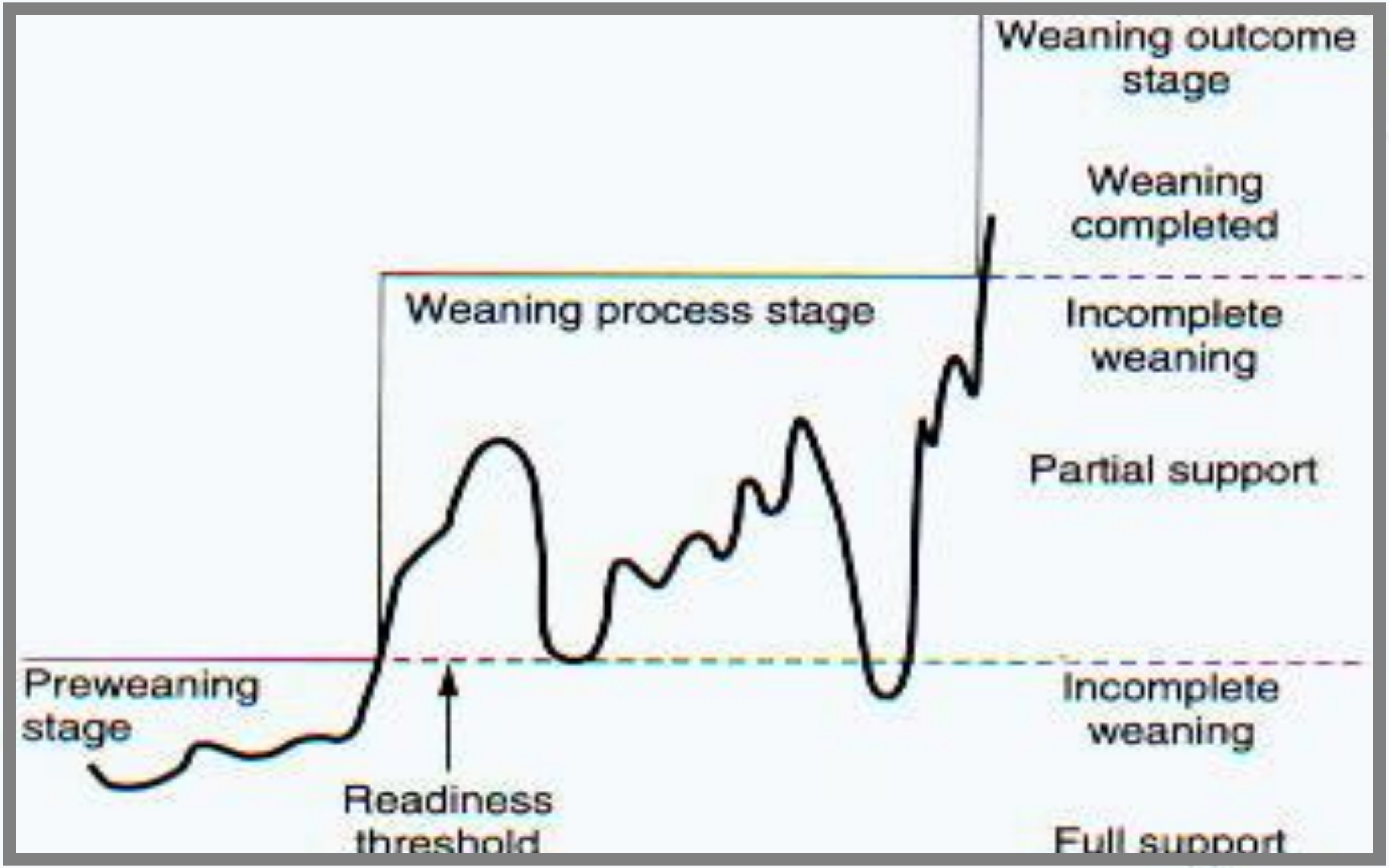
- Auscultate the lungs for evidence of increasing lung consolidation, barotrauma, or wheezing. Call the practitioner if indicated
- Insert a bite block if needed
- Look for secretions in the airway. To remove them, suction the patient or have him cough.
- Check tubing for condensate and remove any fluid
- Check tube position. If it has slipped, call the practitioner, who may need to reposition it.
- If the patient fights the ventilator, the practitioner may order a sedative or neuromuscular blocking agent
- Reposition the patient to see if doing so improves chest expansion. If repositioning doesn’t help, administer the prescribed analgesic

- **WEANING**

Weaning

- **Is the process of reducing ventilator support and resuming spontaneous ventilation.**
- **Patients can be categorized into two groups: those requiring *short-term* ventilation ($\leq$3 days) and those requiring *long-term* ventilation (>3 days).**

Weaning Continuum Model



Guidelines for Weaning From Short-Term Ventilation

- **Patients are often intubated electively for surgical or other procedures, or more urgently owing to respiratory distress related to underlying pulmonary disease or traumatic injury.**
- **The other common reason for intubation is the need for airway protection because of airway swelling (e.g., as a result of acute inhalation injury) or significant change in mental status (e.g., as with cerebrovascular accident [CVA] or head injury).**

Nursing Role in Weaning

- Reduce ventilator rate, then convert to pressure-support ventilation (PSV) only.
- Wean PSV as tolerated to ≤10 cm H2O.
- If patient meets tolerance criteria for at least 2 hours on this level of support.
- If patient fails tolerance criteria, increase PSV or add ventilator rate as needed to achieve “rest” settings (consistent respiratory rate <20 breaths/minute) and review weaning criteria for correctable factors.
- Repeat wean attempt on PSV 10 cm after rest period (minimum 2 hours). If patient fails second wean trial, return to rest settings and use “long-term” ventilation weaning approach.

Tolerance Criteria

If the patient displays any of the following, the weaning trial should be stopped and the patient returned to "rest" settings:

- **Sustained respiratory rate greater than 35 beaths/ minute**
- **SaO_2 <90%**
- **Tidal volume ≤5 mL/kg**
- **Sustained minute ventilation >200 mL/kg/minute**
- **Evidence of respiratory or hemodynamic distress: Labored respiratory pattern Increased anxiety, diaphoresis, or both Sustained heart rate >20% higher or lower than baseline Systolic blood pressure >180 mm Hg or <90 mm Hg**
- **Dysrhythmias**
- **Decrease in level of consciousness**

Guidelines for Weaning From Long-Term Ventilation

- **Patients on mechanical ventilation for longer than 72 hours or those having failed short-term weaning often display significant deconditioning as a result of acute or chronic complex illness, or both. These patients usually require a period of "exercising" respiratory muscles to regain the strength and endurance needed for successful return to spontaneous breathing.**

Goals for this process are:

- **To have the patient tolerate two to three daily weaning trials of reduction in ventilatory support without exercising to the point of exhaustion**
- **To rest the patient between weaning trials and overnight on ventilator settings that provide diaphragmatic rest, with minimal or no work of breathing for the patient**

Methods of weaning

- T-piece trial
- Continuous Positive Airway pressure (CPAP)
- Synchronized Intermittent Mandatory Ventilation (SIMV)
- Pressure Support Ventilation (PSV)

Nursing Role in Weaning

- **Transfer to pressure-support ventilation (PSV) mode, adjust support level to maintain patient's respiratory rate at less than 35 breaths/minute.**
- **Observe for 30 minutes for signs of early failure (same tolerance criteria as with short-term ventilation).**
- **If tolerated, continue trial for 2 hours, then return patient to "rest" settings by adding ventilator breaths or increasing PSV to achieve a total respiratory rate of less than 20 breaths/minute.**
- **After at least 2 hours of rest, repeat trial for 2 to 4 hours at same PSV level as previous trial. If the patient exceeds the tolerance criteria, stop the trial and return to "rest" settings. In this case, the next trial should be performed at a higher support level than the "failed" trial.**

- **Record the results of each weaning episode, including specific parameters and the time frame if “failure” observed, on the bedside flow sheet.**
- **The goal is to increase the length of the trials and reduce the PSV level needed on an incremental basis. With each successive trial, the PSV level may be decreased by 2 to 4 cm H2O, the time interval may be increased by 1 to 2 hours, or both, while keeping the patient within tolerance parameters.**
- **Ensure nocturnal ventilation at “rest” settings (with a respiratory rate of <20 breaths/minute) for at least 6 hours each night until the patient’s weaning trials demonstrate readiness to discontinue ventilatory support.**

Complications of Positive Pressure Ventilation

- ***Cardiovascular System***, **PPV can affect circulation because of the transmission of increased mean airway pressure to the thoracic cavity. increased intrathoracic pressure, thoracic vessels are compressed. This results in decreased venous return to the heart, decreased left ventricular end-diastolic volume (preload), decreased CO, and hypotension. Mean airway pressure is further increased if titrating PEEP (greater than 5 cm H2O) to improve oxygenation.**

- ***Pulmonary System***
- **Barotrauma. As lung inflation pressures increase, risk of barotrauma increases. This results when the increased airway pressure distends the lungs and possibly ruptures fragile alveoli or emphysematous blebs. Air can escape into the pleural space from alveoli or interstitium and become trapped. Pleural pressure increases and collapses the lung, causing a life threatening tension pneumothorax.**

- **Volutrauma. The concept of volutrauma in PPV relates to the lung injury that occurs when a large VT is used to ventilate noncompliant lungs. Volutrauma results in alveolar fractures and movement of fluids and proteins into the alveolar spaces.**
- **Alveolar Hypoventilation. can be caused by inappropriate ventilator settings, leakage of air from the ventilator tubing or around the ET tube or tracheostomy cuff, lung secretions or obstruction, and low ventilation/ perfusion ratio. A low VT or respiratory rate decreases minute ventilation. This results in hypoventilation and leads to *respiratory acidosis.***
- **Alveolar Hyperventilation. *Respiratory alkalosis* can occur if the respiratory rate or VT is set too high (mechanical overventilation) .**

- **Ventilator-Associated Pneumonia. The risk for hospital acquired pneumonia is highest in patients requiring mechanical ventilation because the ET or tracheostomy tube bypasses normal upper airway defenses. In addition, a poor nutritional state, immobility, and the underlying disease process (e.g., immunosuppression, organ failure) make the patient more prone to infection.**

- ***Sodium and Water Imbalance*: Progressive fluid retention often occurs after 48 to 72 hours of PPV, especially PPV with PEEP. Fluid retention is associated with decreased urine output and increased sodium retention. Fluid balance changes may be due to decreased CO, which in turn results in diminished renal perfusion. Consequently, renin release is stimulated with subsequent production of angiotensin and aldosterone. This results in sodium and water retention.**

- ***Neurologic System***. **In patients with head injury, PPV (especially with PEEP) can impair cerebral blood flow. The increased intra-thoracic positive pressure impedes venous drainage from the head, resulting in jugular venous distention. The patient may exhibit increases in intracranial pressure because of the impaired venous return and increase in cerebral volume.**

- ***Gastrointestinal System*: Patients receiving PPV are stressed because of the serious illness, immobility, or discomforts associated with the ventilator.**
- **This places the ventilated patient at risk for developing *stress ulcers* and GI bleeding. Patients with a preexisting ulcer or those receiving corticosteroids are at an increased risk. Any kind of circulatory compromise, including reduction of CO caused by PPV, may contribute to ischemia of the gastric and intestinal mucosa and possibly increase the risk of *translocation of GI bacteria*.**

- To decrease the risk of VAP, guidelines support the use of routine peptic ulcer prophylaxis in mechanically ventilated patients. Peptic ulcer prophylaxis includes the administration of histamine (H2)-receptor blockers (e.g., ranitidine [Zantac]), proton pump inhibitors (PPIs) (e.g., esomeprazole [Nexium]), and enteral nutrition to decrease gastric acidity and diminish the risk of stress ulcer and *hemorrhage.*

- ***Musculoskeletal System*. the problems associated with immobility are pressure ulcers, footdrop, and external rotation of the hip and legs.**
- ***Psychosocial Needs.* The patient receiving mechanical ventilation often experiences physical and emotional stress.**

Relative contraindications

- Inability to cooperate, protect the airway, or clear secretions
- Non respiratory organ failure
- Facial surgery, trauma, or deformity
- High aspiration risk
- Prolonged duration of mechanical ventilation anticipated
- Recent esophageal anastomosis.


Thank You!