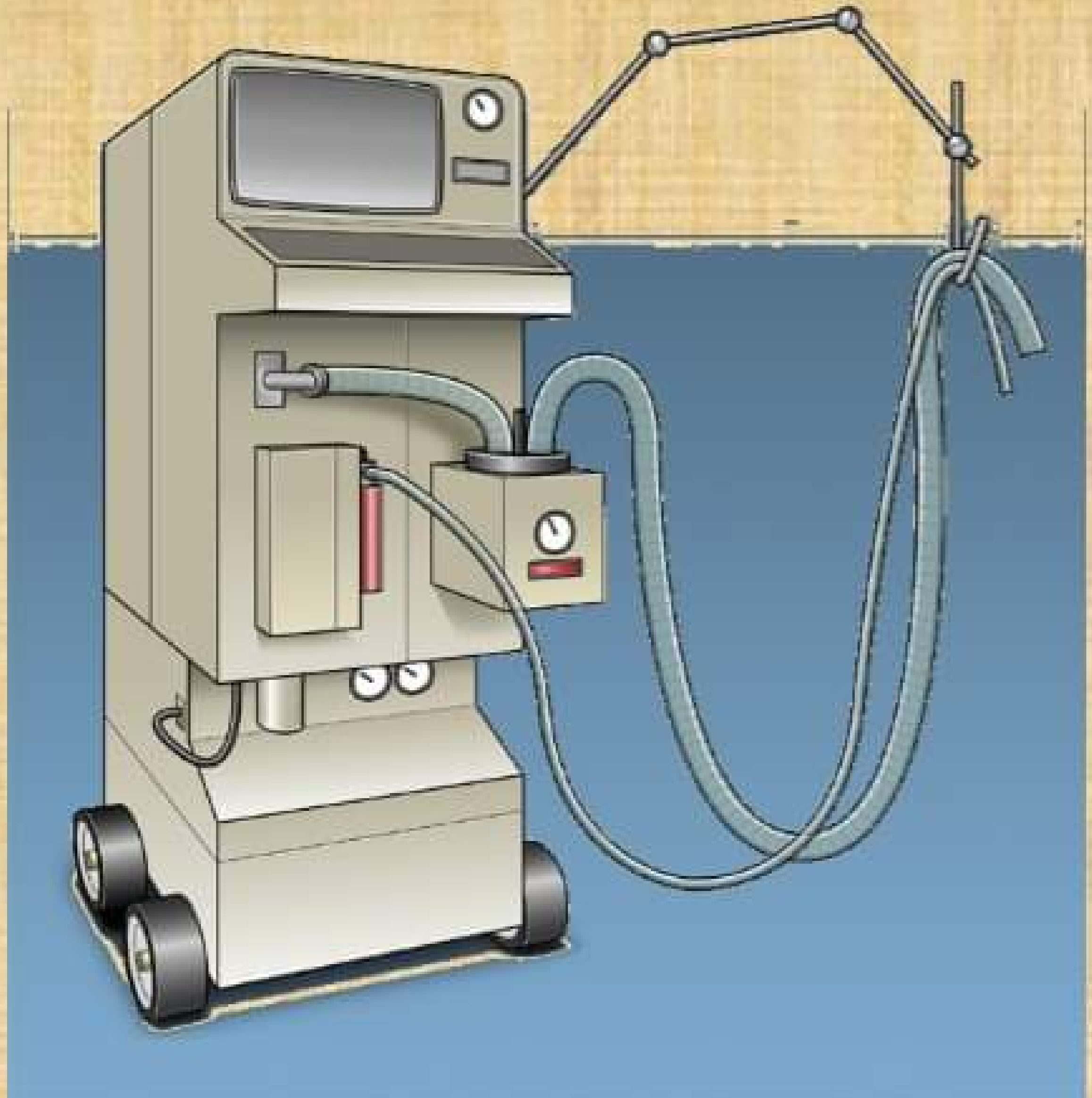
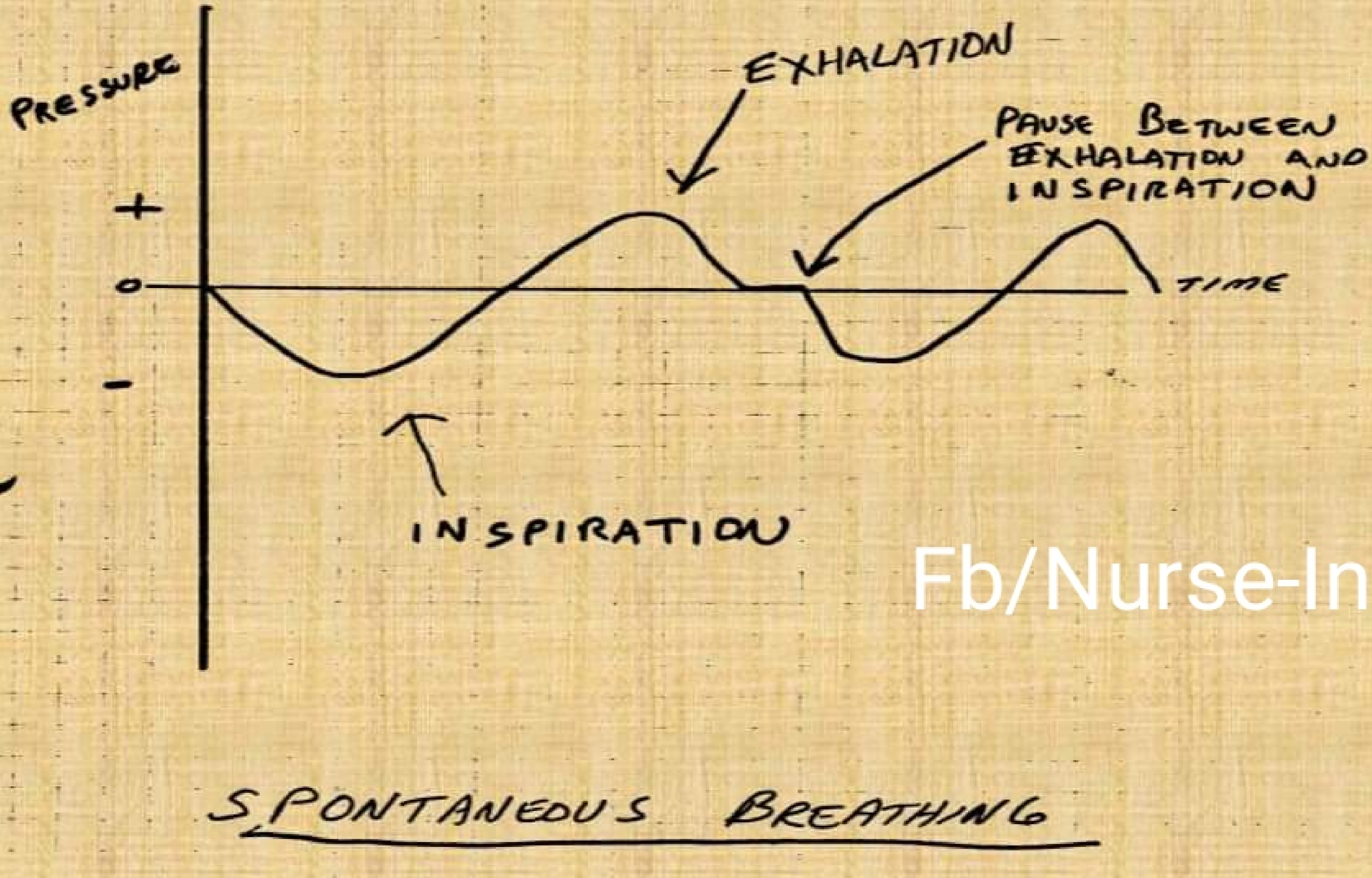
Basics of Mechanical Ventilation

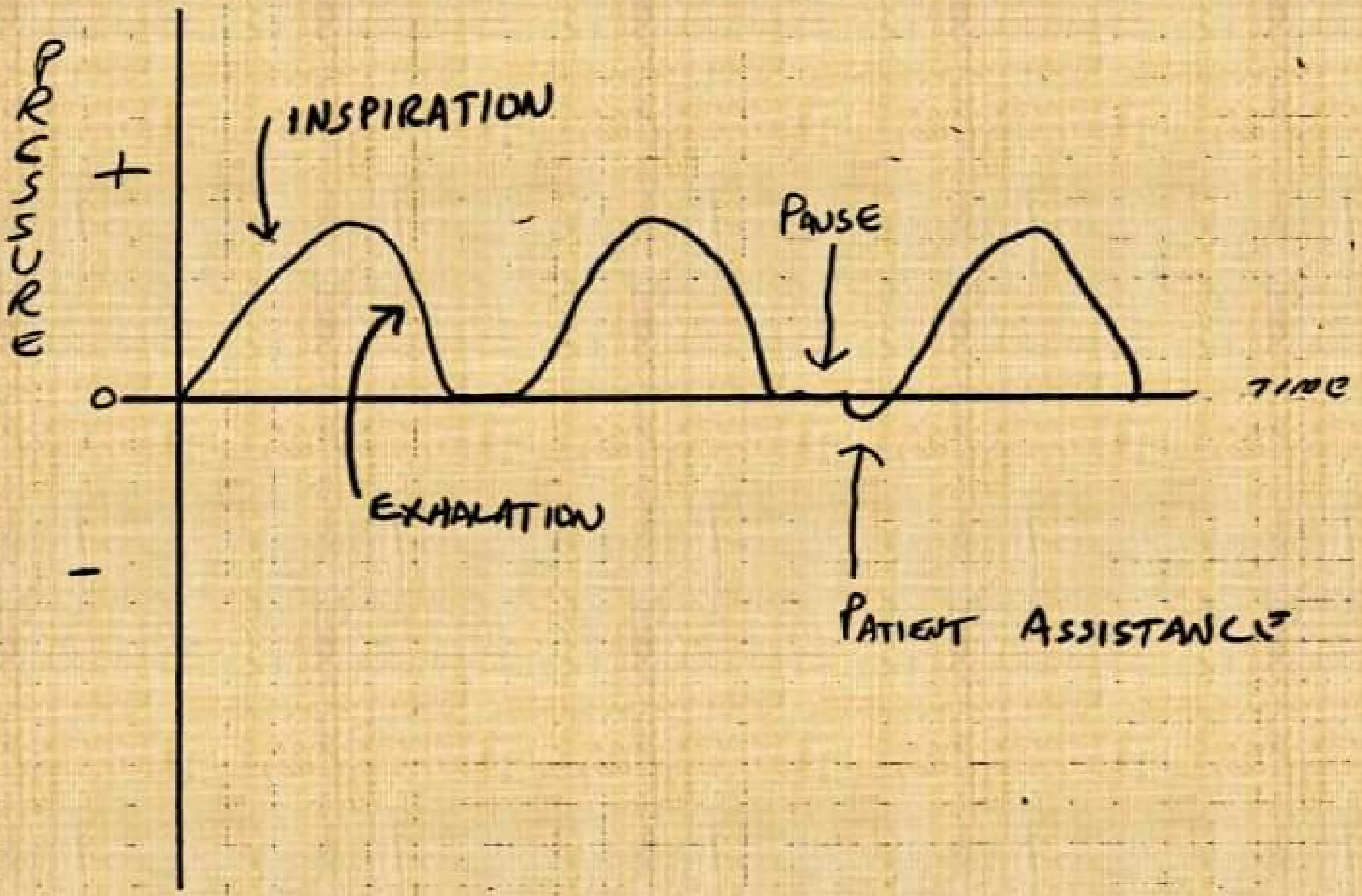


Fb/Nurse-Info

Spontaneous Breathing



Positive Pressure Breath



Agenda

1. Indications
2. Settings
3. Modes
4. Advantages and disadvantages between modes
5. Guidelines in the initiation of mechanical ventilation
6. Common trouble shooting examples with mechanical ventilation
7. Humidification
8. Ventilatory alarm
9. Weaning criteria
10. Complications of MV

Indications of MV:

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.

Settings

1. Trigger mode and sensitivity
2. Respiratory rate
3. Tidal Volume
4. Positive end-expiratory pressure (PEEP)
5. Flow rate
6. Inspiratory time
7. Fraction of inspired oxygen

Trigger

- There are two ways to initiate a ventilator-delivered breath: pressure triggering or flow-by triggering
  - When pressure triggering is used, a ventilator-delivered breath is initiated if the demand valve senses a negative airway pressure deflection (generated by the patient trying to initiate a breath) greater than the trigger sensitivity.
  - When flow-by triggering is used, a continuous flow of gas through the ventilator circuit is monitored. A ventilator-delivered breath is initiated when the return flow is less than the delivered flow, a consequence of the patient's effort to initiate a breath

Tidal Volume

- The tidal volume is the amount of air delivered with each breath. The appropriate initial tidal volume depends on numerous factors, most notably the disease for which the patient requires mechanical ventilation.

Respiratory Rate

- An optimal method for setting the respiratory rate has not been established. For most patients, an initial respiratory rate between 12 and 16 breaths per minute is reasonable

Positive End-Expiratory Pressure (PEEP)

- Applied PEEP is generally added to mitigate end-expiratory alveolar collapse. A typical initial applied PEEP is 5 cmH2O. However, up to 20 cmH2O may be used in patients undergoing low tidal volume ventilation for acute respiratory distress syndrome (ARDS)

Flow Rate

- The peak flow rate is the maximum flow delivered by the ventilator during inspiration. Peak flow rates of 60 L per minute may be sufficient, although higher rates are frequently necessary. An insufficient peak flow rate is characterized by dyspnea, spuriously low peak inspiratory pressures, and scalloping of the inspiratory pressure tracing

Inspiratory Time: Expiratory Time Relationship (I:E Ratio)

- During spontaneous breathing, the normal I:E ratio is 1:2, indicating that for normal patients the exhalation time is about twice as long as inhalation time.
- If exhalation time is too short “breath stacking” occurs resulting in an increase in end-expiratory pressure also called auto-PEEP.
- Depending on the disease process, such as in ARDS, the I:E ratio can be changed to improve ventilation

Fraction of Inspired Oxygen

- The lowest possible fraction of inspired oxygen (FiO_2) necessary to meet oxygenation goals should be used. This will decrease the likelihood that adverse consequences of supplemental oxygen will develop, such as absorption atelectasis, accentuation of hypercapnia, airway injury, and parenchymal injury

Modes of Ventilation: The Basics

- Assist-Control Ventilation Volume Control
- Assist-Control Ventilation Pressure Control
- Pressure Support Ventilation
- Synchronized Intermittent Mandatory Ventilation Volume Control
- Synchronized Intermittent Mandatory Ventilation Pressure Control

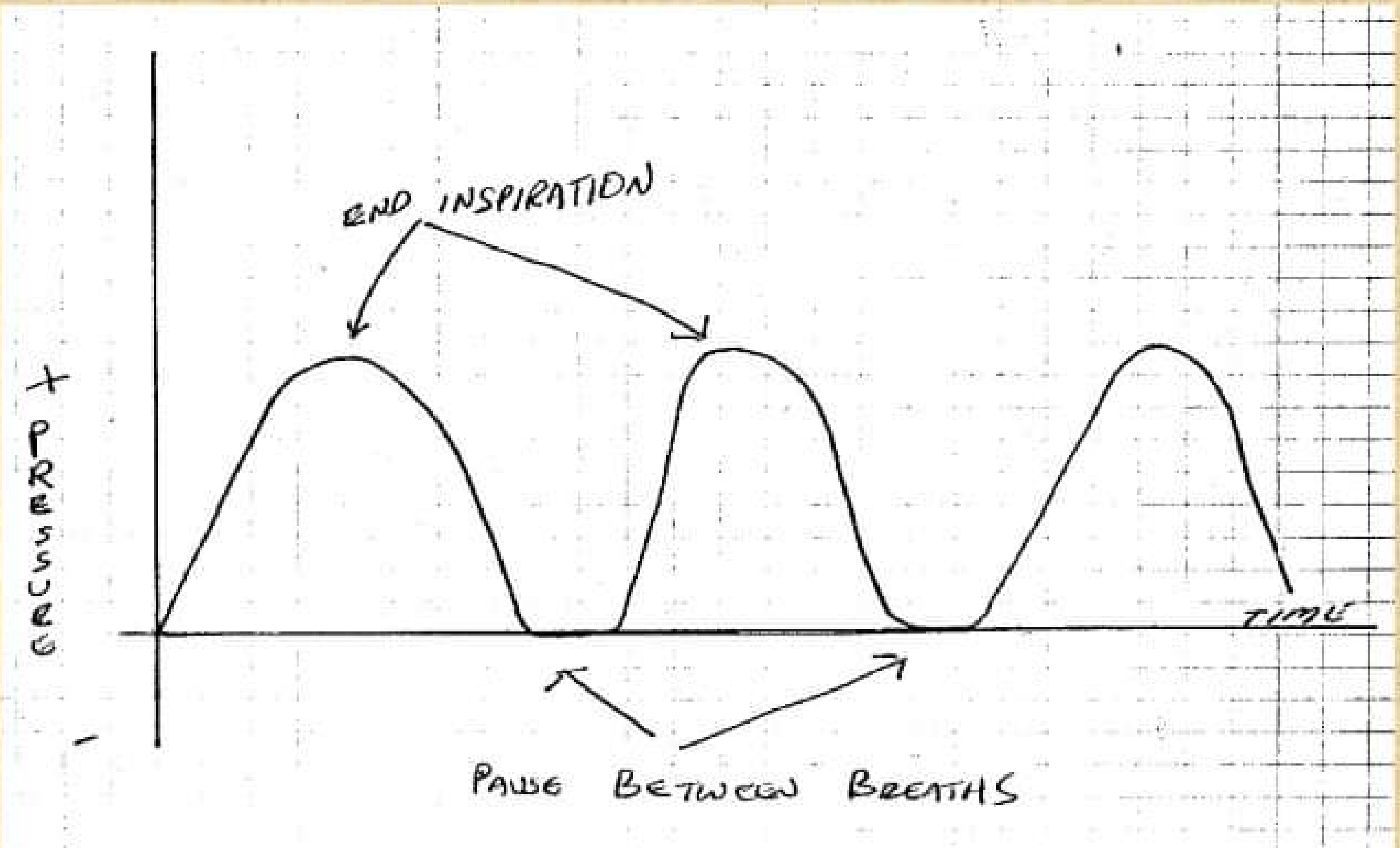
Other advanced modes

- BiPAP
- Pressure-regulated volume control (PRVC)
- Airway pressure release ventilation (APRV) and Biphasic
- Adaptive support ventilation (ASV)
- Volume support / Automatic Pressure Ventilation
- High-frequency ventilation (HFV)

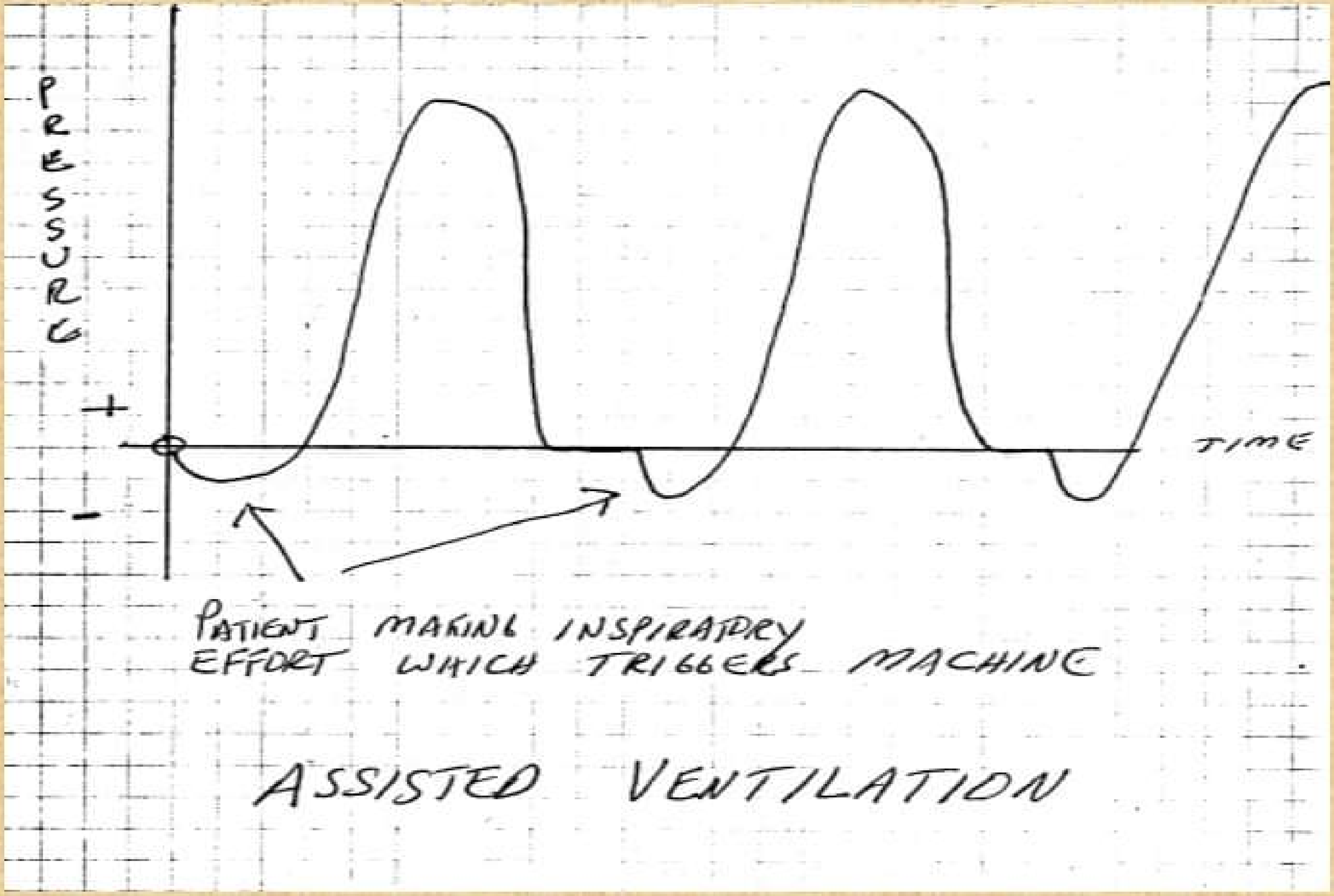
Assist Control Ventilation

- A set tidal volume (if set to volume control) or a set pressure and time (if set to pressure control) is delivered at a minimum rate
- Additional ventilator breaths are given if triggered by the patient

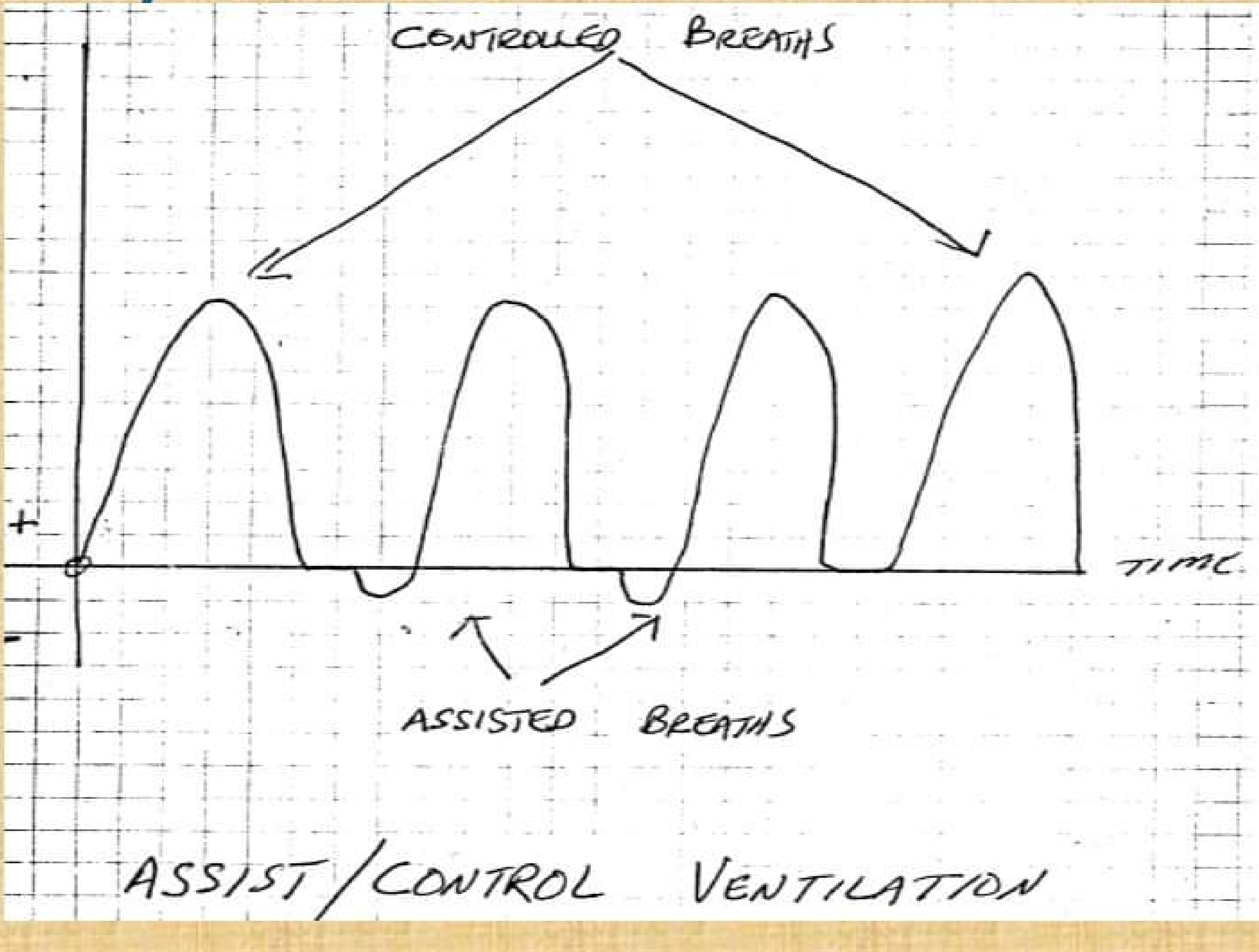
Control Mode



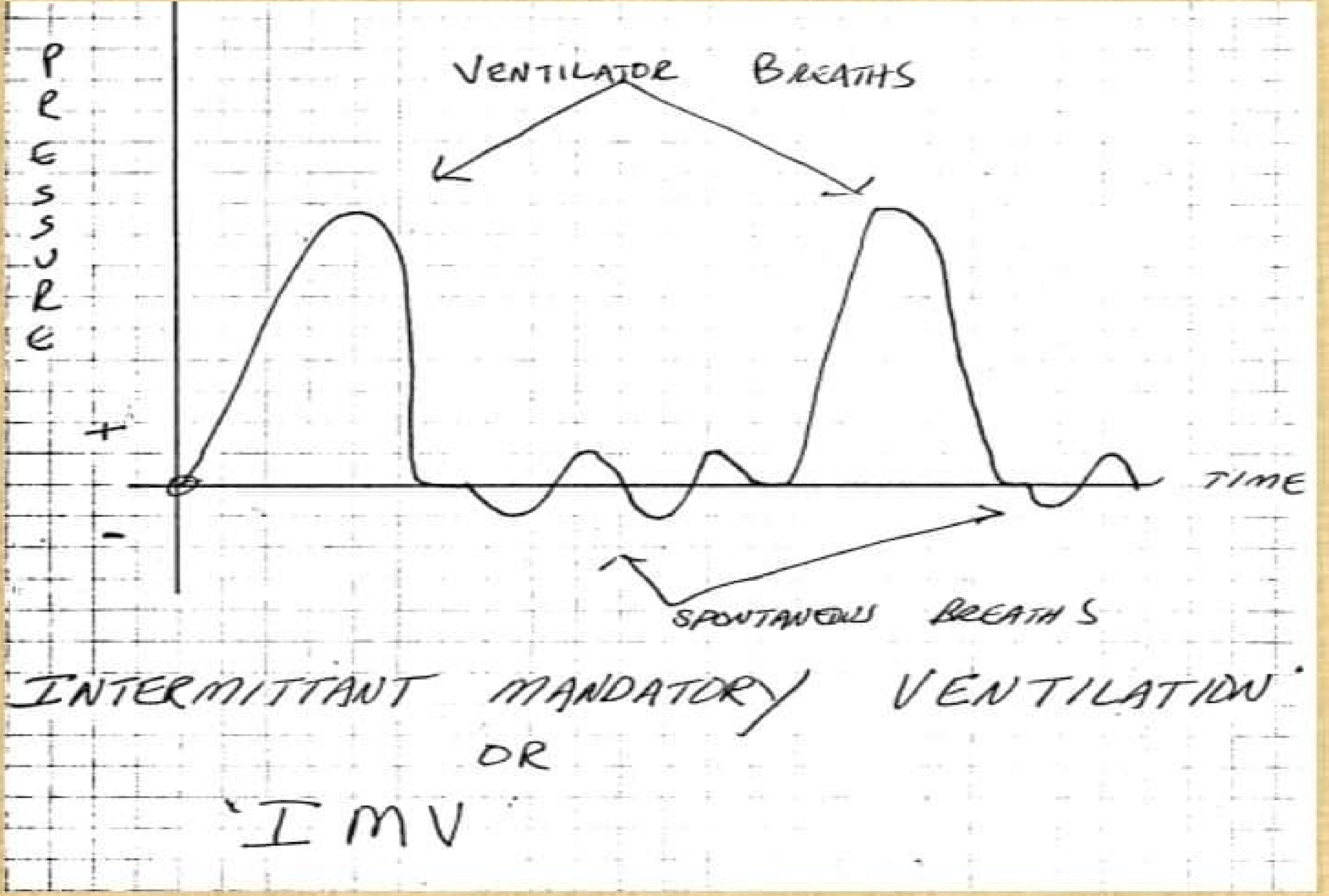
Assist Mode


PRESSURE
+
-
TIME
PATIENT MAKING INSPIRATORY
EFFORT WHICH TRIGGERS MACHINE
ASSISTED VENTILATION

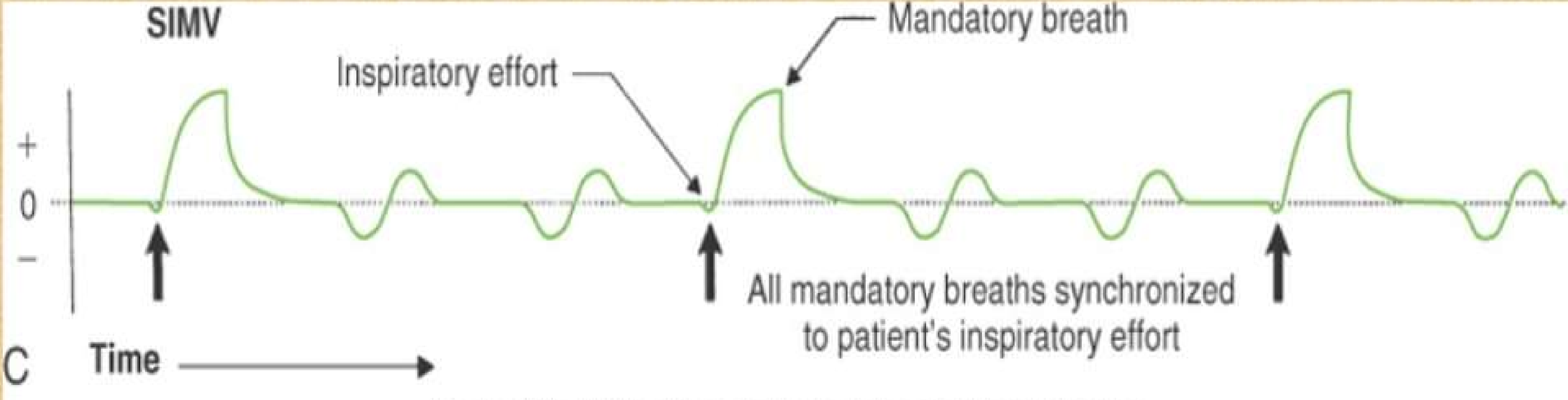
Assist/Control



IMV – Intermittent Mandatory Ventilation

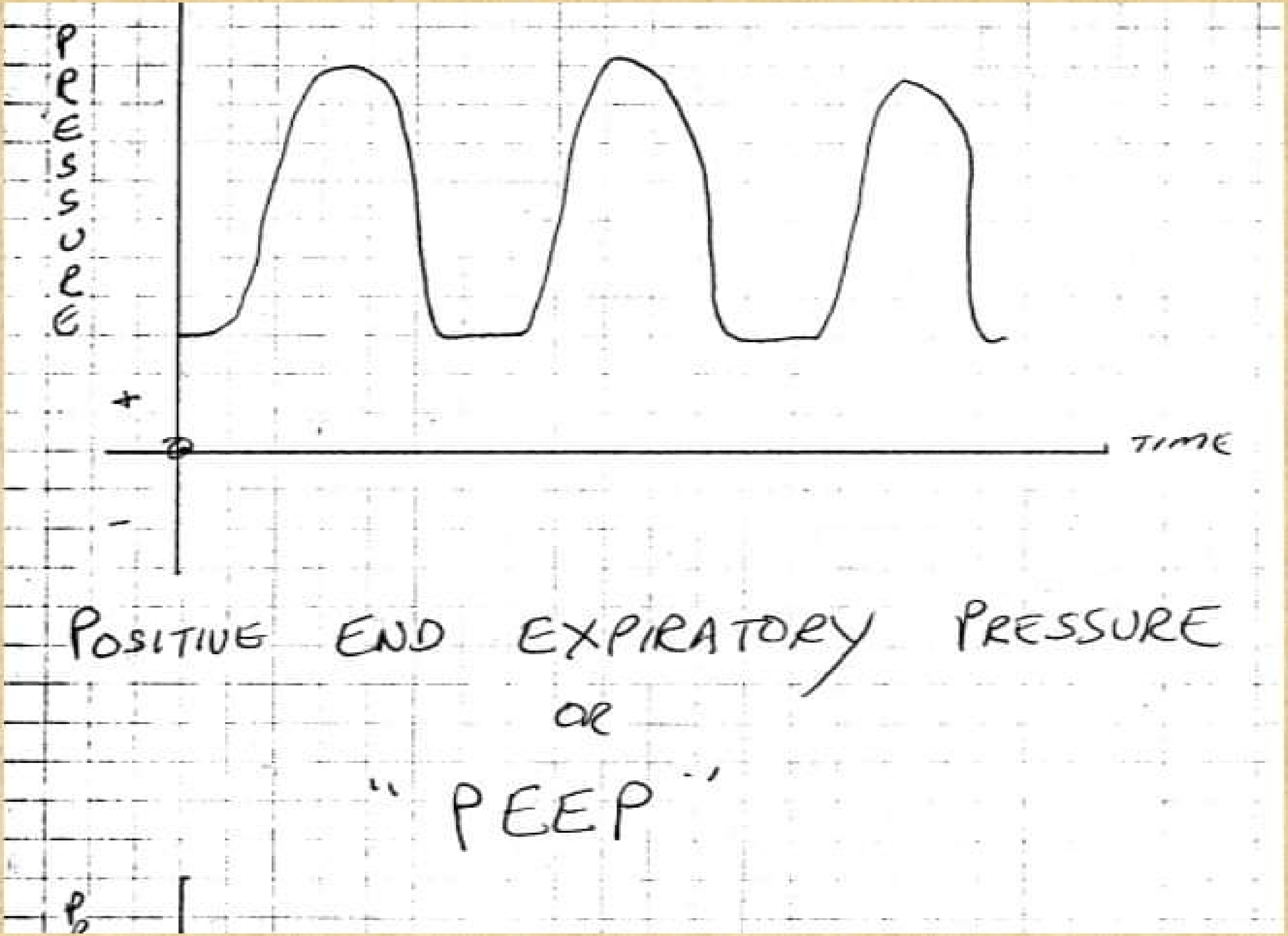


Synchronized Intermittent Mandatory Ventilation

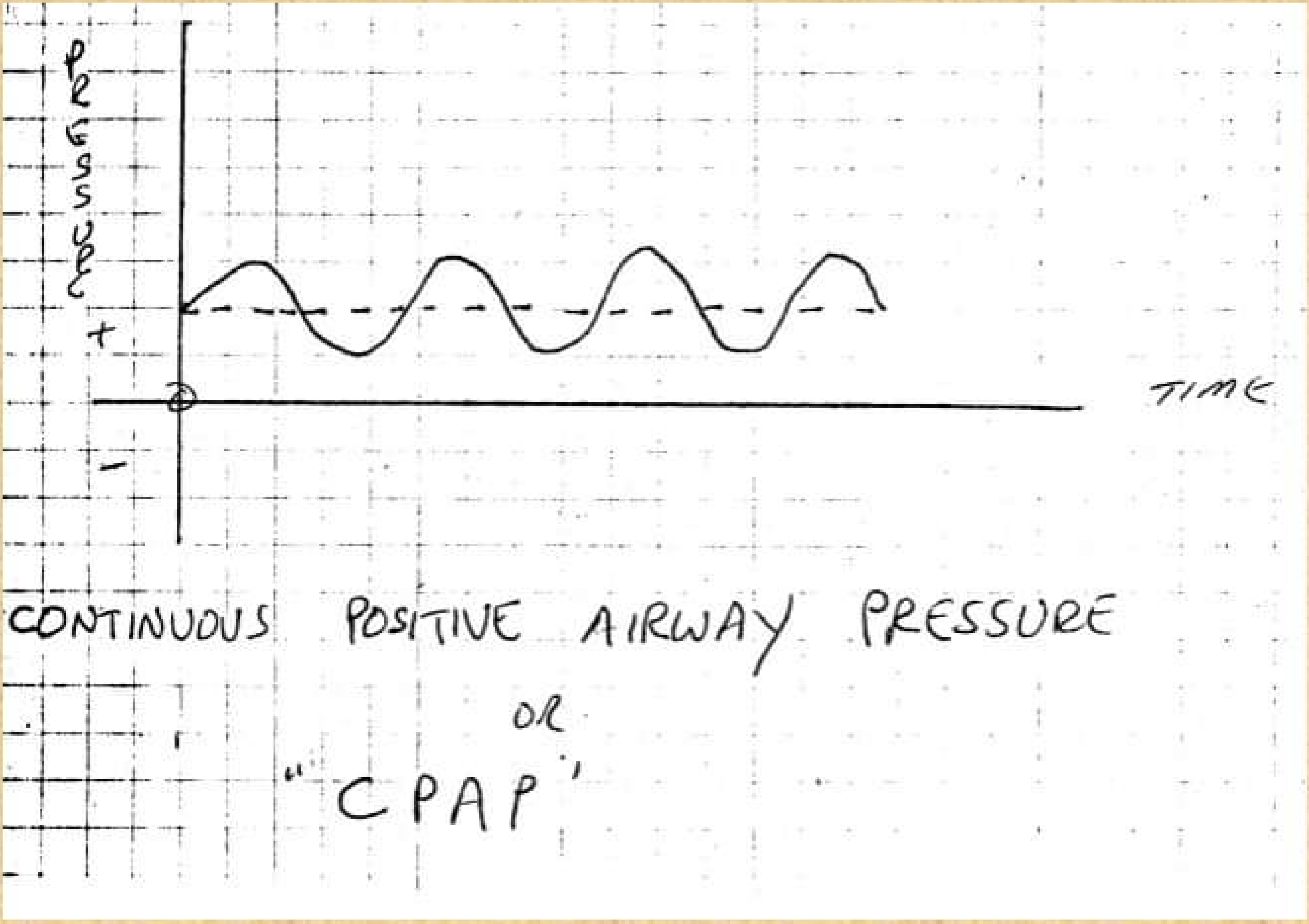


(From Dupuis YG: *Ventilators: theory and clinical applications*, ed 2, St Louis, 1992, Mosby.)

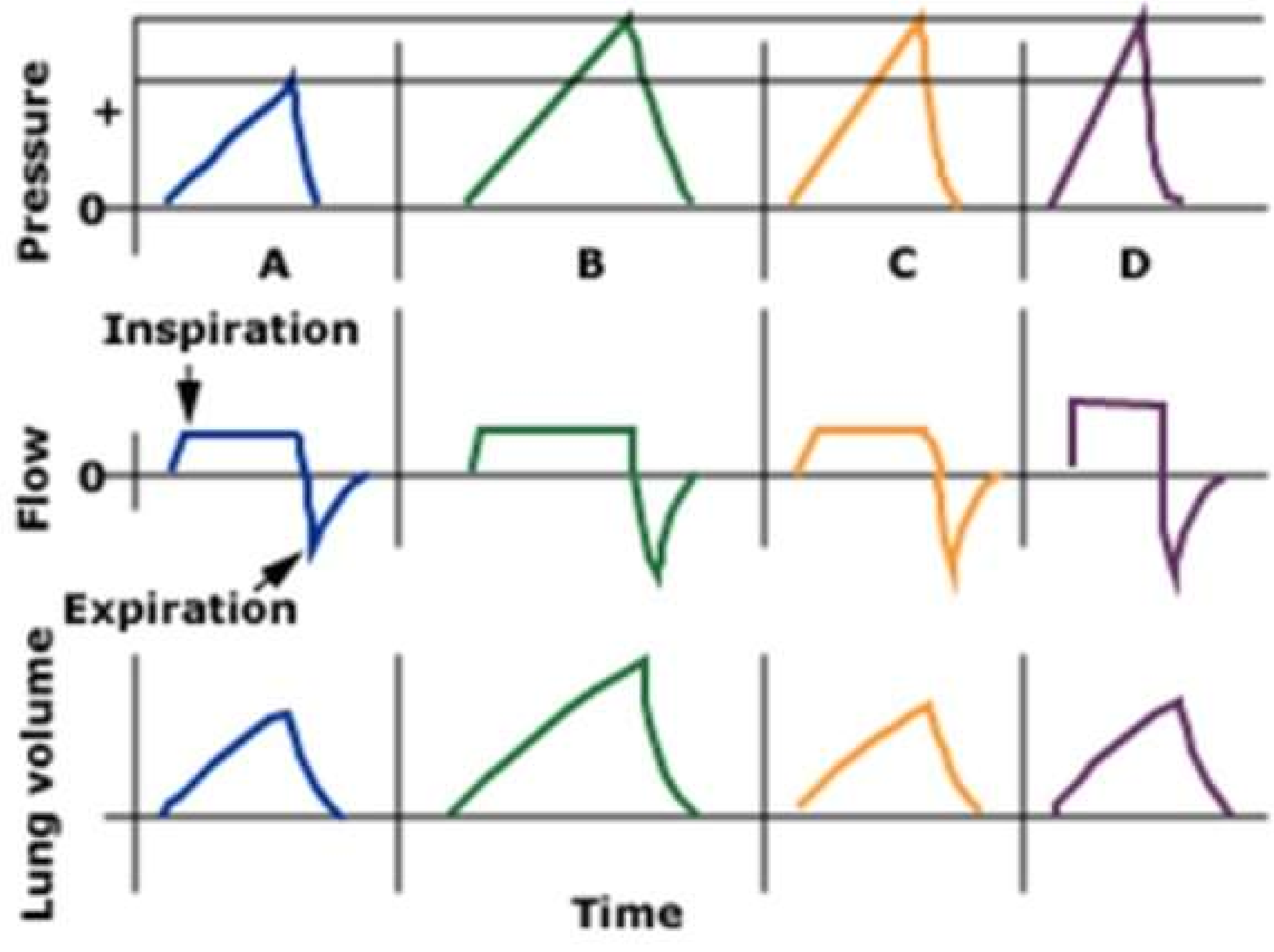
PEEP



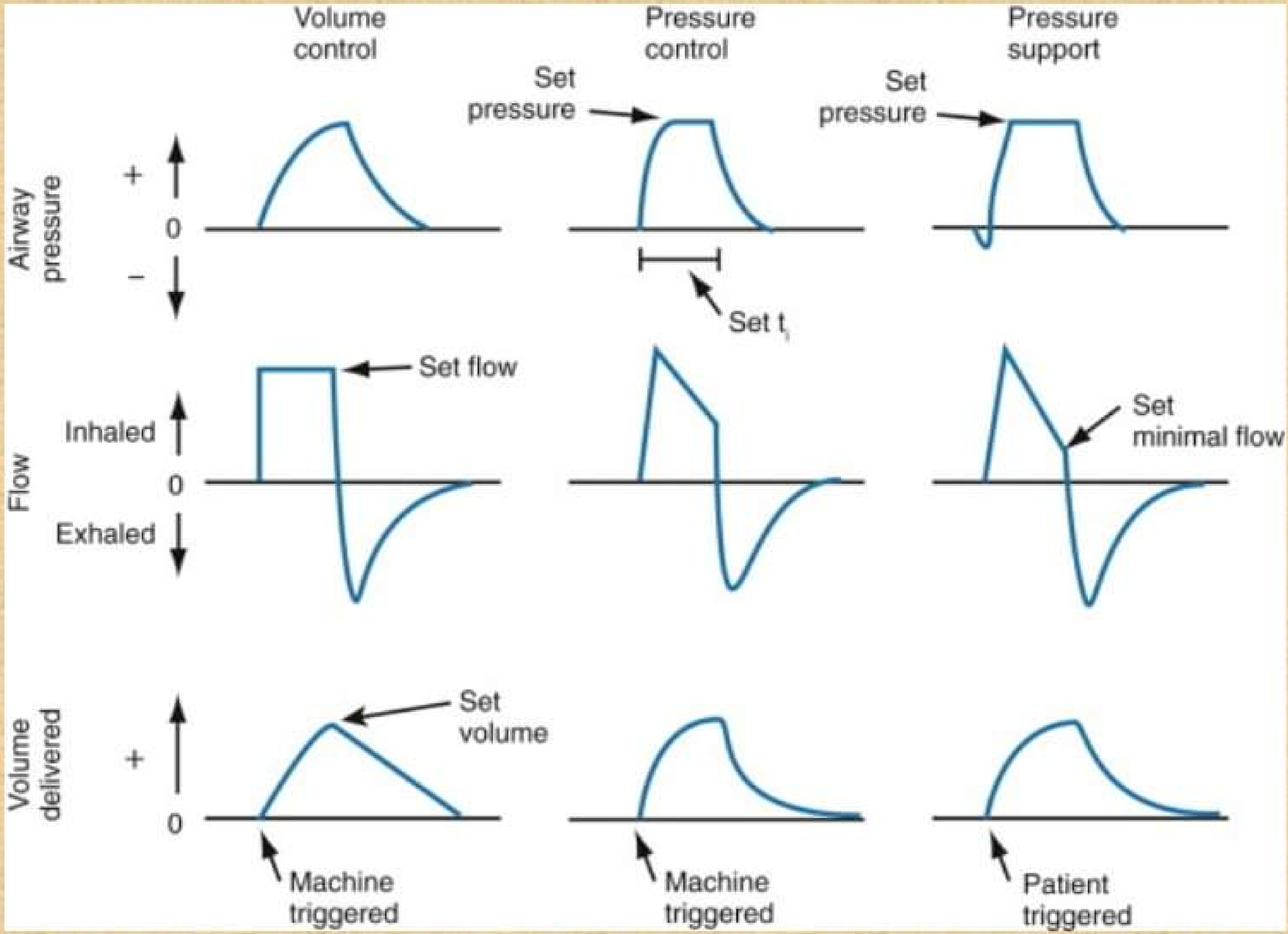
CPAP


PRESSURE
+
0
-
TIME
CONTINUOUS POSITIVE AIRWAY PRESSURE
OR
"CPAP"

Waveforms for volume-cycle ventilator



Comparison of waveforms



Pressure Support Ventilation

- The patient controls the respiratory rate and exerts a major influence on the duration of inspiration, inspiratory flow rate and tidal volume
- The model provides pressure support to overcome the increased work of breathing imposed by the disease process, the endotracheal tube, the inspiratory valves and other mechanical aspects of ventilatory support.

Synchronized Intermittent Mandatory Ventilation

- One advantage of SIMV is that it allows patients to assume a portion of their ventilatory drive
- SIMV is usually associated with greater work of breathing than AC ventilation and therefore is less frequently used as the initial ventilator mode
- Like AC, SIMV can deliver set tidal volumes (volume control) or a set pressure and time (pressure control)
- **Adding pressure support during spontaneous breaths can minimize the risk of increased work of breathing.**
- Negative inspiratory pressure generated by spontaneous breathing leads to increased venous return, which theoretically may help cardiac output and function

Advantages of Each Mode

Mode	Advantages
Assist Control Ventilation (AC)	Reduced work of breathing compared to spontaneous breathing
AC Volume Ventilation	Guarantees delivery of set tidal volume
AC Pressure Control Ventilation	Allows limitation of peak inspiratory pressures
Pressure Support Ventilation (PSV)	Patient comfort, improved patient ventilator interaction
Synchronized Intermittent Mandatory Ventilation (SIMV)	Less interference with normal cardiovascular function

Disadvantages of Each Mode

Mode	Disadvantages
Assist Control Ventilation (AC)	Potential adverse hemodynamic effects, may lead to inappropriate hyperventilation
AC Volume Ventilation	May lead to excessive inspiratory pressures
AC Pressure Control Ventilation	Potential hyper- or hypoventilation with lung resistance/compliance changes
Pressure Support Ventilation (PSV)	Apnea alarm is only back-up Variable patient tolerance
Synchronized Intermittent Mandatory Ventilation (SIMV)	Increased work of breathing compared to AC

Guidelines in the Initiation of Mechanical Ventilation

- Primary goals of mechanical ventilation are adequate oxygenation/ventilation, reduced work of breathing, synchrony of vent and patient, and avoidance of high peak pressures
- Set initial FIO_2 on the high side, you can always titrate down
- Initial tidal volumes should be 8-10ml/kg, depending on patient's body habitus. If patient is in ARDS consider tidal volumes between 5-8ml/kg with increase in PEEP

Guidelines in the Initiation of Mechanical Ventilation

- Use PEEP in diffuse lung injury and ARDS to support oxygenation and reduce FIO_2
- Avoid choosing ventilator settings that limit expiratory time and cause or worsen auto PEEP
- When facing poor oxygenation, inadequate ventilation, or high peak pressures due to intolerance of ventilator settings consider sedation, analgesia or neuromuscular blockage

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	5-8
• 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

Trouble Shooting the Vent

- Common problems
  - High peak pressures
  - Patient with COPD
  - Ventilator synchrony
  - ARDS

Trouble Shooting the Vent

- If peak pressures are increasing:
  - Check plateau pressures by allowing for an inspiratory pause (this gives you the pressure in the lung itself without the addition of resistance)
  - If peak pressures are high and plateau pressures are low then you have an obstruction
  - If both peak pressures and plateau pressures are high then you have a lung compliance issue

Trouble Shooting the Vent

- High peak pressure differential:

High Peak Pressures Low Plateau Pressures	High Peak Pressures High Plateau Pressures
Mucus Plug	ARDS
Bronchospasm	Pulmonary Edema
ET tube blockage	Pneumothorax
Biting	ET tube migration to a single bronchus
	Effusion

Trouble Shooting the Vent

- If you have a patient with history of COPD/asthma with worsening oxygen saturation and increasing hypercapnia differential includes:
  - Given the nature of the disease process, patients have difficultly with expiration (blowing off all the tidal volume)
  - Must be concern with breath stacking or auto- PEEP
  - Management options include:

Decrease respiratory rate	Decrease tidal volume
Adjust flow rate for quicker inspiratory rate	Increase sedation
Adjust I:E ratio	

Trouble Shooting the Vent

- Increase in patient agitation and dis-synchrony on the ventilator:
  - Could be secondary to overall discomfort
    - Increase sedation
  - Could be secondary to feelings of air hunger
    - Options include increasing tidal volume, increasing flow rate, adjusting I:E ratio, increasing sedation

Trouble shooting the vent

- If you are concern for acute respiratory distress syndrome (ARDS)
  - Correlate clinically with HPI and radiologic findings of diffuse patchy infiltrate on CXR
  - Obtain a PaO_2/FiO_2 ratio (if < 200 likely ARDS)
  - Begin ARDSnet protocol:
    - Low tidal volumes
    - Increase PEEP rather than FiO_2
    - Consider increasing sedation to promote synchrony with ventilator

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 °C- 37°C.**
- **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.

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.

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
-

Methods of Weaning

1- T-piece trial,

2- Continuous Positive Airway Pressure (CPAP) weaning,

3- Synchronized Intermittent Mandatory Ventilation (SIMV) weaning,

4- Pressure Support Ventilation (PSV) weaning.

1- T-Piece trial

- It consists of removing the patient from the ventilator and having him / her breathe spontaneously on a T-tube connected to oxygen source.

- During T-piece weaning, periods of ventilator support are alternated with spontaneous breathing.

- The goal is to progressively increase the time spent off the ventilator.

2-Synchronized Intermittent Mandatory Ventilation (SIMV) Weaning

- SIMV is the most common method of weaning.
- It consists of gradually decreasing the number of breaths delivered by the ventilator to allow the patient to increase number of spontaneous breaths

3-Continuous Positive Airway Pressure (CPAP) Weaning

- When placed on CPAP, the patient does all the work of breathing without the aid of a back up rate or tidal volume.
- No mandatory (ventilator-initiated) breaths are delivered in this mode i.e. all ventilation is spontaneously initiated by the patient.
- Weaning by gradual decrease in pressure value

4- Pressure Support Ventilation (PSV) Weaning

- The patient must initiate all pressure support breaths.

- During weaning using the PSV mode the level of pressure support is gradually decreased based on the patient maintaining an adequate tidal volume (8 to 12 mL/kg) and a respiratory rate of less than 25 breaths/minute.

- PSV weaning is indicated for :-

  - Difficult to wean patients
  - Small spontaneous tidal volume.

5- Spontaneous Breathing Trials (SBT)

Settings:

- PEEP = 5, PS = 0 – 5, FiO2 < 40%
- Breathe independently for 30:120 min
- ABG obtained at end of SBT

Failed SBT Criteria:

- RR > 35 for >5 min
- SaO2 <90% for >30 sec
- HR > 140
- Systolic BP > 180 or < 90mm Hg
- Sustained increased work of breathing
- Cardiac dysrhythmia
- pH < 7.32

Causes of Failed SBTs	**Treatments**
Anxiety/Agitation	Benzodiazepines or haldol
Infection	Diagnosis and tx
Electrolyte abnormalities (K^+, PO^{4-})	Correction
Pulmonary edema, cardiac ischemia	Diuretics and nitrates
Deconditioning, malnutrition	Aggressive nutrition
Neuromuscular disease	Bronchopulmonary hygiene, early consideration of trach
Increased intra-abdominal pressure	Semirecumbent positioning, NGT
Hypothyroidism	Thyroid replacement
Excessive auto-PEEP (COPD, asthma)	Bronchodilator therapy

Weaning 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,**
- **Major electrolytes within normal range,**
- **Hematocrit >25%,**
- **Core temperature >36°C and <39°C,**
- **Adequate management of pain/anxiety/agitation,**
- **Adequate analgesia/ sedation (record scores on flow sheet),**
- **No residual neuromuscular blockade.**

Complications of MV

I- **Airway Complications,**

II- **Mechanical complications,**

III- **Physiological Complications,**

IV- **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,
    c- Pneumomediastinum,
    d- Subcutaneous emphysema.
4- Alarm "turned off"
5- Failure of alarms or ventilator
6- Inadequate nebulization or humidification
7- Overheated inspired air, resulting in hyperthermia

III- Physiological Complications

1- Fluid overload with humidified air and sodium chloride (NaCl) retention
2- Depressed cardiac function and hypotension
3- Stress ulcers
4- Paralytic ileus
5- Gastric distension
6- Starvation
7- Dyssynchronous breathing pattern

IV- Artificial Airway Complications

A- Complications related to Endotracheal Tube:-

1- Tube kinked or plugged

2- Rupture of piriform sinus

3- Tracheal stenosis or tracheomalacia

4- Mainstem intubation with contralateral (located on or affecting the opposite side of the

- lung) lung atelectasis

5- Cuff failure

6- Sinusitis

7- Otitis media

8- Laryngeal edema

B- Complications related to Tracheostomy tube:-

1- Acute hemorrhage at the site
2- Air embolism
3- Aspiration
4- Tracheal stenosis
5- Erosion into the innominate artery with exsanguination
6- Failure of the tracheostomy cuff
7- Laryngeal nerve damage
8- Obstruction of tracheostomy tube
9- Pneumothorax
10- Subcutaneous and mediastinal emphysema
11- Swallowing dysfunction
12- Tracheoesophageal fistula
13- Infection
14- Accidental decannulation with loss of airway