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Background of the present Study

An Exploratory study was conducted to assess the knowledge of staff nurses regarding Mechanical Ventilation in Critical Care areas of Christian Medical College and Hospital, Ludhiana, Punjab. The sample size was 110 staff nurses working in Critical Care Areas and sample was selected by using non-probability sampling technique and the data was collected by using self-structured knowledge questionnaire on Mechanical Ventilation. The results showed that, 52(47.3%) staff nurses had average level of knowledge and 32 (29%) of staff nurses had good level of knowledge, while 20(18.2%) of the staff nurses had below average level of knowledge and only 6(5.5%) of the staff nurses had excellent level of knowledge regarding Mechanical Ventilation. These guidelines are prepared with the aim to enhance the knowledge of staff nurses regarding Mechanical Ventilation.

Thus these guidelines are intended to provide information to update the knowledge of Staff Nurses related to:

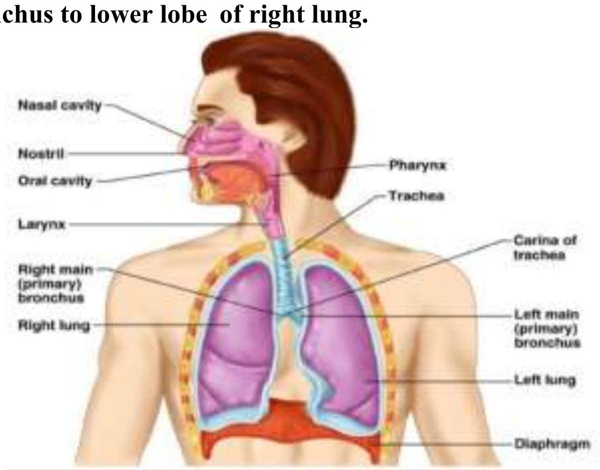
- Conceptualization of M.V
- Indications and Contraindications for M.V
- Components of M.V
- Types of Ventilator Modes
- Initial Settings of Ventilator
- Troubleshooting Problems of M.V
- Weaning from M.V
- Complications of M.V
- Nursing Responsibilities related to the care of patient on M.V

Review of Respiratory System

- The lungs are cone shaped organs that have a total volume air 3.5 to 8.5 liters
- The intrapleural pressure is – 4 to - 10cm of H_2O. The negative pressure in the pleural space keep the lugs inflated.
- The intrapleural pressure is always 1) less than intrapulmonary pressure

2) less than atmospheric pressure 3) considered negative because of the pull of the two pleural membrane in opposite direction.

- During the normal and quite respiration the diaphragm does the 80% of the work of breathing. The action of diaphragm is governed with medulla which sends the impulses through the phrenic nerve.
- The phrenic nerve arises from cervical plexus from C4.And contributory nerves from C3 to C5. Hence trauma involving levels C3-C5 causes Ventillatory Dysfunction.
- The right main bronchus is wider and has 20-30 degrees angle from midline
- The left main bronchus is narrower and has 40-45 degrees angle from midline.
- So because of the angulation and force of gravity **the most common site of the aspiration of foreign object is through right main stem bronchus to lower lobe of right lung.**



Introduction of Normal breathing or Ventilation

- Normal Breathing is also known as Ventilation which is the process of moving air into and out of the lungs to facilitate gas exchange with the internal environment, mostly by bringing in oxygen and flushing out carbon dioxide.
- The normal breathing is enhanced by negative pressure given by diaphragm and pleura and rib muscles.
- It is same as withdrawing venous blood from the syringe, by pulling piston back the vacuum is created which act as negative pressure and the venous blood flows in the syringe.(Fig.1)

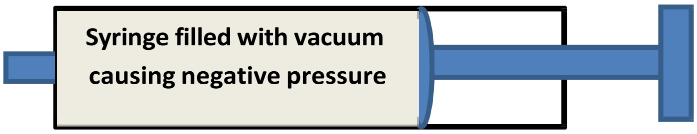


Fig.1 Negative pressure example

- Thus, in normal breathing the diaphragm contracts and creates vacuum and causes air to pass inside the lungs.(Fig.2)

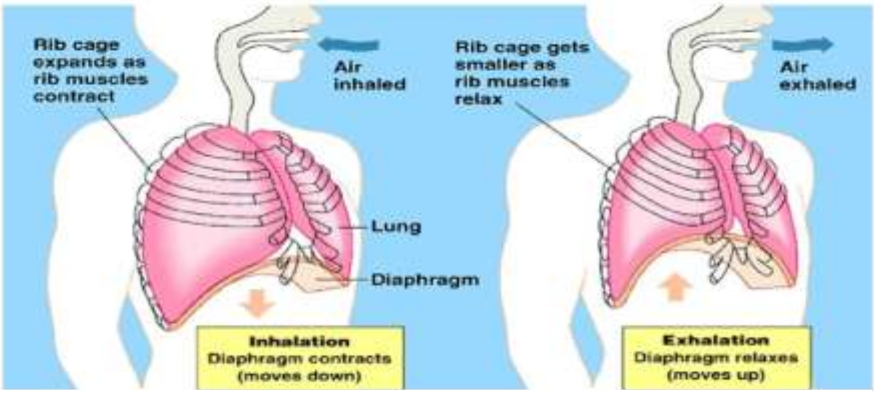


Fig. 2 Breathing through Negative pressure

Mechanical Ventilation

1) Mechanical Ventilation is the process by which the oxygen and air flow is pushed into the lungs and out of the lungs by mechanical ventilator**. (Chintamani,2016)[1]**

2) Mechanical ventilation is a positive or negative pressure breathing device that can maintain ventilation and oxygenation for prolonged period**. (Brunners and Sudharth,2019)[2]**

Understanding Positive pressure Mechanical Ventilation through Physics

In simplistic terms the ventilated lungs can be thought of as tube with a balloon on the end (Fig.3) The tube represents the ventilator tubing, the endotracheal tube and the major airways while the balloon represents the alveoli. For gas to flow from one area to another there must be a difference in pressures in those areas. Thus pressure is required toovercome the resistance of the tube and to inflate the balloon. The pressure required to overcome the resistance is determined by the resistance and the flow such that:
Pressure+ Flow x Resistance

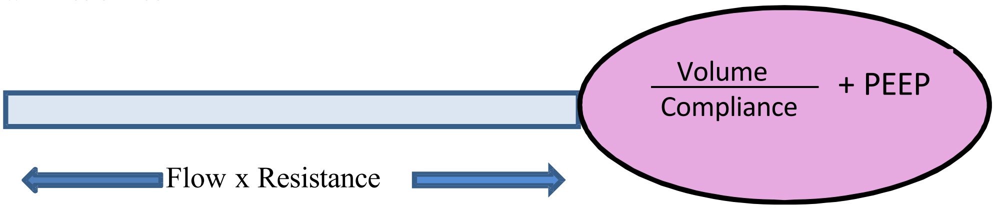


Fig. 3 Simple Lung Model

The pressure inside the balloon (alveolar pressure) can be divided into two components:

i) **Baseline pressure:** The pressure in the alveoli at the end of the expiration or PEEP (positive end- expiratory pressure).
ii) **The pressure due to inflation of lungs:** is determined by volume of gas pumped into the lung and the stiffness or compliance of the lung such that:

$$\textbf{Alveolar pressure} = \frac{\text{Volume}}{\text{Compliance}} + \text{PEEP}$$

The **total pressure (or airway pressure) during inspiration is therefore:**

$$\text{Airway Pressure} = \text{Flow x Resistance} + \frac{\text{Volume}}{\text{Compliance}} + \text{PEEP}$$

From this it can be seen that airway pressure, flow and tidal volume are all interlinked and for any given level of PEEP it is only possible to alter two of these three variables. Morever :

$$\textbf{Flow} = \frac{\textbf{Volume}}{\textbf{Time}}$$

Therefore, if one sets the time during which flow occurs (the inspiratory time) it is only possible to set one of pressure, flow or volume. The other two variables then become dependent on the resistance and compliance. Usually either the tidal volume or the pressure are set.

Classification of Mechanical ventilation

Negative Pressure:
(Extrathorasiac)
The force is applied outside the chest and the to rise and expand (inspiration & expiration)
(Not in use Now-a-Days)

Positive Pressure:
(Intra-Pulmonary)
The ventilator applies the Pressure that will push the air into the patients lungs

Invasive Mechanical Ventilation
It is given with the help of definite airway like Endotracheal Tube & Tracheostomy.

Non-Invasive Mechanical Ventilation
It is given with the help of Face mask, Nasal Mask & BiPAP.

Indications and Contraindications of Mechanical Ventilation:

Indications of Mechanical Ventilation

- Increase in arterial Carbon dioxide ($PaCO_2$>50mm of Hg)
- Continuous decrease in oxygenation(PaO_2)< 55mm of Hg
- Persistent Acidosis (decreased pH<7.32)
- Respiratory Failure
- Vital Capacity <10ml/Kg
- Negative inspiratory force <25cm of H_2O

Contraindications of Mechanical Ventilation

- Untreated pneumothorax
- Family Refusal
- Medical Futility

Components of Ventilator Modes

Breath Type	Control	Phase Variables	Conditional variables
• Mandatory • Assisted • Spontaneous-Assisted	• Pressure • Time • Flow • Volume	• Trigger • Limit • Cycling • Expiration	• PEEP

TERMINOLOGIES

Sr.No	Terms	Meanings
1.	Negative Pressure Ventilator	Device that applies pressure to the body surfaces(at least the ribcage and the abdomen i.e diaphragm)
2.	Positive Pressure Ventilator	Device that applies pressure to the airway opening
3.	Tidal Volume(V_t)	Volume of gas exchanged with each breath. • Lower V_t indicated in patients with stiff, non-compliant lungs. • Higher V_t may cause tachycardia, decreased blood pressure and lung injury.
4.	Inspiratory: Expiratory (I:E) Ratio	• Normal ratio has longer expiratory phase than inspiratory phase (1:2,1:3) • Inverse ratio provides longer inspiratory phase (1:1, 2:1, 3:1, 4:1)
5.	Fraction of Inspired Oxygen(FiO_2)	Concentration of Oxygen in the inspired air. Use the lowest FiO_2 that achies the targeted oxygenation Avoid prolonged $FiO_2 > 60\%$, as this may cause oxygen toxicity.
6.	Frequency (f) or Respiratory Rate (RR) (10-20 breaths/min)	Set number of Ventilator breaths per minute. Actual RR includes the spontaneous breaths taken by the patient. • Hypoventilation may cause respiratory acidosis. • Hyperventilation may cause respiratory alkalosis.
7.	Positive End Expiratory Pressure (PEEP) (3-10 cm H_2O)	Pressure remaining in the lungs at end expiration. • Used to keep alveoli open and "recruit" more alveoli to improve oxygenation for patients. • High levels may cause barotrauma, increased intracranial pressure and decreased cardiac output.
8.	Limit	It is a set level beyond which something may not extend or pass.
9.	Minute Ventilation	Volume of Gas exchanged per minute: M.V = (Respiratory Rate) x (Tidal Volume)
10.	Trigger Sensitivity	It refers to a signal the ventilator ids looking for related to the initiation or start point in the delivery of breath. Breaths can be triggered by Timer (Ventilator-initiated breath) or by Patient effort (patient initiated breath)
11.	Peak Flow Rate	Maximum flow delivered by the ventilator during inspiration.
12.	Troubleshooting Problems	Troubleshooting problems means to analyze and solve serious problems of Mechanical ventilation
13.	Cycling	It is a series of events that happen repeatedly in the same order. It can be Time Cycling or Volume Cycling Time Cycling: It indicates that the breath switches from inspiration to expiration after a set time threshold is reached. This can be accomplished by setting the respiratory rate, inspiratory time or I:E ratio Volume cycling: In this the ventilator changes after a set tidal volume has been delivered.
14.	Peak Inspiratory Pressure(PIP)	Highest proximal airway pressure reached during. • Target PIP is < 35 cm H_2O. • Low PIP may result in Hypoventilation • High PIP may cause Lung damage.
15.	Pressure Support (PS) (8-20 cm of H_2O)	Provides additional pressure during inspiration to ensure a larger V_t with minimal patient effort. Used to help overcome the work of breathing through Ventilator tubing
16.	Mandatory breath	The machine controls the time and size of the breath
17	Assisted breath	The machine provides help for breathing rather than muscles.
18	Spontaneous breath	The patient control the timing and size of the breath

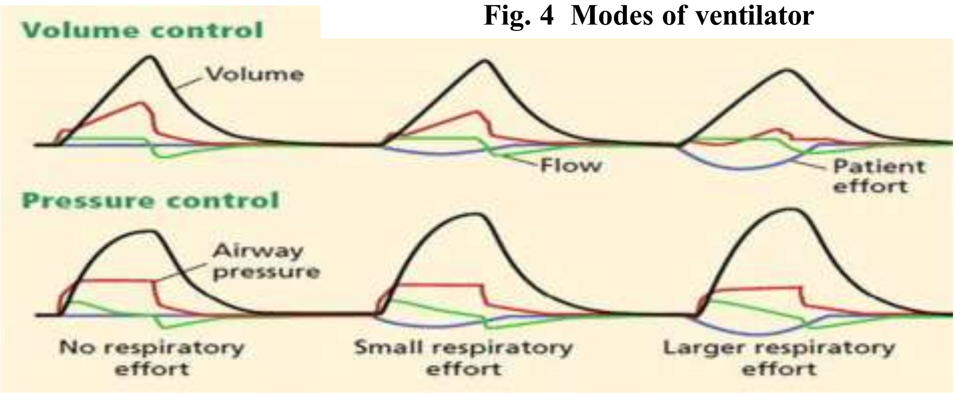
MODES OF VENTILATOR

Modes of Ventilator are classified into two basic types (Fig 4)

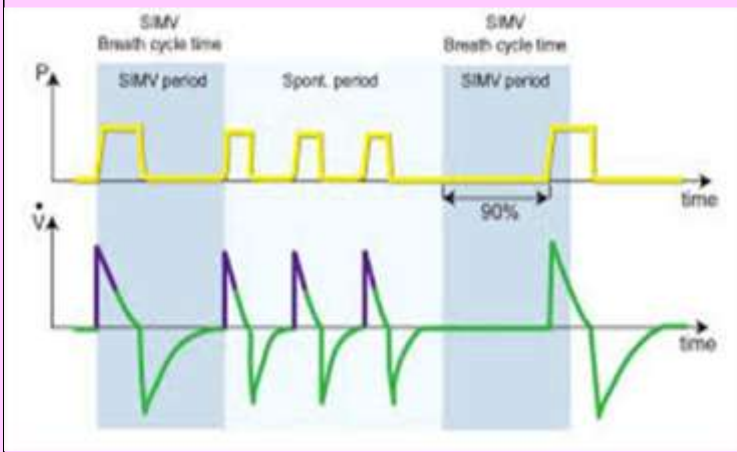
I) Volume Control Modes: Preset Tidal Volume (V_t)

II) Pressure Control Modes: Preset Airway Pressure (PIP)limit

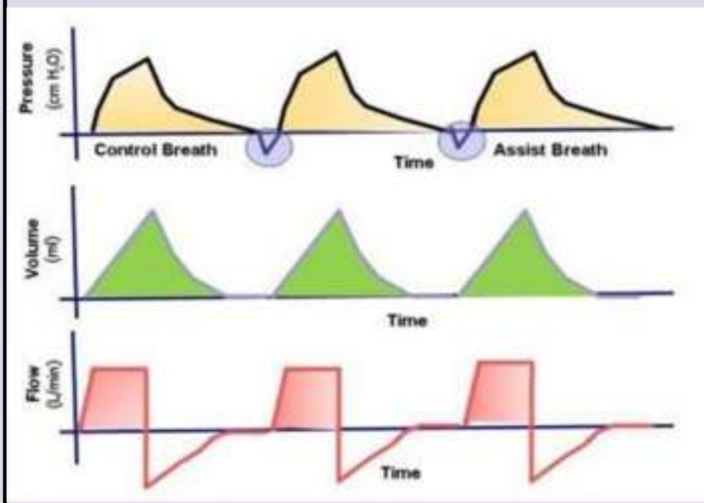
Fig. 4 Modes of ventilator



I) Volume Modes:

Modes	**Definition**
Intermittent Mandatory Ventilation (IMV)	Ventilations are delivered at a preset rate and tidal volume. Spontaneous breaths can occur at the patient's rate and tidal volume.
Synchronized Intermittent Mandatory ventilation (SIMV)	➢ SIMV is synchronized with the patient's spontaneous breathing to reduce friction between spontaneous efforts and machine. ➢ It provides preset V_t for each Ventilator generated breath ➢ In this mode the patient receives a set number of mandatory breaths, which are synchronized (to cause to operate at the same rate) with any attempts by the patient to breath (i.e) spontaneous breath.  **Fig. 5 SIMV Mode flow screen**

II) PRESSURE MODES:

Modes	Definition
Pressure controlled Ventilation (PCV)	**In pressure controlled ventilation the breathing gas flows under constant pressure into the lungs during the selected inspiratory time.**
Pressure Support Ventilation (PSV)	➢ **The patient breathes spontaneously and the ventilator applies a pre-determined amount of positive pressure to the airways upon inspiration and V_t depends on patients effort and lung elasticity.** ➢ **Pressure support ventilation augments patient's spontaneous breaths with positive pressure boost during inspiration i.e. assisting each spontaneous inspiration.** ➢ **It helps to overcome airway resistance and reducing the work of breathing.** ➢
Assist –Control Pressure Mode	➢ **Ventilator delivers breath until set pressure is reached.** ➢ **Limits Peak Inspiratory Pressure(PIP)** ➢ **Ventilator provides control breath if no patient effort and assist breath is delivered as patient effort.**  **Fig.6 Assist Control Mode flow screen**
Continuous Positive Airway Pressure (CPAP).	**CPAP is spontaneous breathing with a constant PEEP applied to the airway throughout the respiratory cycle.**
Noninvasive Bilateral Positive Airway Pressure Ventilation (BiPAP)	**BiPAP is a noninvasive form of mechanical ventilation with constant FiO2 and Pressure Support provided by means of a nasal mask or nasal prongs, or a full-face mask.**

Initial Ventilator settings

Mode	SIMV mode/depends on patients
FiO_2	100% or adjust to maintain FiO_2 above 90%, Later change FiO_2 as per ABG analysis.
Pressure Support	8-10
PEEP	5 cm of H_2O
Tidal Volume	6ml/kg of Body weight for ARDS and COPD Patients. In Normal patients:10ml/kg of Body weight.
Inspiration:Expiration Ratio	1:2
Minute Ventilation	Tidal Volume x Respiratory rate

Note: These settings can be changed as per ABG Analysis.

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TROUBLESHOOTING PROBLEMS & NURSES RESPONSIBILITY RELATED TO TROUBLESHOOTING PROBLEM

Problem	Cause	Nurses Responsibilty
High Pressure Alarm	– Kinking of breathing circuit – Kinking of E.T.Tube – Water in Circuit – Coughing	**- Check for circuit - Check for E.T tube kinking.**
Low Pressure Alarm	– Circuit Disconnection – Circuit Leak – Inadequate ET cuff Pressure – ET tube misplacement – Resistance through HME	**- Check For circuit disconnection & leak - Check for E.T. cuff pressure - Check For E.T tube placement & HME blockage**
Apnea Alarm	Time between two consecutive inspiratory effort exceeds. Adult : 20 sec. Pead : 15 sec. □ Neonate : 10 sec	**- Check for breathing (i.e) whether there is increase in Respiratory Rate.**
High PEEP Alarm	- Causing air trapping in Lungs	**- Reduce PEEP**
Low PEEP Alarm	- Leak In Circuit - Leak In E.T.Tube	**- Check for Circuit Leak or E.T Tube Leak**
Low FiO₂ Alarm	– No connection with the oxygen port – Low central oxygen pressure	**- Check for Oxygen port Connection - Check for central oxygen Pressure**
Low minute Pressure Alarm	– Flow transducer – Faulty Circuit – disconnected from client	**- Check for faulty circuit - Check for disconnect from client.**
High Minute pressure Alarm	– Increased client activity – Ventilator auto cycling – low flow transducer – decreased client activity	**- Check for client activity - Check for ventilator cycling.**

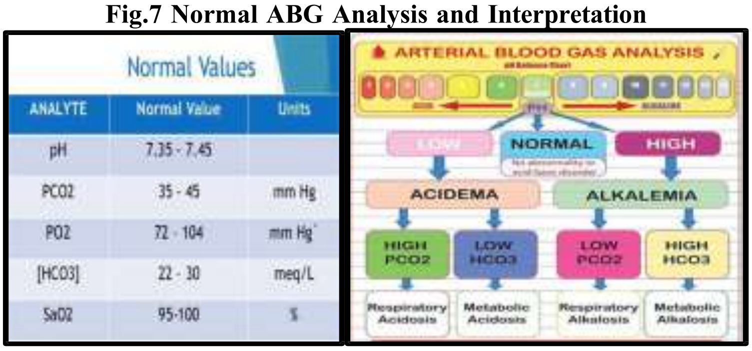
Weaning from Mechanical Ventilation and Nurses Responsibility during Weaning from mechanical ventilation

The process of gradual discontinuation of Mechanical Ventilator Support from the patient is called as weaning.

Steps and Nurses responsibility in Weaning from M.V

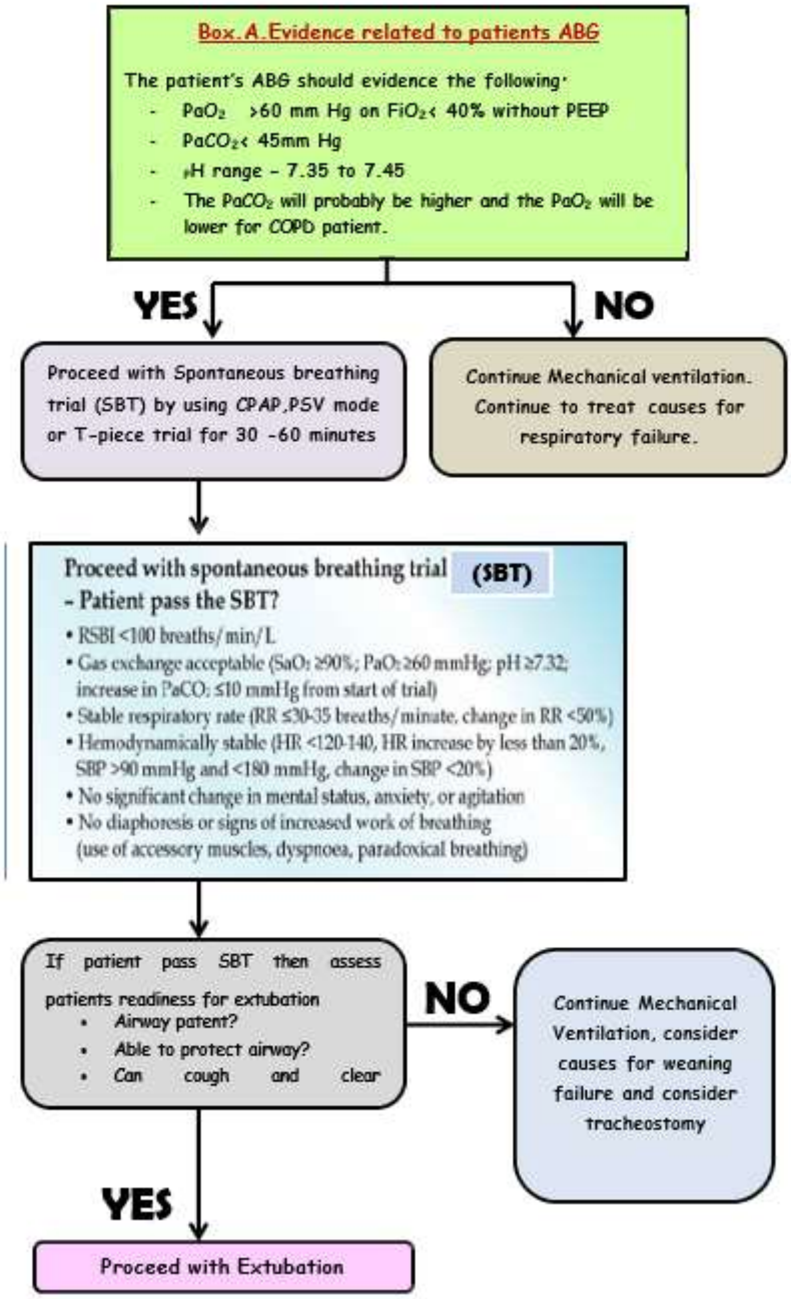
- Assess the patients readiness to wean.
- Ensure patient is awake and able to protect airway.
- Can Cough and clear the airway
- Determine ABG and consider evidences in **Box .A**

Fig.7 Normal ABG Analysis and Interpretation



Normal Values

ANALYTE	Normal Value	Units
pH	7.35 - 7.45	
PCO2	35 - 45	mm Hg
PO2	72 - 104	mm Hg
[HCO3]	22 - 30	meq/L
SaO2	95-100	%



Nurses Responsibility while Extubating the patient

- Withhold feed for minimum 6-8 hrs.
- Nebulize the patient prior suctioning
- Do suctioning
- Give chest physiotherapy
- Keep crash cart & Intubations tray ready
- Remove ETT, do oral suctioning & oxygenate the patient with Oxygen mask

COMPLICATION OF MECHANICAL VENTILATION

- Aspiration
- Decreased clearance of secretions
- Ventilator-acquired pneumonia
- Barotrauma
- Fluid overload with humidified air and sodium chloride (NaCl) retention
- Depressed cardiac function and hypotension
- Stress ulcers
- Paralytic ileus
- Gastric distension
- Starvation
- Dyssynchronous breathing pattern

Nurses responsibility in Prevention of the Complications of Mechanical ventilation

The goal of intensive monitoring, while the patient is on MV is to provide ventilator support safely and effectively by avoiding complications.

Following are the measures to be taken to avoid complications.

a) VAP bundle care

Ventilated Associated Pneumonia(VAP) is common health care associated infection occurring in 10-20% of patients mechanically ventilated in the ICU. Along with it VAP increases the length of stay in ICU and an increase in hospital & health care cost. (Hellyer.T,2017)[3]

Following are the VAP bundle care:

1) Elevation of head of bed (30^0- 45^0)
2) Daily sedation interruption and assessment of readiness to extubate. (early weaning.)
3) Daily oral care with Chlorhexidine (every 2 hrly)
4) Prophylaxis for peptic ulcer disease
5) Prophylaxis for deep venous thrombosis

b) Oxygen Toxicity

Oxygen has both lifesaving and toxic effects. During Mechanical ventilation oxygen has been known to be toxic to the lungs, and F_iO_2 of 100% is associated with adsorption atelactesis, alveolar collapse and hypoxemia. Hyperoxia enhances lung instability and succeptibility to pulmonary and systemic infection. (Kallet R,2016)[4]

As, prolong use of F_iO_2 > 70 % results in oxygen toxicity, Nurses should be careful of hyper-oxygenating the patient.

S/S of Oxygen Toxicity

- Facial pallor,
- cold periphery and intense peripheral vasoconstriction,
- Drowsiness, Irritability
- Nausea and Vomiting
- twitching of hand
- convulsions
- excessive coughing
- Rapid breathing
- "cogwheel" breathing

c) Hypotension

Hypotension after intubation is usually due to diminished central venous blood return to the heart secondary to elevated intrathoracic pressures. This can be treated with fluid infusion and adjustment of ventilator settings to lower intrathoracic pressure.(reducing PEEP, Tidal volume) (Amitai A,2020)[5]

The change in PEEP may alter venous return, blood pressure, cardiac output, arterial and venous blood gas tensions, metabolic rate, respiratory sensation, breathing pattern and work of breathing. Use of high PEEP causes hypotension due to anaesthesis upon venous capacitance and vascular tone. Hence it is important to choose to limit PEEP (Richard A,2014)[6]

d) Desaturation

If the patient desaturates while on a Mechanical Ventilation it is important to consider both patient causes and equipment cases

- Check for pulse oxymeter waveform (does the heart rate corresponds)
- Check for patient's chest movement. Follow the algorithm (Fig8)

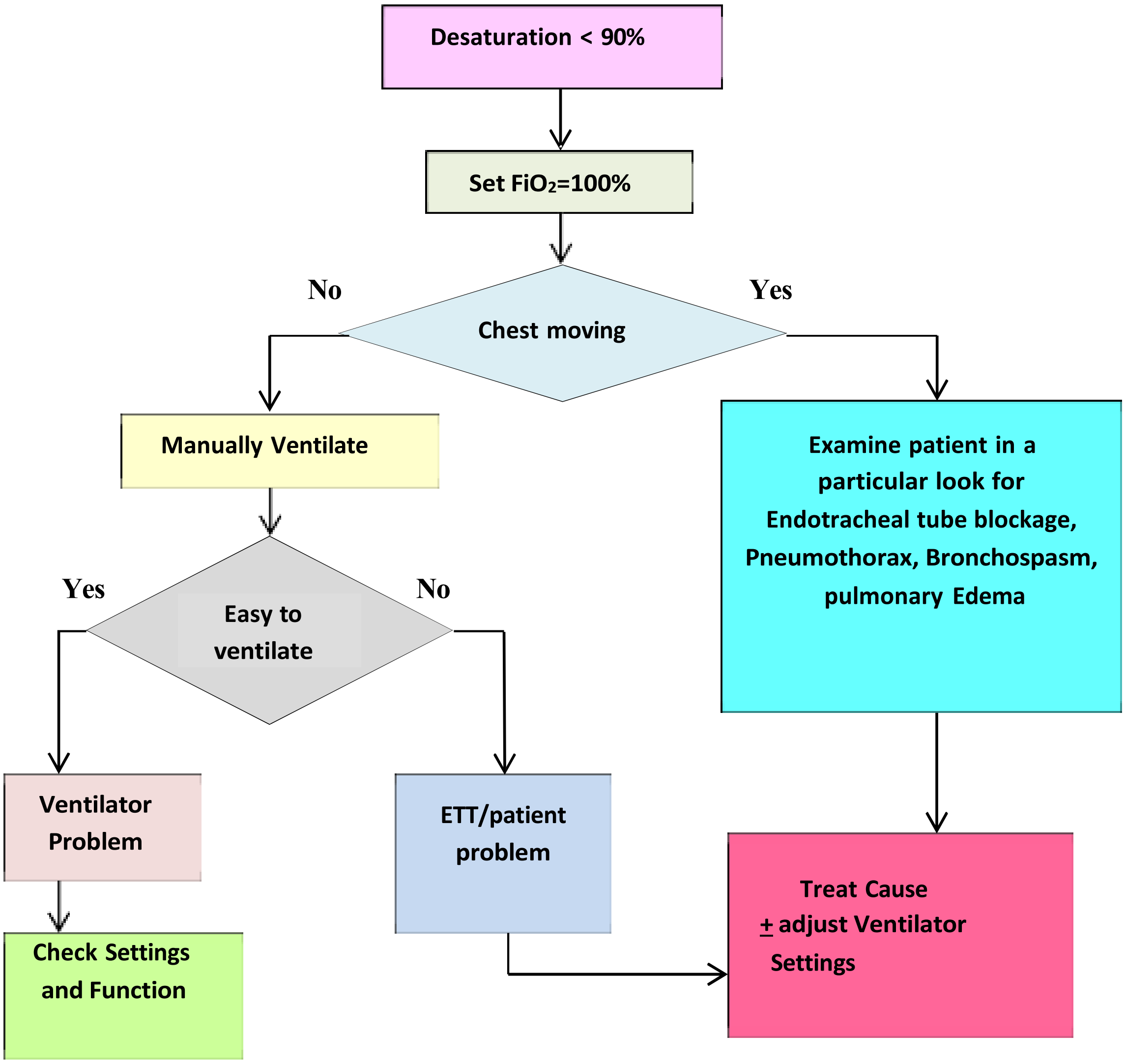


Fig.9 An algorithm for managing desaturation

e) Barotrauma

Barotrauma is well recognized complication of Mechanical Ventilation It can occur in any patient on MV but mostly occurs in patients with wide range of underlying pulmonary conditions.(Asthama, COPD, Pneumonia) In clinical medicine Barotrauma is used to describe the maniufestation of extra-alveolar air during MV.
(Soo Hoo G,2020)[7]

- Monitor watchfully the alarms, for High Peak Inspiratory Pressure
- Monitor watchfully the ventilator settings for High levels on PEEP and High tidal Volume.
- Record and repot the physician.

NURSING RESPONSIBILITIES RELATED TO THE CARE OF PETIENT ON MECHANICAL VENTILATION

The nurses in the Critical Care Areas are constantly present at the patient's bedside, and an experienced nurse can sense problems and can take steps to stop such catastrophe. Nurses also help patients to cope with most embarrassing and demeaning consequences of a critical illness. Hence the responsibility of nurse in ventilator management is quite crucial. (Jubran.A,2012)[8]

1) Check for proper Endotracheal Tube (ET) tube positioning

- Keep close observation towards the lip line fix of ET tube
- Auscultate chest for Air Entry Equal On Both Sides of Lungs. (AEEBS)
- Note down the measurement of the ET tube at lip line where it is fixed and record it in ICU flow sheet.
- If the tube is misplaced reposition it on the same lip line measurement.

Inform Physician and Get the Chest X-Ray done to check ET tube positioning with the help of Radio Opaque line.

2) Suctioning the patient every 2 hourly and as frequent as needed with strict aseptic technique.

- Preferably use closed suction system, change every 72hrs or as per Institutional Policy.
- If using open suction, prefer fresh catheter with every use and use the strict aseptic technique.
- Wear sterile gloves and mask.
- Use dominant hand for suctioning
- Preoxygenate with 100% O_2 with other hand
- Check for suction pressure it should be 100-150 mm of Hg,(for adults) if exceed can cause tissue injury or trauma.
- Disconnect the ventilator or open the suction port at Catheter Mount
- Kink and then insert the catheter till it reaches the Carina approximately 10 cm inside the ET tube, Release the kink and remove the catheter within 10 sec
- Remember suction cycle should be within 10 sec and must not exceed.

3) Check for E.T cuff inflation pressure

Endotracheal tube cuff pressure must be kept within an optimal range that ensures ventilation and prevents aspiration while maintaining tracheal perfusion (Lou Sole M,2011)[9]

Tray containing:

- Aneroid barometer & syringe 10cc
- Fix the Aneroid Barometer at the pilot balloon of the ET tube in the cuff inflation valve.(Fig 8)
- The Barometer shows the reading
- The normal ET cuff pressure is 20 to 30 cm of H_2O
- If it lower than 20 cm inflate it till normal range
- Note: Excessive amount of inflation of ET cuff can cause laryngeal edema, prolong excessive amount of inflation of ET cuff leads to Laryngeal ischemia and then necrosis.

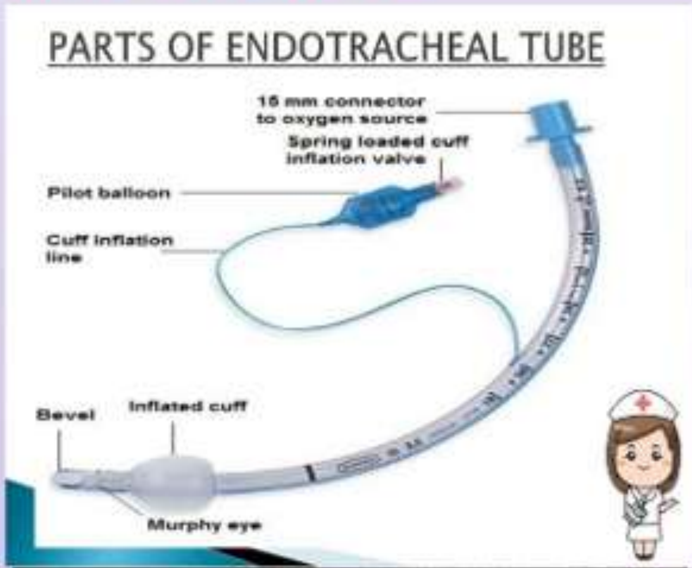


Fig.8. Aneroid Barometer

Fig.8. Aneroid Barometer

4) Frequent Check for Ventilator tubing and HME (Heat and Moisture Exchange) filters

Humidifiers are the device that add molecules of water to gas. Humidification during Mechanical ventilation is necessary to prevent damage of airway mucosa and atelactesis. HMEs operate actively by storing heat and moisture from patients exhaled gas and releasing it to inhaled gas (Haitham S.2014)[10]

- Use of HME is contra indicated in the patients with thick, coipus or bloody secreations.
- Do not use HMEs while giving nebulization
- A nurse must check for complications due to blockage of HMEs
  - Hypoventilation due to mucus plugging in the airway or blockage of HMEs
  - Low pressure alarm due to resistance through HME

Conclusion:

Nurses in Critical Care Areas are the "first-line manager" challenged with patient and ventilator related problems. As a result, it is essential that nurses thoroughly understand the basic of ventilator support, including ventilator modes, settings and alarms. It is also important to be skilled in identifying troubleshooting problems and managing common patient & ventilator related problems. With the help of these guidelines, staff nurses will be able to improve their knowledge and will be able to promptly recognize the problems and could take necessary action in order to provide optimal patient centered care and prevent complications.

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