Mechanical Ventilation

Introduction:

Mechanical ventilation is one of the most commonly applied interventions in intensive care units. Despite its life-saving role, mechanical ventilation is associated with additional risks to the patient and additional healthcare costs if not applied appropriately. Mechanical ventilation may be required for a variety of reasons: to control the patient's respirations during surgery or during treatment of severe head injury, to oxygenate the blood when the patient's ventilator efforts are inadequate, and to rest the respiratory muscles, among others.

Definition of mechanical ventilation:-

- Mechanical ventilator is a positive- or negative-pressure breathing device that can maintain ventilation and oxygen delivery for a prolonged period.
- Mechanical ventilation is defined as an 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.

Indications

A) - Objective criteria for consideration of mechanical ventilation include:

- Respiratory rate >35 mmHg
- Oxygenation: PaO2 <60 mmHg (8 kPa) on 60% oxygen
- Ventilation: PaCO2 >60 mmHg (8 kPa) accompanied by arterial pH <7.3.

B) - Clinical applications can be summarized as follows:

- Cardiopulmonary resuscitation

- Respiratory failure
- Postoperative ventilation following major surgery, to permit correction of homeostatic disturbances before the patient awakens (eg, hypothermia, electrolyte imbalance, profound anemia)
- Severe sepsis, when the patient is unable to meet the increased work of breathing demanded by high CO2 production and metabolic acidosis
- Control of PaCO2 as part of the management of severe intracranial hypertension (eg, head injuries).
- Support ventilation in patients requiring endotracheal intubation to protect/ maintain the airway
- Reduction of cardiac work in cardiogenic shock.

Classification of Ventilators

A) - Positive Pressure Ventilation

1. **Volume-Cycled Ventilator:** Delivers a preset constant volume of air and preset O2.
2. **Pressure-Cycled Ventilator:** Produces a flow of gas that inflates the lung until the preset airway pressure is reached.
3. **Time-Cycled Ventilator:** Programmed to deliver a volume of gas over a specific time period through adjustments in inspiratory to- expiratory ratio.
4. High-Frequency Jet Ventilator (HFJV): Delivers 60–100 bpm with low tidal volumes under considerable pressures.

B) - Negative Pressure Ventilation

Use the old iron lung principle by exerting a negative pressure on the chest wall to cause inspiration. No intubation required. Custom fitted “cuirass” or

“turtle” shell unit that fits over the chest wall, May be utilized at night for patients who require assistance during sleep.

Modes of Ventilation

1. **Controlled Mechanical Ventilation (CMV):** Machine controls rate of breathing. Delivery of preset volume (TV) and rate regardless of patient’s breathing pattern. Sedation or paralyzing agent (e.g., Pavulon) usually required.

2. **Assist Controlled Ventilation (ACV):** Patient controls rate of breathing. Inspiratory effort triggers delivery of preset volume. Between machine-initiated breaths, the patient can trigger the ventilator, and receive an assisted breath at a preset VT.

3. **Intermittent Mandatory Ventilation (IMV):** in which mandatory (machine) breaths are delivered at a set frequency and preset VT Patient breathes spontaneously (own tidal volume) between ventilator breaths of a preset volume and rate.

4. **Synchronized Intermittent Mandatory Ventilation (SIMV):** A form of pressure support ventilation. Administers mandatory ventilator breath at a preset level of positive airway pressure. Monitors negative inspiratory effort and augments patient’s spontaneous tidal volume or inspiratory effort, Synchronized with patient’s breathing pattern.

5. **Positive End-Expiratory Pressure (PEEP):** Increases oxygenation by increasing functional residual capacity (FRC). Keeps alveoli inflated after expiration. Can use lower O2 concentrations with PEEP; decreases risk of O2 toxicity, Ordered as 5–10 cm H2O.

6. **Continuous Positive Airway Pressure (CPAP):** Maintains positive pressure throughout the respiratory cycle of a spontaneously breathing patient. Increases the amount of air remaining in the lungs at the end of expiration, less complications than PEEP. Ordered as 5–10 cmH2O.

7. **Bi-level Positive Airway Pressure (BiPAP):** Same as CPAP but settings can be adjusted for both inspiration and expiration.

8. **Pressure Support Ventilation (PSV):** Patient's inspiratory effort is assisted by the ventilator to a certain level of pressure. Patient initiates all breaths and controls flow rate and tidal volume. Decreases work of breathing.

9. **Inverse Ratio Ventilation (IRV):** All breaths are pressure limited and time cycled. Inspiratory time usually set longer than expiratory time.

NOTE: IMV, SIMV, CPAP, BiPAP and PSV can all be used in the weaning process.

Criteria for institution of ventilatory support:

Parameters	Ventilation indicated	Normal range
Pulmonary function studies:		
• Respiratory rate	• >35(breaths / min).	• 10-20
• Tidal volume spontaneously	• <5 (ml/kg body wt.)	• 5-7
• Vital capacity	• <15(ml/kg body wt)	• 65-75
• Maximum inspiratory force (cm H2o)	• <-20	• 75-100
• GCS	• < 8	• 13-15

Arterial blood gases: • PH • PaO2 (mmHg) • PaCO2(mmHg)	 • <7.25 • <60 • >50	 • 7.35 -7. 45 • 75- 100 • 35 - 45

Common ventilator settings/ parameters/ controls

Parameter	Definition	Usual setting
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 or expired with each breath.	between 5 to 15 ml/ kg body weigh
Respiratory Rate (f):	(**Mandatory respiratory rate**) 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.	5: 10 cm H2O
Pressure support (PS)	Preset pressure delivered by ventilator to assess spontaneous breath.	10-15 cm H2O
I:E Ratio:	Is the ratio of inspiratory time to expiratory time during breath	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.
Peak inspiratory pressure limits (high-pressure alarm).	It is the highest pressure allowed in the ventilator circuit where the inspiration is terminated.	
Sensitivity.	The sensitivity function controls the amount of patient effort needed to initiate an inspiration, as measured by negative inspiratory effort**.**	

Ventilator Alarms:

Ventilator alarms should never be ignored or turned off. They may be muted or silenced temporarily until problem is resolved.

Common Causes of Ventilator Alarms

1- Patient causes:

- Biting down on endotracheal tube.
- Patient needs suctioning.
- Coughing.
- Gagging on endotracheal tube.
- Patient “bucking” or not synchronous with the ventilator.

- Patient attempting to talk.
- Patient experiences period of apnea.

2- Mechanical causes:

- Kinking of ventilator tubing.
- Endotracheal tube cuff may need more air.
- Leak in endotracheal tube cuff.
- Excess water in ventilator tubing.
- Leak or disconnect in the system.
- Air leak from chest tube if present.
- Malfunctioning of oxygen system.
- Loss of power to ventilator.

3- Pathophysiological causes:

- Increased lung noncompliance, such as in ARDS.
- Increased airway resistance, such as in bronchospasm.
- Pulmonary edema.
- Pneumothorax or hemothorax.

Nursing Interventions for controlling ventilator alarms:

1. Check ventilator disconnects and tubing.
2. Assess breath sounds, suction as needed.
3. Remove excess water from ventilator tubing.
4. Check endotracheal cuff pressure.
5. Insert bite block or oral airway.

- If cause of the alarm cannot be found immediately or cause cannot be readily resolved, remove patient from ventilator and manually ventilate patient using a resuscitation bag.
- Call respiratory therapy stat.
- Continue to assess patient's respiratory status until mechanical ventilation is resumed.

Complications of Mechanical Ventilation:

Complications	Signs & symptoms & Nursing intervention
Barotrauma or volutrauma—acute lung injury, may result in pneumothorax or tension pneumothorax, subcutaneous crepitus	1- High peak inspiratory and mean airway pressures. 2- Diminished breath sounds. 3- Tracheal shift. 4- Subcutaneous crepitus. 5- Hypoxemia **(NI):** Insert chest tube or needle thoracotomy
Intubation of right mainstem bronchus	1. Absent or diminished breath sounds in left lung. 2. Unilateral chest excursion **(NI):** Reposition ETT
Endotracheal tube out of position or unplanned extubation	1. Absent or diminished breath sounds **Note** location of tube at the lip (21–22 cm). **(NI):** Reposition ETT or reintubate. -Restrain only when necessary.
Tracheal damage due to	1. Blood in sputum when suctioning

excessive cuff pressure (>30 cm H2O)	2. Frequent ventilator alarm **(NI):** Monitor ETT cuff pressure every 4–8 hrs. - Perform minimal leak technique. - Ensure minimal occluding volume.
Aspiration: Tracheo-esophageal fistulas	1. Feeding viewed when suctioning 2. If blue dye is used, sputum is blue in color **(NI):** Use blue dye with enteral feedings if aspiration suspected. - Keep head of bed 30–45 degrees. - Administer proton pump inhibitors or histamine. - H2-receptor antagonists.
Ventilator-assisted pneumonia (Respiratory infection)	1. Refer to section on VAP **(NI):** Assess color and odor of sputum. - Monitor temperature, WBC count, ESR.
Decreased venous return due to increased intrathoracic pressure	1- Hypotension. 2- Decreased CVP, RAP, and preload **(NI):** Monitor vital signs and hemodynamics.
Damage to oral or nasal mucosa	1- Skin breakdown or necrosis to lips, nares, or oral mucous membranes **(NI):** - Reposition tube side-side of mouth every day. - Apply petroleum jelly to nares. - Provide oral care with toothbrush every 2 hrs.

Stress ulcer and GI bleeding	1- Blood in nasogastric drainage 2- Hematemesis and/or melena **(NI):** - Administer proton pump inhibitors or histamine. - H2-receptor antagonists.
Increased intracranial pressure	1- Changes in level of consciousness 2- Unable to follow commands **(NI):** Assess neurological status frequently.
Immobility Skin breakdown	**(NI):** -Turn and position patient frequently. - Assess skin for breakdown. - Assist patient out of bed to chair unless contraindicated. - Keep skin clean and dry, sheets wrinkle free.
Communication difficulties	**(NI):** Keep communication simple. - Obtain slate or writing board. - Use letter/picture chart. - Communicate using sign language.
Urinary tract infection	1- Urine becomes cloudy, concentrated, odorous - **(NI):** Change/remove Foley catheter. - Ensure adequate hydration. - Administer anti-infective.
Deep vein thrombosis	1- Painful, swollen leg; pain may increase on dorsiflexion **(NI):** Assess for pulmonary embolism. See respiratory section.

	Administer heparin or enoxaparin.
Psychosocial concerns: fear, loss, powerlessness, pain, anxiety, sleep disturbances, nightmares, loneliness	• Anxious • Difficulty sleeping • Poor pain control **(NI):** - Administer anxiolytics, sedatives, and analgesics. - Cluster activities to promote periods of sleep. - Allow patient to make choices when appropriate. - Allow for frequent family visits. - Keep patient and family informed.

Weaning

Definitions:

- **Weaning**: is the process of withdrawing mechanical ventilatory support and transferring the work of breathing from the ventilator to the patient. In most cases, weaning may be accomplished rapidly from full ventilatory support to unassisted spontaneous breathing.
- **Weaning success:** is defined as absence of ventilatory support 48 hours following the extubation. While the spontaneous breaths are unassisted by mechanical ventilation, supplemental oxygen, bronchodilators, pressure support ventilation, or continuous positive airway pressure may be used to support and maintain adequate spontaneous ventilation.
- **Weaning failure**: is defined as either the failure of spontaneous breathing trial (SBT) or the need for reintubation within 48 hours following extubation.

Sample Criteria for Weaning: Readiness

1- Alert and cooperative.

2- FIO2 < 40%–50% and PEEP <5–8 cm H2O.

3- Hemodynamically stable.

4- PH >7.3.

5- PaO2 >80 mm Hg.

6- PaCO2 <45 mm Hg.

7- PaO2/FIO2 ratio >200.

8- Vital capacity 15 mL/kg and minute ventilation <10.

9- Hemoglobin >7–9 g/dL and serum electrolytes within normal limits.

10- Spontaneous respirations >6 b/min. or <35 b/min.

11- Negative inspiratory pressure –30 cm H2O.

12- Relatively afebrile with limited respiratory secretions.

13- Inotropes reduced or unchanged within previous 24 hrs.

14- Sedation discontinued.

Weaning Methods

■ **T-tube weaning:** Place patient on T-tube circuit on same FIO2 as on ventilatory assistance. Monitor ABGs after 30 min. provide a brief rest period on the ventilator as needed and continue to monitor ABGs until satisfactory. Extubate when patient is rested, good spontaneous respiratory effort and ABGs within acceptable parameters.

■ **IMV/SIMV weaning:** Decrease IMV rates every 1–4 hrs. Monitor spontaneous breaths. Obtain ABGs within 30 min. of ventilator change. Allows for gradual change from positive-pressure ventilation to spontaneous- pressure ventilation.

■ **PSV:** Use low levels of PSV (5–10 cm H2O). Decrease in 3–6 cm of H2O increments, Useful in retraining respiratory muscles due to long-term ventilation.

■ **CPAP/BiPAP:** Provides expiratory support, maintains positive intrathoracic pressure. BiPAP adds inspiratory support to CPAP. Prevents respiratory muscle fatigue.

Nursing assessment during weaning

1- Vital signs and hemodynamics.

2- Dysrhythmias or ECG changes.

3- Oxygenation/Efficiency of gas exchange.

4- CO_2 production and elimination.

5- PH level.

6- Bedside pulmonary function tests.

7- Work of breathing including use of accessory muscles.

8- Level of fatigue.

9- Patient discomfort.

10- Adequate nutrition.

Signs of weaning intolerance

- Dysrhythmias
- Increase or decrease in heart rate of >20b/m or heart rate >110b/m.
- Increase or decrease in blood pressure of >20mmHg.
- Increase in respiratory rate of >10 above baseline or >30
- Diaphoresis
- Dyspnea
- Restlessness
- Decrease in level of consciousness
- $Sao_2 < 90\%$
- $Pao_2 < 60$ mmHg
- Increase in $Paco_2$ with a decrease in PH of < 7.35.