بسم الله الرحمن الرحيم

Mechanical Ventilation

- Mechanical Ventilation is ventilation of the lungs by artificial means usually by a ventilator.
- A ventilator delivers gas to the lungs with either negative or positive pressure.

Purposes:

- To maintain or improve ventilation, & tissue oxygenation.

- To decrease the work of breathing & improve patient's comfort.

Indications:

1- Acute respiratory failure due to:

Mechanical failure, includes neuromuscular diseases as Myasthenia Gravis, Guillain-Barré Syndrome, and Poliomyelitis (failure of the normal respiratory neuromuscular system)

Musculoskeletal abnormalities, such as chest wall trauma (flail chest)

Infectious diseases of the lung such as pneumonia, tuberculosis.

2- Abnormalities of pulmonary gas exchange as in:

- Obstructive lung disease in the form of asthma, chronic bronchitis or emphysema.

- Conditions such as pulmonary edema, atelectasis, pulmonary fibrosis.

- Patients who has received general anesthesia as well as post cardiac arrest patients often require ventilatory support until they have recovered from the effects of the anesthesia or the insult of an arrest.

Criteria for institution of ventilatory support:

Parameters	Ventilation indicated	Normal range
A- Pulmonary function studies:		
• Respiratory rate (breaths/min).	> 35	10-20
• Tidal volume (ml/kg body wt)	< 5	5-7
• Vital capacity (ml/kg body wt)	< 15	65-75
• Maximum Inspiratory Force (cm HO_2)	<-20	75-100

Criteria for institution of ventilatory support:

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

Common Ventilator Settings parameters/ controls

* Fraction of inspired oxygen (FIO_2)
* Tidal Volume (VT)
* Peak Flow/ Flow Rate
* Respiratory Rate/ Breath Rate / Frequency (F)
* Minute Volume (VE)
* I:E Ratio (Inspiration to Expiration Ratio)

● Fraction of inspired oxygen (FIO2)

*The percent of oxygen concentration that the patient is receiving from the ventilator. (Between 21% & 100%) (room air has 21% oxygen content).

* Initially a patient is placed on a high level of FIO_2 (60% or higher).

* Subsequent changes in FIO_2 are based on ABGs and the SaO_2.

* **In adult patients** the initial FiO_2 may be set at 100% until arterial blood gases can document adequate oxygenation.

* An FiO_2 of 100% for an extended period of time can be dangerous **(oxygen toxicity)** but it can protect against hypoxemia

* **For infants**, and especially **in premature infants**, high levels of FiO_2 (>60%) should be avoided.

* Usually the FIO_2 is adjusted to maintain an SaO_2 of greater than 90% (roughly equivalent to a PaO_2 >60 mm Hg).

* **Oxygen toxicity** is a concern when **an FIO_2 of greater than 60% is required** for more than 25 hours

Signs and symptoms of oxygen toxicity :-

1- Flushed face

2- Dry cough

3- Dyspnea

4- Chest pain

5- Tightness of chest

6- Sore throat

● Tidal Volume (VT)

* The volume of air delivered to a patient during a ventilator breath.

* Usual volume selected is between 5 to 15 ml/ kg body weight)

* the large tidal volumes may lead to (volutrauma) aggravate the damage inflicted on the lungs

* For this reason, lower tidal volume targets (6 to 8 mL/kg) are now recommended

● Peak Flow/ Flow Rate

* The speed of delivering air per unit of time, and is expressed in liters per minute.

* The higher the flow rate, the faster peak airway pressure is reached and the shorter the inspiration;

* The lower the flow rate, the longer the inspiration.

● Respiratory Rate/ Breath Rate / Frequency (F)

* The number of breaths the ventilator will deliver/minute (10-16 b/m).

* Total respiratory rate equals patient rate plus ventilator rate.

* The nurse double-checks the functioning of the ventilator by observing the patient’s respiratory rate.

● Minute Volume (VE)

* The volume of expired air in one minute .

* Respiratory rate times tidal volume equals minute ventilation

$$VE = (VT \times F)$$

● I:E Ratio (Inspiration to Expiration Ratio):-

The ratio of inspiratory time to expiratory time during a breath

(Usually = 1:2)

Types of Positive-Pressure Ventilators

1-Volume Ventilators.

2- Pressure Ventilators

1- Volume Ventilators

* The volume ventilator is commonly used in critical care settings.

* The basic principle of this ventilator is that a designated volume of air is delivered with each breath.

* The amount of pressure required to deliver the set volume depends on :-

- Patient's lung compliance
- Patient–ventilator resistance factors.

* Therefore, peak inspiratory pressure (PIP) must be monitored in volume modes because it varies from breath to breath.

* With this mode of ventilation, a respiratory rate, inspiratory time, and tidal volume are selected for the mechanical breaths.

2- Pressure Ventilators

* The use of pressure ventilators is increasing in critical care units.

* A typical pressure mode delivers a selected gas pressure to the patient early in inspiration, and sustains the pressure throughout the inspiratory phase.

* By meeting the patient's inspiratory flow demand throughout inspiration, patient effort is reduced and comfort increased.

* Although pressure is consistent with these modes, volume is not.

* Volume will change with changes in resistance or compliance,

* Therefore, exhaled tidal volume is the variable to monitor closely.

* With pressure modes, the pressure level to be delivered is selected, and with some mode options (i.e., pressure controlled [PC], described later), rate and inspiratory time are preset as well.

Ventilator mode

* The way the machine ventilates the patient

* How much the patient will participate in his own ventilatory pattern.

* Each mode is different in determining how much work of breathing the patient has to do.

Modes of Mechanical Ventilation

A- Volume Modes

B- Pressure Modes

A- Volume Modes

1-Control Mode (CM)

2- Assist-control (A/C)

3- Synchronized intermittent mandatory ventilation (SIMV)

1- Control Mode (CM) Continuous Mandatory Ventilation (CMV)

* Ventilation is completely provided by the mechanical ventilator with a preset tidal volume, respiratory rate and oxygen concentration

* Ventilator totally controls the patient's ventilation i.e. the ventilator initiates and controls both the volume delivered and the frequency of breath.

* Client does not breathe spontaneously.

* Client can not initiate breathe

2- Assist Control Mode A/C

* The ventilator provides the patient with a pre-set tidal volume at a pre-set rate .

* The patient may initiate a breath on his own, but the ventilator assists by delivering a specified tidal volume to the patient. Client can initiate breaths that are delivered at the preset tidal volume.

* Client can breathe at a higher rate than the preset number of breaths/minute

* The total respiratory rate is determined by the number of spontaneous inspiration initiated by the patient plus the number of breaths set on the ventilator.

* In A/C mode, a mandatory (or "control") rate is selected.

* If the patient wishes to breathe faster, he or she can trigger the ventilator and receive a full-volume breath.

3- Synchronized Intermittent Mandatory Ventilation (SIMV)

* The ventilator provides the patient with a pre-set number of breaths/minute at a specified tidal volume and FiO_2.

* In between the ventilator-delivered breaths, the patient is able to breathe spontaneously at his own tidal volume and rate with no assistance from the ventilator.

* The tidal volume of these breaths can vary drastically from the tidal volume set on the ventilator, because the tidal volume is determined by the patient's spontaneous effort.

* Adding pressure support during spontaneous breaths can minimize the risk of increased work of breathing.

* Ventilators breaths are synchronized with the patient spontaneous breathe. (no fighting)

* Used to wean the patient from the mechanical ventilator.

* Weaning is accomplished by gradually lowering the set rate and allowing the patient to assume more work

B- Pressure Modes

1- Pressure-controlled ventilation (PCV)

2- Pressure-support ventilation (PSV)

3- Continuous positive airway pressure (CPAP)

4- Positive end expiratory pressure (PEEP)

1- Pressure-Controlled Ventilation Mode (PCV)

The PCV mode is used

- **If compliance is decreased and the risk of barotrauma is high.**
- **It is used when the patient has persistent oxygenation problems despite a high FiO_2 and high levels of PEEP.**

*** The inspiratory pressure level, respiratory rate, and inspiratory–expiratory (I:E) ratio must be selected.**

* In pressure controlled ventilation the breathing gas flows under constant pressure into the lungs during the selected inspiratory time.
* The flow is highest at the beginning of inspiration(i.e when the volume is lowest in the lungs).
* volume varies with compliance and airway resistance and must be closely monitored.
* Sedation and the use of neuromuscular blocking agents are frequently indicated, because any patient–ventilator asynchrony usually results in profound drops in the SaO_2.

* Inverse I:E ratios are used in conjunction with pressure control to improve oxygenation by expanding stiff alveoli by using longer distending times, thereby providing more opportunity for gas exchange and preventing alveolar collapse.

* When the PCV mode is used, the mean airway and intrathoracic pressures rise, potentially resulting in a decrease in cardiac output and oxygen delivery. Therefore, the patient's hemodynamic status must be monitored closely.

2- Pressure Support Ventilation (PSV)

* The patient breathes spontaneously while the ventilator applies a pre-determined amount of positive pressure to the airways upon inspiration.

* Pressure support ventilation augments patient's spontaneous breaths with positive pressure boost during inspiration i.e. assisting each spontaneous inspiration.

* Helps to overcome airway resistance and reducing the work of breathing.

* It is a mode used primarily for weaning from mechanical ventilation.

* Indicated for patients with small spontaneous tidal volume and difficult to wean patients.

* Patient must initiate all pressure support breaths.

* Pressure support ventilation may be combined with other modes such as SIMV or used alone for a spontaneously breathing patient.

* The patient’s effort determines the rate, inspiratory flow, and tidal volume.

* In PSV mode, the inspired tidal volume and respiratory rate must be monitored closely to detect changes in lung compliance.

3- Continuous Positive Airway Pressure (CPAP)

- **Constant positive airway pressure during spontaneous breathing**

- **CPAP allows the nurse to observe the ability of the patient to breathe spontaneously while still on the ventilator.**

- **CPAP can be used for intubated and nonintubated patients.**

4- Positive end expiratory pressure (PEEP)

- Positive pressure applied at the end of expiration during mandatory \ ventilator breath

- positive end-expiratory pressure with positive-pressure (machine) breaths.

Uses of CPAP & PEEP

- Prevent atelactasis or collapse of alveoli
- Treat atelactasis or collapse of alveoli
- Improve gas exchange & oxygenation
- Treat hypoxemia refractory to oxygen therapy.(prevent oxygen toxicity
- Treat pulmonary edema (pressure help expulsion of fluids from alveoli

Complications of Mechanical Ventilation:-

I- Airway Complications,

II- Mechanical complications,

III- Artificial Airway Complications

I- Airway Complications

1- Aspiration

2- Decreased clearance of secretions

3- Nosocomial or ventilator-acquired pneumonia

II- Mechanical complications

1- Hypoventilation with atelectasis with respiratory acidosis or hypoxemia.
2- Hyperventilation with hypocapnia and respiratory alkalosis
3- Barotrauma
   a- Closed pneumothorax,
   b- Tension pneumothorax,
4- Failure of alarms or ventilator
5- Inadequate nebulization or humidification
6- Overheated inspired air, resulting in hyperthermia

III- Artificial Airway Complications

A- Complications related to Endotracheal Tube:-

1- Tube kinked or plugged

2- Tracheal stenosis or tracheomalacia

3- Cuff failure

4- Sinusitis

5- Otitis media

6- Laryngeal edema

B- Complications related toTracheostomy tube:-

1- Acute hemorrhage at the site
2- Air embolism
3- Aspiration
4- Tracheal stenosis
5- Failure of the tracheostomy cuff
6- Laryngeal nerve damage
7- Obstruction of tracheostomy tube
8- Tracheoesophageal fistula
9- Infection

Nursing care of patients on mechanical ventilation

Assessment:

1- Assess the patient

2- Assess the artificial airway (tracheostomy or endotracheal tube)

3- Assess the ventilator

Nursing Interventions

1-Maintain airway patency & oxygenation

2- Promote comfort

3- Maintain fluid & electrolytes balance

4- Maintain nutritional state

5- Maintain urinary & bowel elimination

6- Maintain eye , mouth and cleanliness and integrity

7- Maintain mobility/ musculoskeletal function

8- Maintain safety

9- Provide psychological support

10- Facilitate communication

11- Responding to ventilator alarms /Troublshooting

ventilator alarms

12- Prevent nosocomial infection

13- Documentation

Ensuring humidification and thermoregulation

*All air delivered by the ventilator passes through the water in the humidifier, where it is warmed and saturated.

* Humidifier temperatures should be kept close to body temperature 35 ºC- 37ºC.

* In some rare instances (severe hypothermia), the air temperatures can be increased.

* The humidifier should be checked for adequate water levels

* An empty humidifier contributes to drying the airway, often with resultant dried secretions, mucus plugging and less ability to suction out secretions.

* Humidifier should not be overfilled as this may increase circuit resistance and interfere with spontaneous breathing.

* As air passes through the ventilator to the patient, water condenses in the corrugated tubing. This moisture is considered contaminated and must be drained into a receptacle and not back into the sterile humidifier.

* If the water is allowed to build up, resistance is developed in the circuit and PEEP is generated. In addition, if moisture accumulates near the endotracheal tube, the patient can aspirate the water.

Ventilator alarms:-

* Mechanical ventilators comprise audible and visual alarm systems, which act as immediate warning signals to altered ventilation.

* Alarm systems can be categorized according to volume and pressure (high and low).

* High-pressure alarms warn of rising pressures.

* Low-pressure alarms warn of disconnection of the patient from the ventilator or circuit leaks.

Causes of Ventilator Alarms

High pressure alarm

***Increased secretions**
*** Kinked ventilator tubing or endotracheal tube (ETT)**
*** Patient biting the ETT**
*** Water in the ventilator tubing.**
*** ETT advanced into right mainstem bronchus.**

Low pressure alarm

* Disconnected tubing
* A cuff leak
* A hole in the tubing (ETT or ventilator tubing)
* A leak in the humidifier

Oxygen alarm

The oxygen supply is insufficient or is not properly connected.

High respiratory rate alarm

* Episodes of tachypnea,
* Anxiety,
* Pain,
* Hypoxia,
* Fever.

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Apnea alarm

* During weaning, indicates that the patient has a slow Respiratory rate and a period of apnea.

Temperature alarm

* Overheating due to too low or no gas flow.

Improper water levels

Weaning readiness Criteria

* Awake and alert

* Hemodynamically stable, adequately resuscitated, and not requiring vasoactive support

* Arterial blood gases (ABGs) normalized or at patient’s baseline

- $PaCO_2$ acceptable
- PH of 7.35 – 7.45
- $PaO_2 > 60$ mm Hg ,
- $SaO_2 > 92\%$
- $FIO_2 \leq 40\%$

* Positive end-expiratory pressure (PEEP) ≤5 cm H_2O
* F < 25 / minute
* Vt 5 ml / kg
* VE 5- 10 L/m (f x Vt)
* VC > 10- 15 ml / kg
* PEP (positive expiratory pressure) > - 20 cm H2O (indicates patient's ability to take a deep breath & cough)
* Chest x-ray reviewed for correctable factors; treated as indicated,
* Hematocrit >25%,
* Core temperature >36°C and <39°C,

Role of nurse duringweaning:-

1- Ensure that indications for the implementation of Mechanical ventilation have improved

2- Ensure that all factors that may interfere with successful weaning are corrected:-

- Acid-base abnormalitie
- Fluid imbalance
- Electrolyte abnormalities
- Infection
- Fever
- Anemia
- Hyperglycemia
- Protein
- Sleep deprivation

Role of nurse during weaning:-

3- Ensure that the weaning criteria / parameters are met.

4- Explain the process of weaning to the patient and offer reassurance to the patient.

5- Initiate weaning in the morning when the patient is rested.

6- Elevate the head of the bed & Place the patient upright

7- Ensure a patent airway and suction if necessary before a weaning trial, 8- Provide for rest period on ventilator for 15 – 20 minutes after suctioning

9- Ensure patient's comfort & administer pharmacological agents for comfort, such as bronchodilators or sedatives as indicated.

10- Help the patient through some of the discomfort and apprehension.

11- Evaluate and document the patient's response to weaning.

Good Luck