



Al – Noor University College

Department of anesthesiology

مرحلة / الرابعة

محاضرة اجهزة نظري 1

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Medical Suction machine

A suction machine, also known as an aspirator, is a type of medical device that is primarily used for removing obstructions — like mucus, saliva, blood, or secretions — from a person's airway. When an individual is unable to clear secretions due to a lack of consciousness or an ongoing medical procedure, suction machines help them breathe by maintaining a clear airway.

surgery suction can be used to remove blood from the area being operated on to allow surgeons to view and work on the area.

Uses of suction unit include:

- 1-Removing respiratory secretions and blood from the airway
- 2-Assisting a patient that is vomiting while he is unconscious
- 3-Removing a foreign substance from a patient's airway and/or lungs (pulmonary aspiration)
- 4-During surgery, suction is used to provide a clear operating field for the surgeon
- 5-used for other procedures: gastrointestinal, wound pleural drainage. and liposuction

Mechanism of suction machine:

Suction applies negative pressure, which is any pressure less than atmospheric pressure (760 mmHg, 100kPa or 14.7 psi), to allow for the movement of fluids or substances. The suction developed by the machine will be measured as a pressure. The common units of pressure are millimeters of mercury (mm Hg) or Pascal's (Pa or kPa), or centimeters of water (inH₂O), or pounds per square inch (psi).

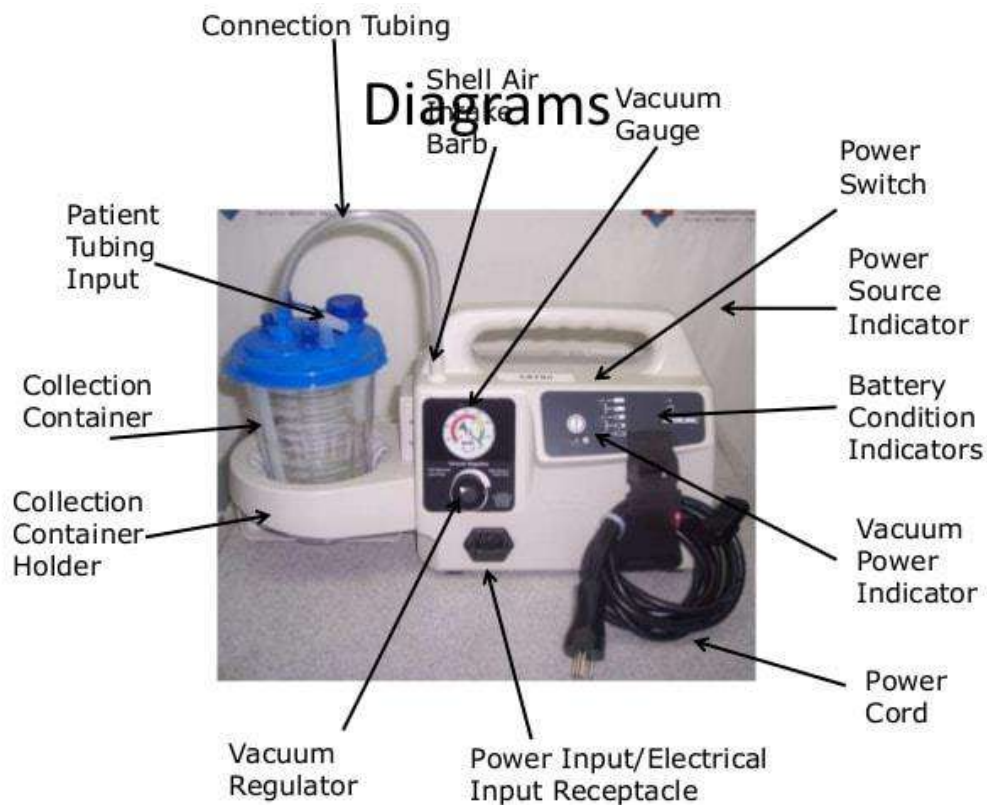
How is medical suction measured?

The movement of air into the tank causes vacuum (suction). Suction, causing flows toward the tank will continue until the air pressures inside and outside the tank are the same

Suction pressure is always measured by the amount of pressure below atmospheric pressure e.g. a suction pressure of 100 mbar means 100 mbar below the atmospheric air pressure.

Component of Suction machine:

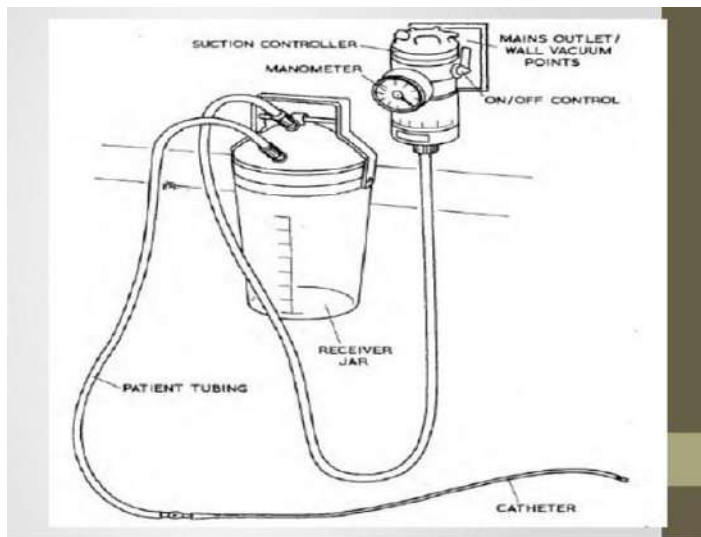
1. Suction pumps
2. Tubing
3. Connecting tube and filter
4. Catheter
5. Suction trolley



Type of Suction pumps:

1. Common vacuum pumps :

A vacuum point close to the patient's bed • The power is provided by a large motor situated at some convenient site within the hospital grounds
Commonly found in ICUs and on wards in modern hospitals • An on/off switch • Control dial for set negative pressure to be increased or decreased • A manometer displays the pressure used • They have approximately — 50mmHg,— 100mmHg and — 300mmHg.



2. Electrical suction apparatus :

Powered from the mains • This type has its own small motor, with an on/off switch and a control dial • This is the equipment most commonly used on wards where a vacuum point is not available



4-Manual Suction Devices

A manual suction device is any device that creates suction without the use of a battery or electricity. Not commonly used because the suction they create is often unpredictable.

These devices generally work by squeezing a pump to create a vacuum. They're often attached to large canisters. For some of these devices, the strength of the suction is heavily dependent on the speed at which you squeeze the pump. Smaller devices, such as the bulbs used to clear the nostrils and mouths of newborns, are also considered manual suction devices

.



Suction tubing :

This leads from the suction bottle to the connection for the suction catheter • Usually the tubing is made from clear plastic for easy viewing of secretions , Disposable • Sometimes rubber tubing is used

Filters :

Suction machine filters trap bacteria and prevent it from entering the pump. The bacteria filters also stop liquids from flowing back up the tubing .

Certain filters may also be used to protect against dust and dangerous gases that can damage the machine.

Suction Catheters :

A wide variety of suction catheters are used in the hospital. Most have special features related to their intended use. Yankauer tip suction are typically more rigid and usually have a large openings. These allow

rapid removal of secretions or vomitus from the oropharyngeal cavity in trauma settings or blood and irrigation fluids in the operating room.

Catheters for airway suctioning are liner systems are available in sizes convenient for different clinical needs. All feature disposable shutoff valves and many have disposable filter options.

Types of suctioning catheters

1 - Whistle – tipped catheter.

2 - Open – tipped catheter.

3- Yankauer Suction Catheter

whistle – tipped catheter Less irritate the airway

open tipped catheter More effective for removing thick mucus plugs.

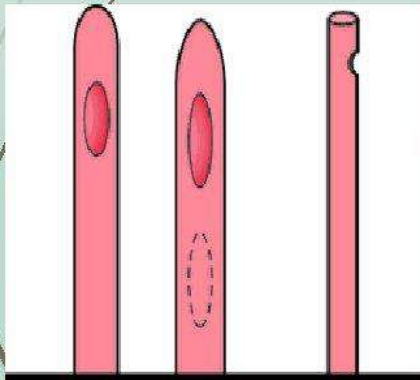


Yankauer catheter

TYPES OF SUCTION CATHETERS

∞ Types of suctioning catheters :

- 1- Whistle – tipped catheter.
- 2- Open – tipped catheter.



Suction trolley :

- 1- Sterile plastic gloves - disposable •
- 2- Suction catheters - appropriate sizes for the patient •
- 3- Lubricating jelly
- 4- Sterile gauze swabs - to transfer jelly to tip of catheter •
- 5- Bowl of sodium bicarbonate or sterile water - to flush the secretions through the catheter and tubing •
- 6- Plastic bag for the collection of disposables •



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محاضرة أجهزة (2)

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Principles of Operation :

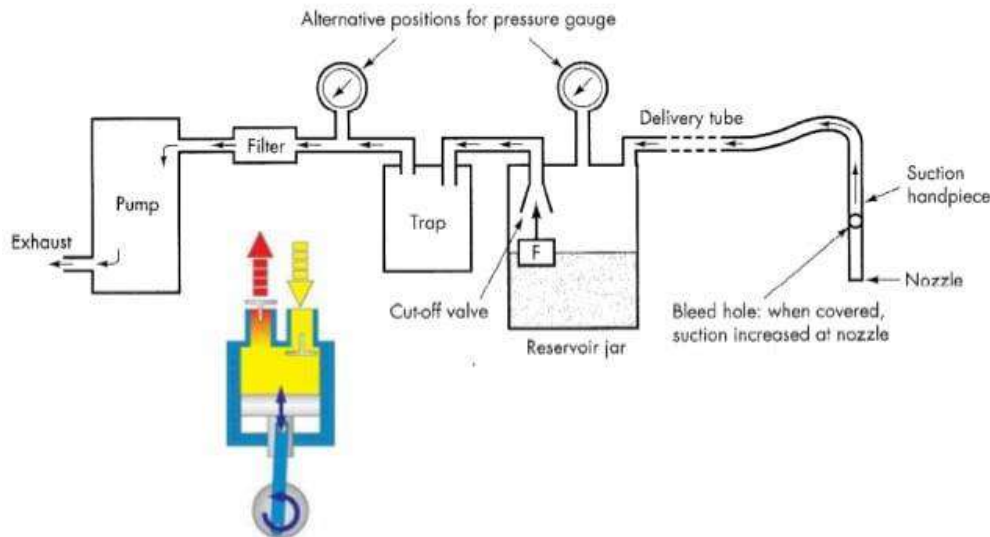
Pump powered by electrical motor or foot pedal –

- Pump moves piston up and down •

- Piston attached to air tight diaphragm • Pulls air in from collection container through one-way valve to reduce pressure – Reduced pressure draws fluid from patient via tubing •

- Fluid remains in bottle until disposal • Valve prevents fluid from passing into motor – Motor speed determines suction strength

Principles of Operation



Type of Suction techniques :

The type of suctioning depends on the type of suctioning you intend to do. There are three basic types:

1-Oropharyngeal suctioning: The most commonly used form of suctioning in emergency medicine, this type of suctioning maintains a patent airway by suctioning the throat via the mouth.

2-Nasopharyngeal suctioning: An alternative to oropharyngeal suctioning, nasopharyngeal suctioning allows access to the throat through the nose. It can be especially helpful for patients with broken or missing teeth, serious jaw injuries, or any type of physical trauma that makes accessing the mouth difficult.

Neck extended • Introduce on Inspiration phase only • Not for head injury patient due to leakage of CSF •

3-Suction via tube (Artificial airways): catheter is introduced into an endotracheal, or tracheostomy

Artificial airways must regularly be cleared of secretions,

Patients with airway obstructions may also require suctioning through an artificial airway.

Suction techniques :

Sterile technique • First practice with unconscious patient

Procedure :

Whatever the mode of entry, no suction pressure is applied while the catheter is being introduced •

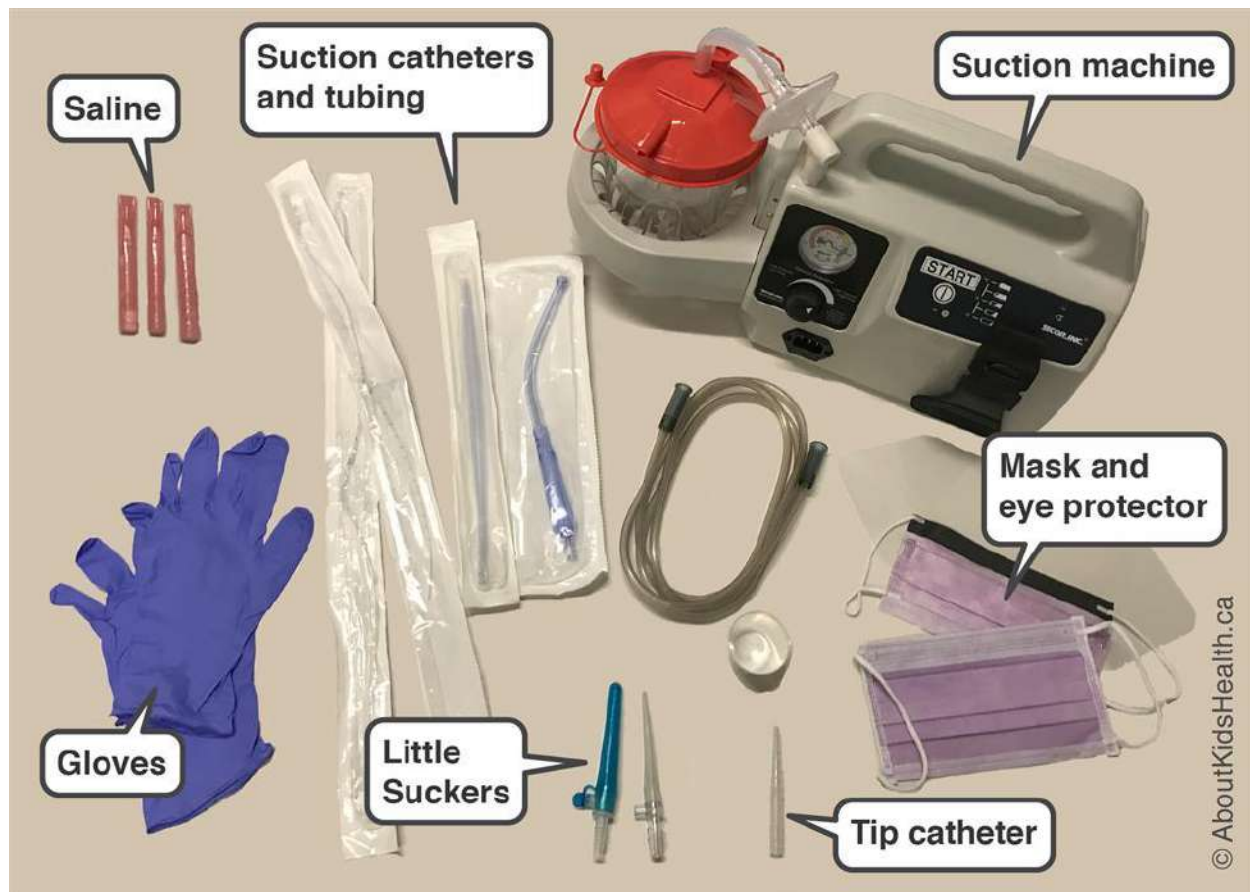
To avoid tracheal trauma , catheter itself may be pinched or disconnected from the tubing during introduction • Advanced until either a cough reflex is elicited or some resistance in the trachea is met • Apply suction gentle withdrawn of catheter with rolling • observe the patient for signs of hypoxia •

side lying or with the head rotated to one side to avoid aspiration of gastric contents when vomiting occur

Apply suction for a maximum of 10 to 15 seconds. Allow patient to rest in between suction for 30 seconds to 1 minute. If required, replace oxygen on patient and clear out suction catheter by placing Yankauer in the basin of water

Additional equipment and supplies

- Sterile or distilled water
- Clean container for flushing solution
- Clean disposable gloves (to avoid direct contact with secretions from
- Water-based lubricant for nasopharyngeal suctioning
- Good light source
- Towel or small blanket for positioning if needed
- Oximeter
- Oxygen, if needed
- Plastic bag for soiled supplies



Position the patient.

Semi – Fowler’s position with: Head turned to one side for oral suctioning

For Nasal suctioning with the Neck hyperextended. Lateral position & the patient facing you .

Setting up the suction machine

1. Connect the suction tubing to the canister.

2. Check the suction pressure by turning on the unit and covering the end of the tubing with your finger. Look at the number on the gauge, and make sure it is the number set by your health-care provider. This should be checked each time before you suction.
 - Pressure setting for neonates (newborn): 60-80 mmHg
 - Pressure setting for infants: 80-100 mmHg
 - Pressure setting for children/teens: 100-120 mmHg
3. Attach the correct suction catheter, Yankauer or tip to the tubing.
4. Proceed with suctioning.

How do know the right size catheter for child

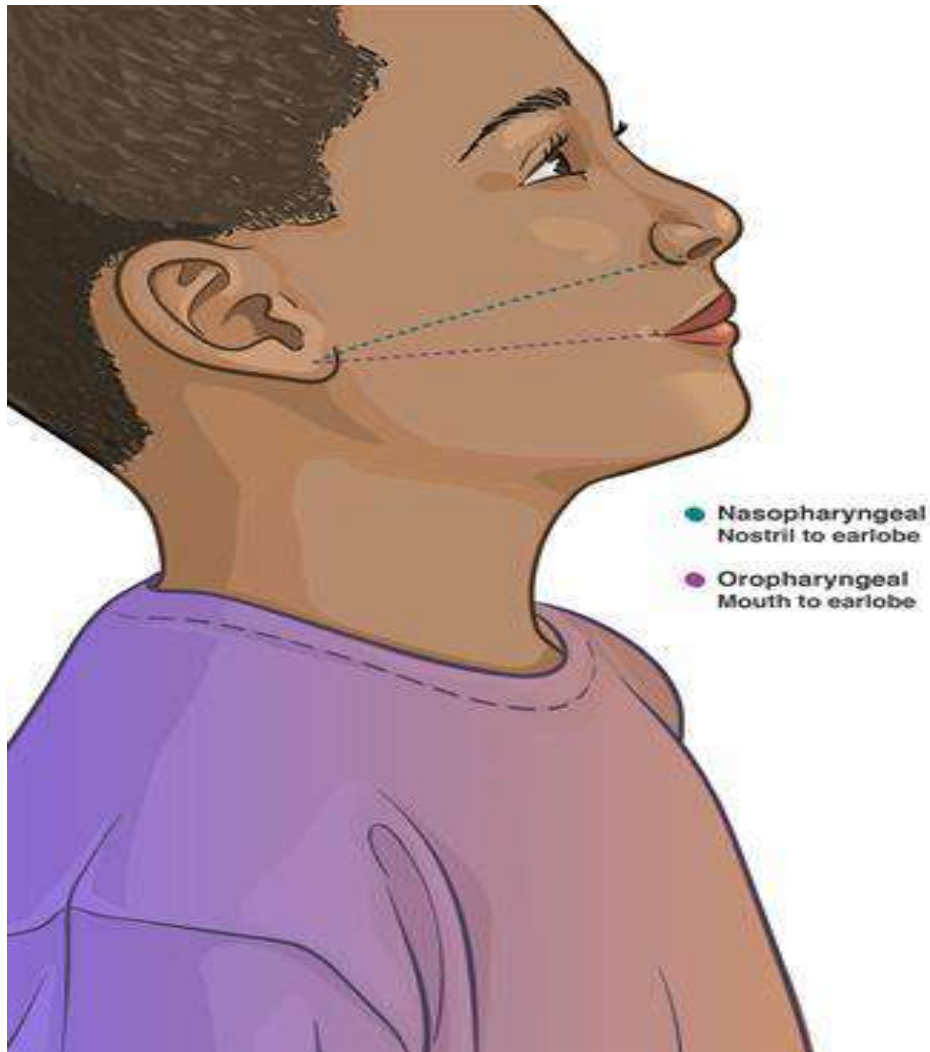
In general, the recommended suction catheter sizes and suction depth depend on the size of your child and the type of suctioning being done. As a general guideline, for nasal, nasopharyngeal and oropharyngeal suctioning, the size of the suction catheter should not be any larger than half the size of your child's nostril.

Identifying the correct suction depth

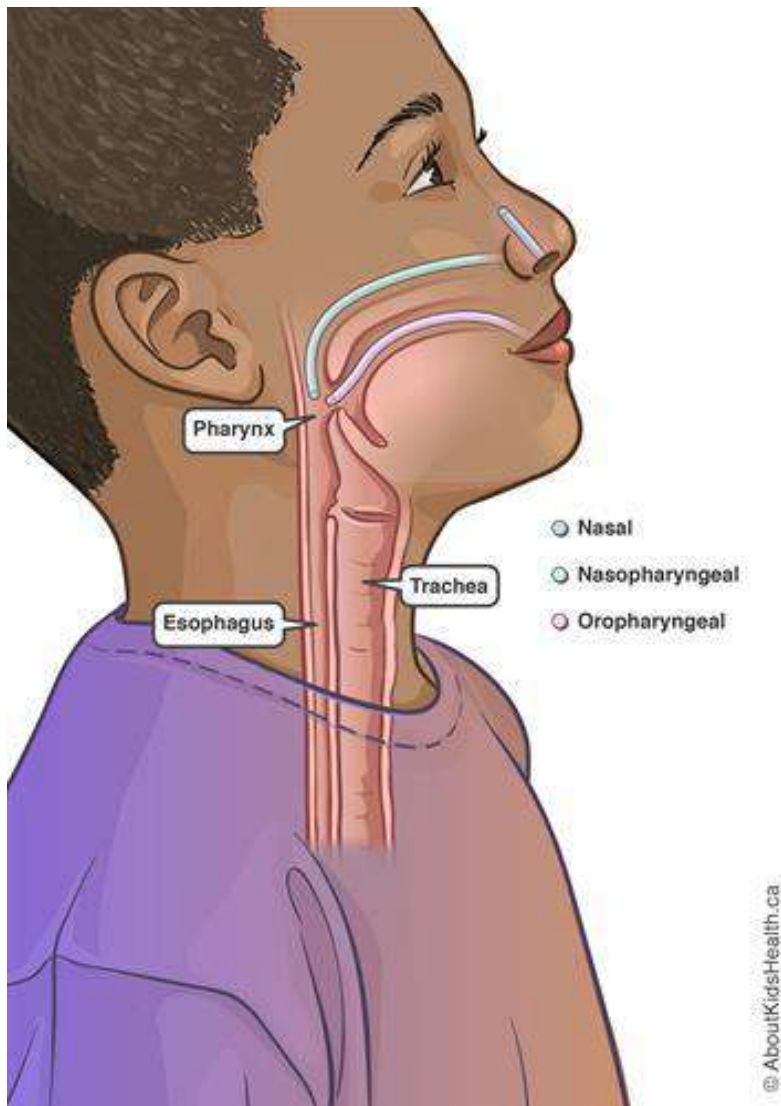
1-For nasal suctioning measure from your child's nostril to the middle of the nose.

2-For nasopharyngeal and oropharyngeal suctioning measure from your child's nostril to the tip of the earlobe.

Measuring the length of suction catheters



Use this illustration to measure the length of suction catheter needed for nasopharyngeal and oropharyngeal suctioning. **Correct suctioning depths**



Use the pre-measured suction catheters (where available) to make sure you are suctioning at the correct depth.

For ET and tracheostomy suctioning, the diameter of the suction catheter should be about half the inside diameter of the Tracheostomy or ET tube so that hypoxia can be prevented. To determine suction catheter size, multiply the artificial airway's diameter X 2 (i.e. # 8 ET tube, use #16 French suction catheter)

Closed airway/tracheal suction.

The suction catheter attaches to the ventilator tubing and the patient does not need to be disconnected from the ventilator

Open method: Disconnecting the patient from the ventilator, suction and reconnect

Promoting Oxygenation

Deep breathing and coughing: The nurse can facilitate respiratory functioning by encouraging deep breathing exercises and coughing to remove secretions from the airways. When coughing raises secretions high enough, the client may either expectorate = spit out, or swallow them



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Complication of suction :

5 complications is usually associated with suctioning

Suctioning can prevent a wide range of severe complications and can save lives in emergencies. But like all medical procedures, it carries some risks

1. Hypoxia

Hypoxia is one of the primary risks of suctioning. This can happen if:

- a) The suctioning machine stimulates the vagus nerve

- b) The suctioning is ineffective and does not remove an airway obstruction
- c) The suction equipment causes airway trauma that occludes the airway
- d) The suctioning equipment blocks the airway or you suction for too long

To reduce the risk of hypoxia, pre-oxygenate the patient before suctioning. Never suction longer than 15 seconds. If you must suction the patient again because suctioning has failed, you must pre-oxygenate them again.

2. Airway Trauma

It's easy to damage the airway, especially if you use inappropriately sized equipment, rush the procedure, or work with geriatric or pediatric patients. To reduce the risk of airway trauma, use a thin and flexible catheter. Use smaller equipment for geriatric and pediatric patients

3. Bleeding – This can be prevented by proper technique

4. Infection:

The airway is highly vulnerable to a wide variety of contaminants, particularly if suctioning equipment is not clean. Never reuse disposable equipment, and keep all equipment sealed until use. Medical personnel

with active infections should not suction patients, and all team members should wash their hands before and after all suctioning procedures.

Preventing airway trauma can reduce the risk of infection, so only suction a patient whose airway is visible. Aspiration is also a risk factor for infection

5. Bradycardia

A slow heart rate, known as bradycardia, is one of the most common suctioning complications, because suctioning stimulates the vagus nerve. This increases the risk of fainting and loss of consciousness. In patients in cardiac distress, it can elevate the risk of severe cardiovascular complications. Before suctioning, ask about a history of bradycardia and other heart problems. Then monitor vital signs during and after suctioning.

Personal Protection:

Personal protection has always been important. If anything COVID-19 has demonstrated this importance more than it has added to it. Properly use PPE (personal protection equipment) to protect both the patient and yourself.

How to Clean a Suction Machine

A suction machine has many parts, so frequent cleanings are an absolute necessity. Ideally, medical professions should clean an aspirator after every use while wearing personal protective equipment to protect against hazardous waste, and then clean the reusable parts in regular intervals to ensure the aspirator and its components are free of dangerous contaminant

many aspirator parts are of single use.



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محاضرة أجهزة (4)

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Ventilators

Introduction:

Breathing :

Breathing: It is taking air in (inspiration) and out of your lungs (expiration). It can be consciously controlled (voluntary action). Breathing involves two stages — ventilation and gas exchange.

Ventilation:

is the movement of air in and out of lungs

gas exchange:

is the absorption of oxygen from the lungs and release of carbon dioxide.

Respiration :is a process where the body breaks down the oxygen, so that the cells in the body can use it . Therefore ,Breathing is a physical process and respiration is a chemical process

Normal Mechanics Of Spontaneous Ventilation And

Respiration :

Spontaneous breathing or spontaneous ventilation is simply the movement of air into and out of the lungs. The main purpose of ventilation is to bring in fresh air, for gas exchange into the lungs and to allow the exhalation of air that contains CO₂.

Respiration : It is defined as movement of gas molecules across a membrane.

External Respiration: is movement of O₂ from the lungs into bloodstream and of CO₂ from bloodstream into alveoli.

Internal Respiration: is movement of CO₂ from the cells into the blood and movement of O₂ from the blood into cells.

Normal inspiration is accomplished by the expansion of thorax or chest cavity. It occurs when the muscles of inspiration contract. During contraction , the diaphragm descends and enlarges the vertical size of thoracic cavity. The external intercostal muscles contract and raise the ribs slightly, increasing the circumference of thorax. The activities of these muscles represent the “work” required to inspire.

Normal exhalation is passive and does not require any work. During normal exhalation, the muscles relax, the diaphragm moves upward to its resting position, and the ribs return to their normal position. The volume of thoracic cavity decreases, and air is forced out of alveoli.

Basic Physiology :

Negative pressure circuit : - Gradient between mouth and pleural space is the driving pressure - need to overcome resistance - maintain alveolus open • overcome elastic recoil forces - Balance between elastic recoil of chest wall and the lung=FRC

Gas Flow And Pressure Gradients During Ventilation :

Basic of Air flow is that, for air to flow through a tube or airway, pressure at one end must be higher than the pressure at the other end. Air always flows from the high pressure point to the low pressure point (pressure gradient). The conductive airway begins at the mouth & nose, and ends at the small airways near the alveoli. Therefore, gas flows into the lungs, when the pressure in the alveoli is lower than the pressure at the mouth and nose.

Conversely, gas flows out of lungs, when the pressure in the alveoli is greater than the pressure at the mouth and nose. When the pressure at the mouth and alveoli are same, as occurs at the end of inspiration or the end of expiration, then no gas flow occurs as there is no pressure gradient.

Definition Of Pressures And Gradients In The Lungs

Airway opening pressure (P_{aw})/ Mouth pressure(P_M) is often called **airway pressure (P_{aw})**. Unless pressure is applied to mouth or nose, P_{aw} is Zero (atmospheric). Body surface pressure (P_{bs}) is the pressure at body surface . This is equal to Zero unless the person is using a pressurized chamber or a negative pressure.

P_{pl} = Intrapleural pressure : pressure in the intrapleural space ; generally negative because the lungs are “naturally” smaller than the chest wall; the negative pressure helps to keep the airways open and helps the lungs from collapsing.

P_{alv} = Intra-alveolar pressure : pressure within the alveoli; positive on expiration, negative on inspiration, and zero (same as atmospheric) when there no air movement.

During normal spontaneous inspiration, as the volume of thoracic space increases, the intrapleural pressure becomes more negative in relation to atmospheric pressure . This negative intrapleural pressure goes from -5cm H₂O at end expiration to -10cm H₂O at end inspiration. The negative intrapleural pressure is transmitted to the alveolar space.

Ventilation Parameters

A. Lung Volumes :

- a- **Tidal Volume (V_T , T_V)**: volume of gas exchanged each breath; can change as ventilation pattern changes .(500 ml) b.

- b- Inspiratory Reserve Volume (IRV):** maximum volume that can be inspired, starting from the end inspiratory position (potential volume increase at the end of inspiration).(3000ml)
- c- Expiratory Reserve Volume (ERV):** maximum volume that can be expired, starting from the end expiratory position (potential volume decrease at the end of expiration)(1200ml)
- d- Residual Volume (RV):** volume remaining in the lungs and airways following a maximum expiratory effort (1300 ml)

Capacities:

- a. Vital Capacity (VC):** maximum volume of gas that can be exchanged in a single breath $VC = TV + IRV + ERV$ (4700 ml)
- b. Total Lung Capacity (TLC):** maximum volume of gas that the lungs(and airways) can contain $TLC = VC + RV = TV + IRV + ERV + RV$ (6000 ml)
- c. Functional Residual Capacity (FRC):** volume of gas remaining in the lungs (and airways) at the end expiratory position $FRC = RV + ERV$ (2500 ml)

Terms related to mechanical ventilation

Respiratory rate (f): Number of breaths per minute (10 to 20 bpm).

Tidal volume (VT): Volume of air inhaled /exhaled during each respiratory cycle (7 to 12 ml/kg).

Minute ventilation total volume inspired or expired per unit time sometimes called Minute Volume (MV) when measured per minute

$MV \text{ or } VE' = f \times TV$, At rest= $12/\text{min} \times 0.5L = 6 \text{ L/min}$

Fraction of inspired oxygen(FIO₂) - :amount of oxygen delivered to the patient. It can range from 21% (room air) to 100%.

I:E Ratio :- The inspiratory time compared to the expiratory time; I + E = total cycle time. (1:2 or less).

Maximal Inspiratory pressure (MIP): Maximal negative pressure generated during inhalation.(15 -20cmH₂O)

Flow rate: Flow rate is the speed with which the tidal volume is delivered. (40 to 100 L/min).

Positive end expiratory pressure(PEEP): keeps the air way open at the end of expiration ; 5 to 20 cms of H₂O.

Ventilation: Ventilation or breathing is the process of moving air into and out of the lungs.

Mechanical ventilation : Mechanical ventilation The use of a ventilator to move room air or oxygen-enriched air into and out of the lungs mechanically to maintain proper levels of oxygen and carbon dioxide in the blood. • Types of ventilators include negative-pressure and positive-pressure ventilators.

Mechanical ventilator

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

A ventilator is a device that supports or takes over the breathing process, pumping air into the lungs. People who stay in intensive care units (ICU) may need the support of a ventilator. This includes people with severe COVID-19 symptoms



Figure 1

Goals of Mechanical Ventilation:

Mechanical ventilation alone does not treat or reverse the underlying pathology. Rather, it is applied as one of the support systems until the

reversal of the pathological condition, so that the patient may then become weaned from mechanical ventilation.

The goals of mechanical ventilation are:

- 1- Adjust alveolar ventilation pH, PaCO₂
- 2- Improve oxygenation Assess with pulse oximetry
- 3- Decrease work of breathing
- 4- To support the lung and improve pulmonary mechanics
- 5-To Maintain ABG values within normal range
- 6-To Permit lung and airway healing

Need of Ventilator :

- 1-In anaesthesia (as a component of an anaesthesia machine).
- 2-Home care in hypoventilated patients.
- 3-Emergency medicine.
- 4-Intensive care medicine.

Indications of mechanical ventilation

- 1-Acute respiratory failure
- 2- Apnoea or inability to breathe

3- Severe hypoxia

4-Cardiac diseases:- Cardiogenic shock.

5- Central Nervous system diseases:- Cerebral trauma, Cerebrovascular accident, Spinal cord injury.

6-Neuro muscular diseases:- Guillain-Barre syndrome. Multiple sclerosis. Poliomyelitis.

7-Musculoskeletal diseases:- Kyphoscoliosis. Myasthenia gravis

8-Others:- Trauma like rib fractures, head injury, facial trauma. Surgery like cardiac surgery, pulmonary and gastro intestinal surgery.

Clinical parameters: ventilator is indicated when:

1-Respiratory Rate $> 35/\text{min}$

2-Tidal volume $< 5\text{ml/kg}$

3-Vital capacity $< (15\text{ml/kg body wt.})$

4- $\text{PaO}_2 < 60 \text{ mm Hg}$, $\text{PaCO}_2 > 50\text{mm Hg}$ with $\text{pH} < 7.25$

Criteria for institution of ventilatory support:

Parameters	Ventilation indicated	Normal range
<u>A- Pulmonary function studies:</u>		
• 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 H ₂ O)	< -20	75-100

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Criteria for institution of ventilatory support:

Parameters	Ventilation indicated	Normal range
<u>B- Arterial blood Gases</u>		
• PH	< 7.25	7.35-7.45
• PaO ₂ (mmHg)	< 60	75-100
• PaCO ₂ (mmHg)	> 50	35-45

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Types of Mechanical ventilators

1-Negative-pressure ventilators

2-Positive-pressure ventilators

Negative-pressure ventilators:

Negative pressure applied to chest wall increases the volume of the thoracic cage. Mimics spontaneous ventilation. Negative Intrathoracic pressure gradient causes air to enter lungs. No need for artificial airway. Used mainly for chronic care of patients with neuromuscular disorders. Examples: iron lung and chest cuirass

IRON LUNG : Encloses patients body except for the head and neck in a tank and the air in it is evacuated to produce a negative pressure around the chest. • This negative pressure surrounding the chest & underlying alveoli results in chest wall and alveolar expansion. • The tidal volume delivered to the patient is directly related to the negative pressure gradient

CHEST CUIRASS : It is a form of negative pressure ventilation that was intended to avoid the problems of patient access & TANK SHOCK associated with iron lungs. •

It covers only the patient's chest and leaves the arms and lower body exposed. • To overcome the problem of air leakage, individually designed cuirass minimize air leaks, & they have been used successfully to ventilate patients with chest wall diseases such as scoliosis

Complications With Negative Pressure Ventilation:

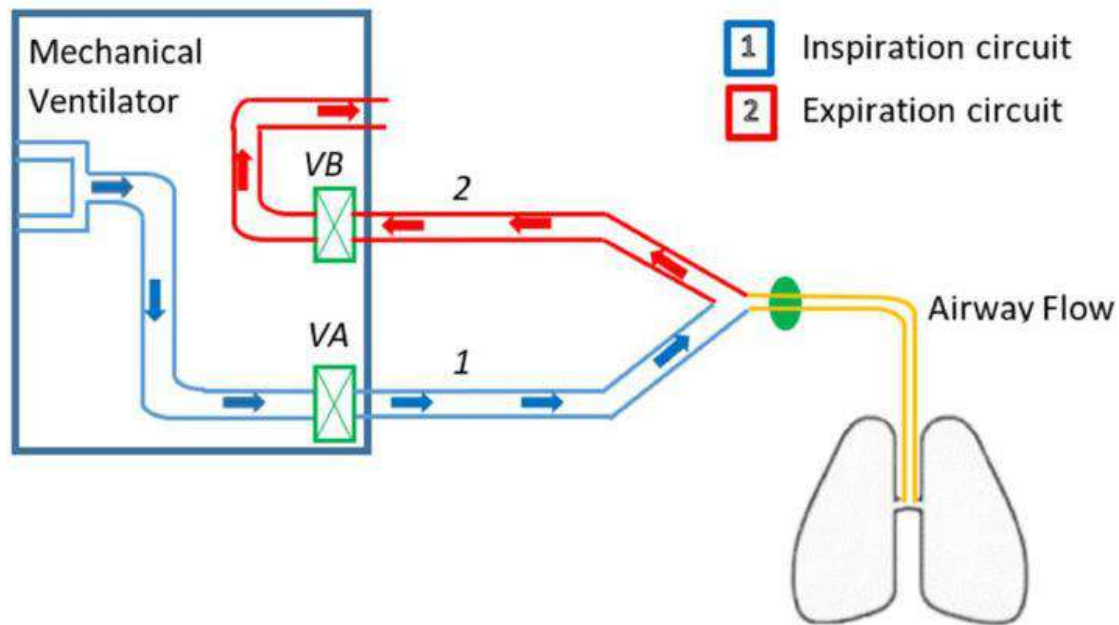
- 1- Limited access for patient care.
- 2- Inability to properly monitor pulmonary mechanics.
- 3- Patient discomfort.

Positive-pressure ventilators:

Intrathoracic pressure remains positive throughout respiration. Force oxygen into the patients lungs through an endotracheal or tracheostomy tube to initiate respiration

Mechanical ventilation process

The operating principle of mechanical ventilation is illustrated in Fig. below. Frequently, the respiratory cycle consists of the inspiratory time (TI) of 1 s and the expiratory time (TE) of 2 s. In this case, the respiratory frequency is often 20 cycles per minute. Once inspiration gets triggered, the inspirator opens the inspiratory valve VA and closes the expiration valve VB, causing the airway pressure to rise and then, compressed gas enters the lung. During expiration, the mechanism is reversed. The inspiratory valve is closed and the expiratory valve opens, causing the airway pressure to drop, and the gas leaves the lung (passive exhalation). These two valves always act in opposite ways. However, this mechanism cannot generate a PEEP. The regulation of the expiratory valve causes the desired PEEP by taking into account the resistance of the breathing circuit



Essential components in mechanical ventilation :

- 1- Patient
- 2-Artificial airway
- 3-Ventilator circuit
- 4- Mechanical ventilator
- 5-A/c or D/c power source
- 6- O₂ cylinder or central oxygen supply

Classification of positive pressure ventilator (ppv):

1. Pressure-cycled ventilator: The ventilator pushes air into the lungs until a specific airway pressure is reached; it is used for short periods, as in the post anesthesia care unit.

2- Time-cycled ventilator: The ventilator pushes air into the lungs until a preset time has elapsed; it is used for the pediatric or neonatal patient

3- Volume-cycled ventilator:

- a. The ventilator pushes air into the lungs until a pre-set volume is delivered.
- b. A constant tidal volume is delivered regardless of the changing compliance of the lungs and chest wall or the airway resistance in the client or ventilator.

4. Microprocessor ventilator

- a. A computer or microprocessor is built into the ventilator to allow continuous monitoring of ventilatory functions, alarms, and patient parameters.
- b. This type of ventilator is more responsive to patients who have severe lung disease or require prolonged weaning

The Basic structures of ventilator

The basic components of a mechanical ventilator, are four main parts: the power source, controls, safety features, and monitors.

1-The Power Source

The power source consists of the energy used to keep the machine functioning and the gas flowing to the patient. Ventilators are powered by electricity flowing from a wall outlet and a series of backup batteries. The gas flowing to the patient is, of course, oxygen, so they can breathe.

2-The Controls

Like any machine, there are controls that the doctor or nurse uses to operate the machine. Ventilators have many controls that do different functions. They have gas blenders, gas accumulators, flow regulators, humidifiers, and pressure regulators. All perform a specific function that is vital for the patient . Flow and pressure regulators keep the flow of the gasses constant so that the doctor can set the rate and pressure of the gas and the machine will maintain it.

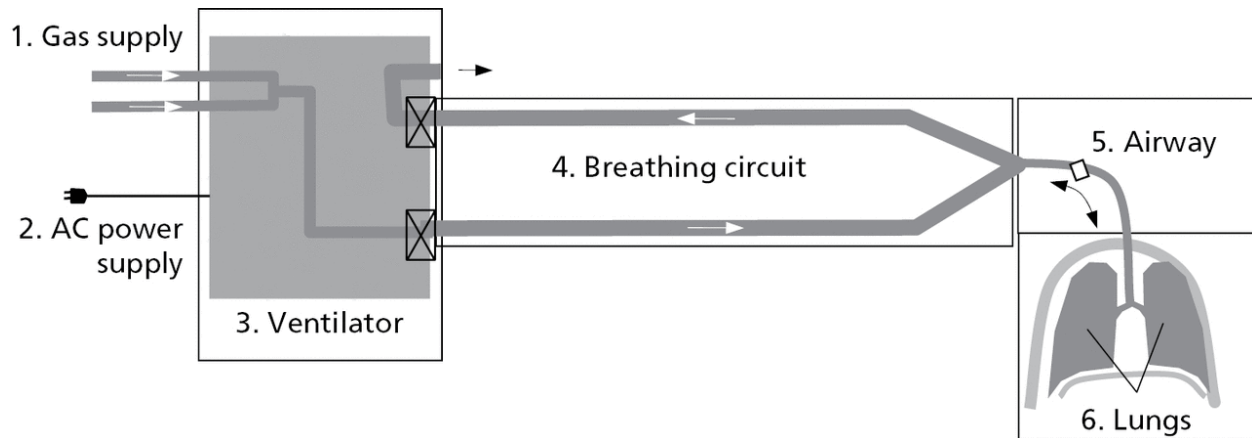
3-The Monitors

The monitors sense and present the characteristics of the gas delivery, so the doctor can assess the performance of the machine. The doctor can look at the monitors to ensure that the settings are being maintained and the patient is doing okay. The main thing they watch is the flow of the gasses that keep the patient alive.

4-Safety Features

The safety features on a ventilator are present so that, in the event of a catastrophic accident, the patient will stay alive. There are alarms to

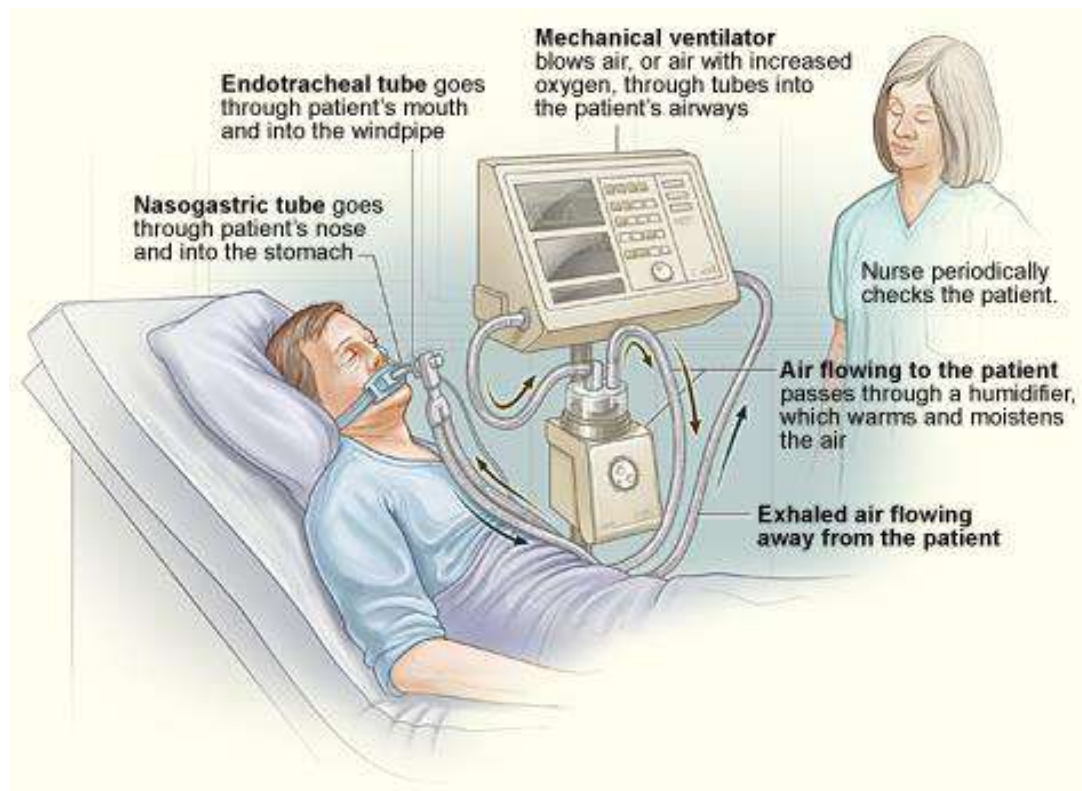
warn the attending staff if the machine loses power or the pressure level drops. The features usually include emergency backups in the event of power loss.



How does a ventilator work?

A ventilator uses pressure to blow air into the lungs. This pressure is known as positive pressure. A patient usually exhales the air on their own, but sometimes the ventilator does it for them too.

The amount of oxygen the patient receives can be controlled through a monitor connected to the ventilator. If the patient's condition is particularly fragile, the monitor will be set up to send an alarm to the caregiver, indicating an increase in air pressure.



The machine works by bringing oxygen to the lungs and taking carbon dioxide out of the lungs. This allows a patient who has trouble breathing to receive the proper amount of oxygen. It also helps the patient's body to heal, since it eliminates the extra energy of labored breathing.

A ventilator blows air into the airway through a breathing tube. One end of the tube is inserted into patient's windpipe and the other end is attached to the ventilator. The breathing tube serves as an airway by letting air and oxygen from the ventilator flows into the lungs. Depending on the patient's medical condition, they may be able to use a respiratory mask instead of the breathing tubes.

What to expect while on a ventilator?

What to expect depends on the severity of the patient's illness. For example, some people can resume regular activities, such as reading or watching television, while others need to be restrained to prevent them from pulling out their respiratory tubes.

Patients or caregivers also need to learn how to provide suctioning to prevent mucus from blocking the tubes.

Ventilators normally don't cause pain. The breathing tube in patient's airway may cause some discomfort. and the patient is not able to speak and eat. Instead of food, the health care team may give nutrients through a tube inserted into a vein. If a patient is on a ventilator for a long period, they will likely get food through a nasogastric, or feeding tube.

A ventilator greatly restricts patient's activity and limits their movement. They may be able to sit up in bed or in a chair, but usually can't move around much.



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محاضرة أجهزة (6)

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Characteristics of the ideal ventilator

1-The ventilator should be simple, portable, strong and economical. If compressed gas is used to drive the ventilator, a significant wastage of the compressed gas is expected. Some ventilators use a Venturi to drive the bellows, to reduce the use of compressed oxygen.

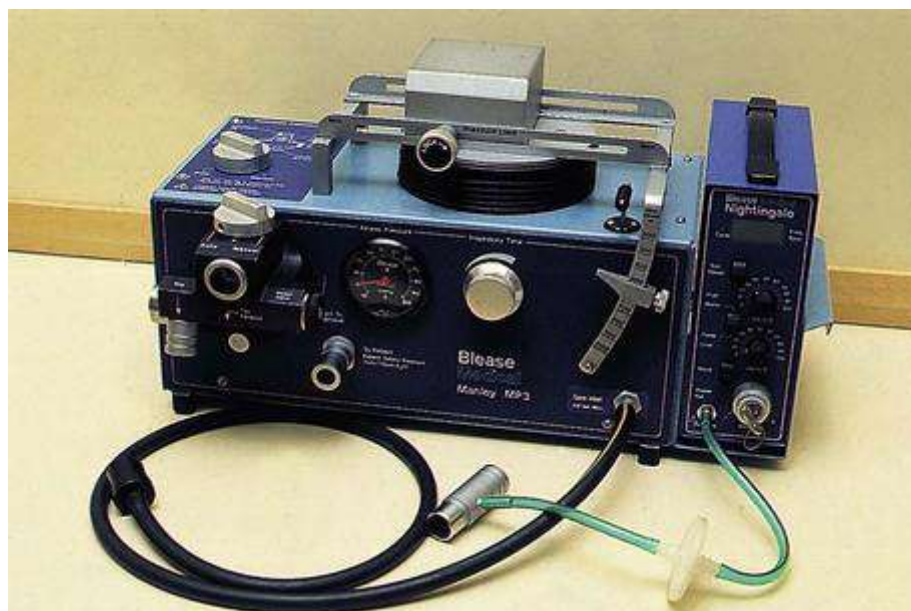
2- It should be versatile and supply tidal volumes up to 1500 mL with a respiratory rate of up to 60/min and variable I : E ratio. It can be used with different breathing systems. It can deliver any gas or vapour mixture. The addition of positive end expiratory pressure (PEEP) should be possible.

- 3- It should monitor the airway pressure, inspired and exhaled minute and tidal volume, respiratory rate and inspired oxygen concentration.
- 4- There should be facilities to provide humidification. Drugs can be nebulized through it.
- 5- Disconnection, high airway pressure and power failure alarms should be present.
- 6- There should be the facility to provide other ventilatory modes, e.g. SIMV, CPAP and pressure support.
- 7- It should be easy to clean and sterilize.

Some of the commonly used ventilators are :

Manley MP3 ventilator

This is a minute volume divider (time cycled, pressure generator).





Components

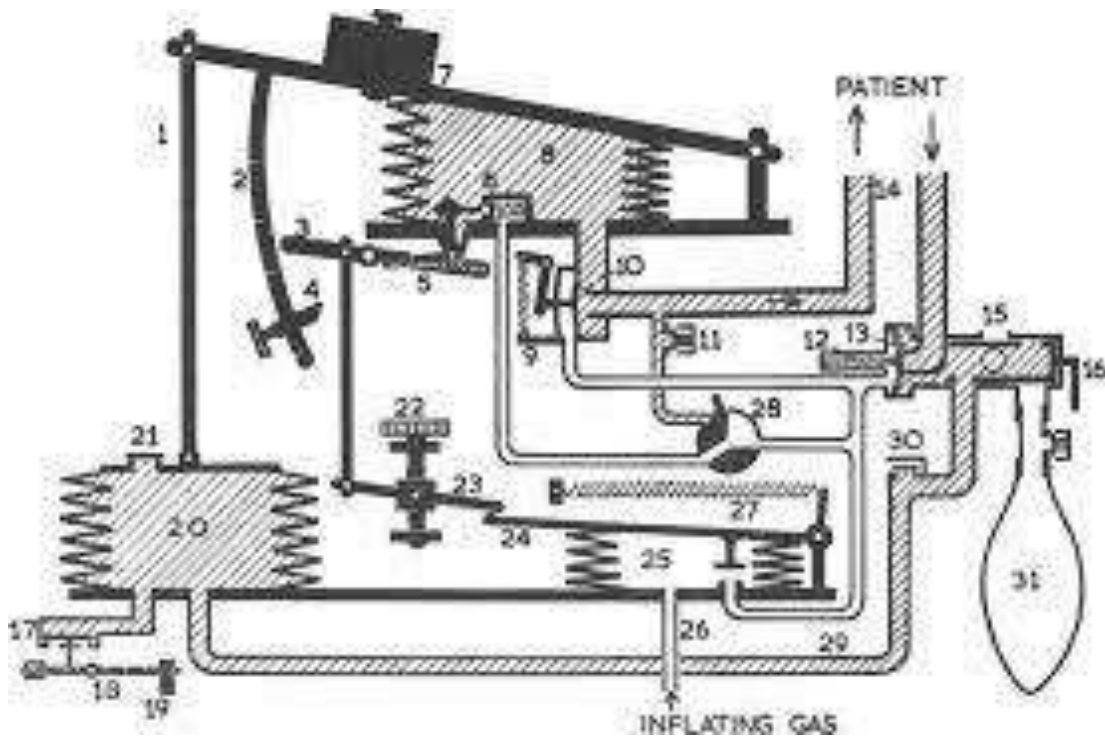
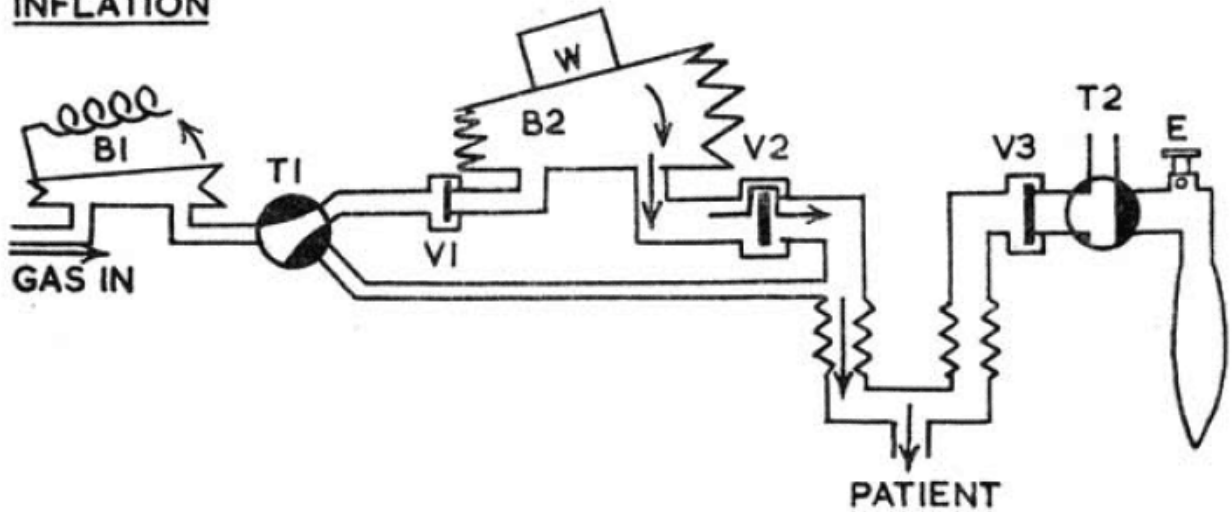
1. Rubber tubing delivers the FGF from the anaesthetic machine to the ventilator.
2. Two sets of bellows. A smaller time-cycling bellows receives the FGF directly from the gas source and then empties into the main bellows.
3. Three unidirectional valves.
4. An adjustable pressure limiting (APL) valve with tubing and a reservoir bag used during spontaneous or manually controlled ventilation.

5. The ventilator has a pressure gauge (up to 100 cm H₂O), inspiratory time dial, tidal volume adjuster (up to 1000 mL), two knobs to change the mode of ventilation from and to controlled and spontaneous (or manually controlled) ventilation. The inflation pressure is adjusted by sliding the weight to an appropriate position along its rail.

Mechanism of action

1. The FGF drives the ventilator.
2. During inspiration, the smaller bellows receives the FGF, while the main bellows delivers its contents to the patient. The inspiratory time dial controls the extent of filling of the smaller bellows before it empties into the main bellows.
3. During expiration, the smaller bellows delivers its contents to the main bellows until the predetermined tidal volume is reached to start inspiration again.
4. Using the ventilator in the spontaneous (manual) ventilation mode changes it to a Mapleson D breathing system.

INFLATION



Problems in practice and safety features

1. The ventilator ceases to cycle and function when the FGF is disconnected. This allows rapid detection of gas supply failure.

2. Ventilating patients with poor pulmonary compliance is not easily achieved.
3. It generates back pressure in the back bar as it cycles.
4. The emergency oxygen flush in the anaesthetic machine should not be activated while ventilating a patient with the Manley.

Penlon Anaesthesia Nuffield Ventilator Series 200

This is an intermittent blower ventilator. It is small, compact, versatile and easy to use with patients of different sizes, ages and It can be used with different breathing systems .

It is a volume-preset, time-cycled, flow generator in adult use. In Paediatric use, it is a pressure-preset, time-cycled, flow generator.



The Penlon Nuffield 200 ventilator.

Components

1. The control module, consisting of an airway pressure gauge (cm H₂O), inspiratory and expiratory time dials (seconds), inspiratory flow rate dial (L/s) and an on/off switch. Underneath the control module there are connections for the driving gas supply and the valve block. Tubing connects the valve block to the airway pressure gauge.
2. The valve block has three ports:
 - a) a port for tubing to connect to the breathing system reservoir bag mount
 - b) an exhaust port which can be connected to the scavenging system
 - c) a pressure relief valve which opens at 60 cm H₂O.
3. The valve block can be changed to a paediatric (Newton) valve

Mechanism of action

1. The ventilator is powered by a driving gas independent from the FGF. The commonly used driving gas is oxygen (at about 400 kPa) supplied from the compressed oxygen outlets on the anaesthetic

machine. The driving gas should not reach the patient as it dilutes the FGF, lightening the depth of anaesthesia.

2. It can be used with different breathing systems such as Bain, T-piece and the circle. In the Bain and circle systems, the reservoir bag is replaced by the tubing delivering the driving gas from the ventilator. The APL valve of the breathing system must be fully closed during ventilation.
3. The inspiratory and expiratory times can be adjusted to the desired I/E ratio. Adjusting the inspiratory time and inspiratory flow rate controls determines the tidal volume. The inflation pressure is adjusted by the inspiratory flow rate control.
4. With its standard valve, the ventilator acts as a time-cycled flow generator to deliver a minimal tidal volume of 50 mL. When the valve is changed to a Paediatric valve, the ventilator changes to a time-cycled pressure generator capable of delivering tidal volumes between 10 and 300 mL. This makes it capable of ventilating premature babies and neonates.

The new valve came to be known as the Newton Valve. Without it, the smallest tidal volume that the Penlon 200 could deliver was 50 ml. With the Newton valve, the ventilator could deliver tidal volumes as low as 10 ml. (The Penlon Nuffield 300 ventilator)

5. A PEEP valve may be fitted to the exhaust port.

Problems in practice and safety features

1. The ventilator continues to cycle despite breathing system disconnection.
2. Requires high flows of driving gas.

Summery :

Penlon Nuffield Anaesthesia Ventilator Series 200

- An intermittent blower with a pressure gauge, inspiratory and expiratory time and flow controls.
- Powered by a driving gas.
- Can be used for both adults and Paediatric patients.
- Can be used with different breathing systems.



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Department of anesthesiology المرحلة / الرابع

محاضرة أجهزة (7)

د. نزار الحيالي

Bag in bottle ventilator

Modern anaesthetic machines often incorporate a bag in bottle ventilator.

Components

1. A driving unit consisting of:
 - a) a chamber with a tidal volume range of 0–1500 mL (a Paediatric version with a range of 0–400 mL exists)
 - b) an ascending bellows accommodating the FGF.



FIG. Bag in bottle ventilator.

2. A control unit with a variety of controls, displays and alarms: the tidal volume, respiratory rate (6–40/min), I/E ratio, airway pressure and power supply



FIG. Control panel of the Datex-Ohmeda 7900 ventilator.

Mechanism of action

1. It is a time-cycled ventilator.

2. Compressed air is used as the driving gas. On entering the chamber, the compressed air forces the bellows down, delivering the fresh gas to the patient (the fresh gas is accommodated in the bellows).

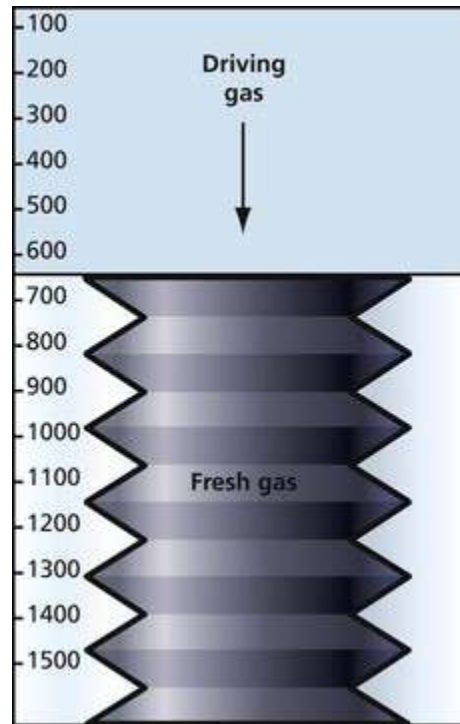


FIG. 8.5 Mechanism of action of the bag in bottle ventilator.

3. The driving gas and the fresh gas remain separate.
4. The volume of the driving gas reaching the chamber is equal to the tidal volume.
5. Some designs feature a descending bellows instead.

Problems in practice and safety features

1. Positive pressure in the standing bellows causes a PEEP of 2–4 cm H₂O.

2. The ascending bellows collapses to an empty position and remains stationary in cases of disconnection or leak.
3. The descending bellows hangs down to a fully expanded position in a case of disconnection and may continue to move almost normally in a case of leakage.

Summary: Bag in bottle ventilator

- It is a time-cycled ventilator.
- Consists of driving and control units.
- Fresh gas is within the bellows whereas the driving gas is within the chamber.

Servo-*U* ventilator:

It is intensive care ventilator, used for Paediatric and adult patient

It is portable machine

The power source can be electrical and batteries

It cannot be used with inhalational anesthetic but can be used with iv anesthesia in the theater

The most modern version has touchable screen

It has a wide range of controls and alarms

It has various modes of ventilation (SIMV, PCV, supported ventilation mode ---)

Component:

- 1- it has patient unit where gases are mixed and administered
- 2- The ventilator has graphical user interface where setting are made and ventilation monitored

**Causes of Ventilator Alarms****High-Pressure Alarm**

- 1- Increased secretions are in the airway.

2-Wheezing or bronchospasm causes decreased airway size.

3-The endotracheal tube is displaced.

4-The ventilator tube is obstructed because of water or a kink in the tubing.

5-Patient coughs, gags, or bites on the oral endotracheal tube.

6-Patient is anxious or fights the ventilator.

Low-Pressure Alarm

1-Disconnection or leak in the ventilator or in the client's airway cuff occurs.

2-The patient stops spontaneous breathing.



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المرحلة / الرابع

(8محاضرة أجهزة)

د. نزار الحياي

Complications of ventilator

1. Hypotension caused by the application of positive pressure, which increases intrathoracic pressure and inhibits blood return to the heart
2. Respiratory complications such as pneumothorax or subcutaneous emphysema as a result of positive pressure
3. Gastrointestinal alterations such as stress ulcers
4. Malnutrition if nutrition is not maintained
5. Infections
6. Muscular weakness

7. Ventilator dependence or inability to wean

8. Ventilator associated pneumonia

9. Baro trauma

Weaning from mechanical ventilation

It is defined as the Process of going from ventilator dependence to spontaneous breathing

Before weaning, the patient should have recovered from the acute phase of the disease leading to mechanical ventilation and be able to assume adequate spontaneous breathing.

Weaning is gradually started after evaluating the patient's clinical condition, pulmonary and cardiovascular status. • Depending upon these parameters patient may be given spontaneous breathing trials (SBT) on air and extubated. • If SBT unsuccessful patient is taken back on partial ventilatory support or pressure support and gradually the settings reduced and SBT repeated.

Weaning criteria :

Weaning criteria are used to evaluate the readiness of a patient for a weaning trial and the weaning success.

1-Clinical criteria :

- a) Resolution of acute phase of disease
- b) Adequate cough

c) Absence of excessive secretions

d) Cardiovascular and hemodynamic stability

2-Ventilatory criteria: spontaneous breathing trial for 20-30 minutes

f = Frequency of breaths, VT = Tidal Volume > 5 ml/kg

vital capacity > 10 ml/kg

3- Oxygenation criteria:

PaO₂ > 60 mmHg. SaO₂ > 90%

Weaning Procedure :

Weaning can be done by using : –

Spontaneous breathing trials

T-piece

Pressure support Ventilation

Synchronized Mandatory Intermittent Ventilation (SIMV)

1-Spontaneous breathing trial (SBT): An evaluation of a patient's readiness for weaning from mechanical ventilation and extubation. • SBT is the major diagnostic test to determine if patients can be successfully extubated and weaned from mechanical ventilation. • Spontaneous breathing may be augmented with low-level (≤ 8 cm H₂O) of pressure support, CPAP

SBT may last up to 30 minutes.

2- Synchronized Intermittent Mandatory Ventilation (SIMV)

- a. The client (patient) breathes between the preset breaths per minute rate of the ventilator.
- b. The SIMV rate is decreased gradually until the client is breathing on his or her own without the use of the ventilator.

3- T-piece :

A T-piece trial is done by disconnecting the patient from the ventilator and attaching a T-piece to the endotracheal tube. There is no ventilator support in this modality, but there is oxygen supplementation.

- a. The client is taken off the ventilator and the ventilator is replaced with T-piece or continuous positive airway pressure, which delivers humidified oxygen.
- b. The client is taken off the ventilator for short periods initially and allowed to breathe spontaneously.
- c. Weaning progresses as the client is able to tolerate progressively longer periods off the ventilator.

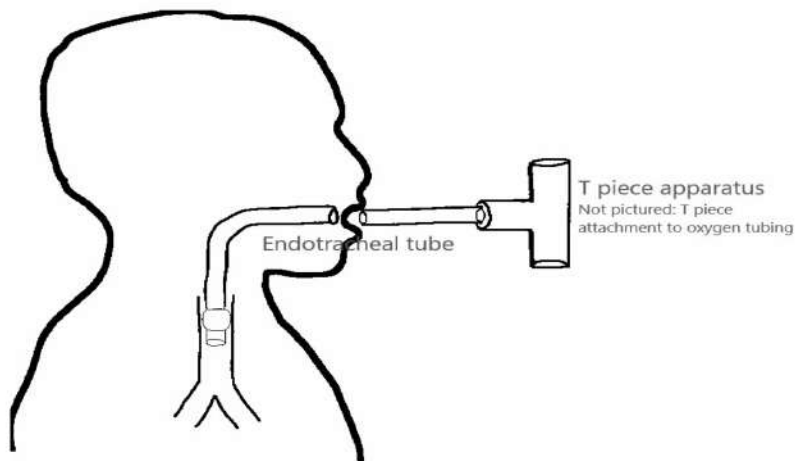
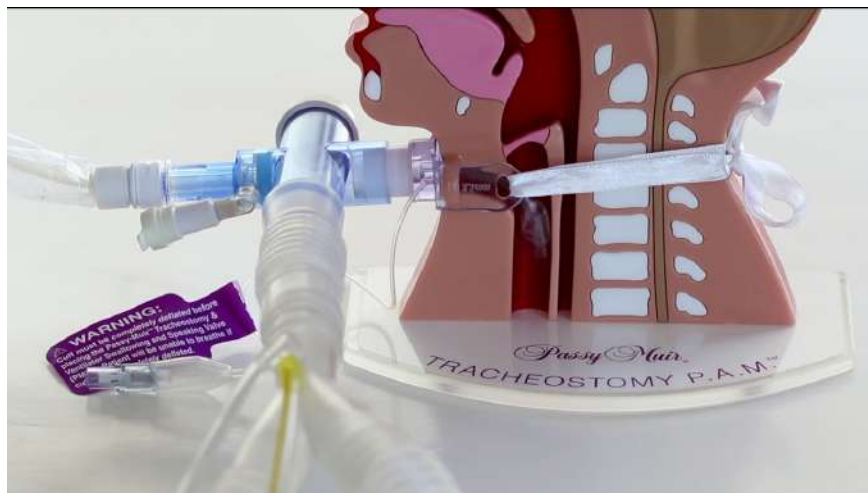


Figure 2: Schematic of a T-piece.



4-Pressure support

- a. Pressure support is a predetermined pressure set on the ventilator to assist the client in respiratory effort.
- b. As weaning continues, the amount of pressure is decreased gradually.
- c. With pressure support, pressure may be maintained while the preset breaths per minute of the ventilator gradually are

decreased.

Nursing Care Of Mechanically Ventilated Patient

1. Assess vital signs, lung sounds, respiratory status, and breathing patterns).
2. Monitor skin color, particularly in the lips and nail beds.
3. Monitor the chest for bilateral expansion.
4. Obtain pulse oximetry readings.
5. Monitor ABG results.
6. Assess the need for suctioning and observe the type, color, and amount of secretions.
7. Assess ventilator settings.
8. Assess the level of water in the humidifier and the temperature of the humidification system because extremes in temperature can damage the mucosa in the airway.
9. Ensure that the alarms are set.
10. If a cause for an alarm cannot be determined, ventilate the patient manually with a resuscitation bag until the problem is corrected.
11. Empty the ventilator tubing when moisture collects.

12. Turn the patient at least every 2 hours or get the patient out of bed, to prevent complications of immobility.

13. Have resuscitation equipment available at the bedside.

14. Hyperventilate the patient before suctioning. Stop feeding during 30 – 60 minutes before suctioning & chest physiotherapy.

15-Oral hygiene:• Provide careful oral hygiene• Apply lubricant to lips to prevent drying and cracking.• Rotate the ET tube from one corner of mouth to the other side at least every 24 hours

16-Removing anxiety & fear

17-Care of ventilator circuit:• Keep the water level in humidifier in normal limit.• Humidification during mechanical ventilation required to prevent hypothermia, destruction of airway epithelium & atelectasis.• A heated humidifier should be set to deliver an inspired gas temperature of $33 \pm 2^{\circ}\text{C}$.• The temperature of inspired gas should not exceed 37°C • Sterile water should be used only.



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محاضرة أجهزة (9)

د. نزار الحياي

Patient Monitoring

Monitoring : it means to be aware of the state of a system and to observe a situation for any changes which may occur over time,
In anaesthesia ,monitoring is important to prevent anaesthesia complication ' Sophisticated monitor available, only to aid, not to fully dependent on them

Monitoring in the Past include visual monitoring of respiration and overall clinical appearance • pulse • Blood pressure

Monitoring In The Present include Standardized basic monitoring requirements (guidelines) from the ASA (American Society of Anesthesiologists),

ASA Monitoring Guidelines:

Standard I: Qualified anesthetist should be present in the room throughout the conduct of all general anesthetics, regional anesthetics and monitored anesthesia care. i.e. A person who is qualified to monitor, evaluate and care for the patient must be present throughout the conduct of Anaesthesia

Standard II: During all anesthetics, the patient's oxygenation, ventilation, circulation and temperature should be continually evaluated (monitored).

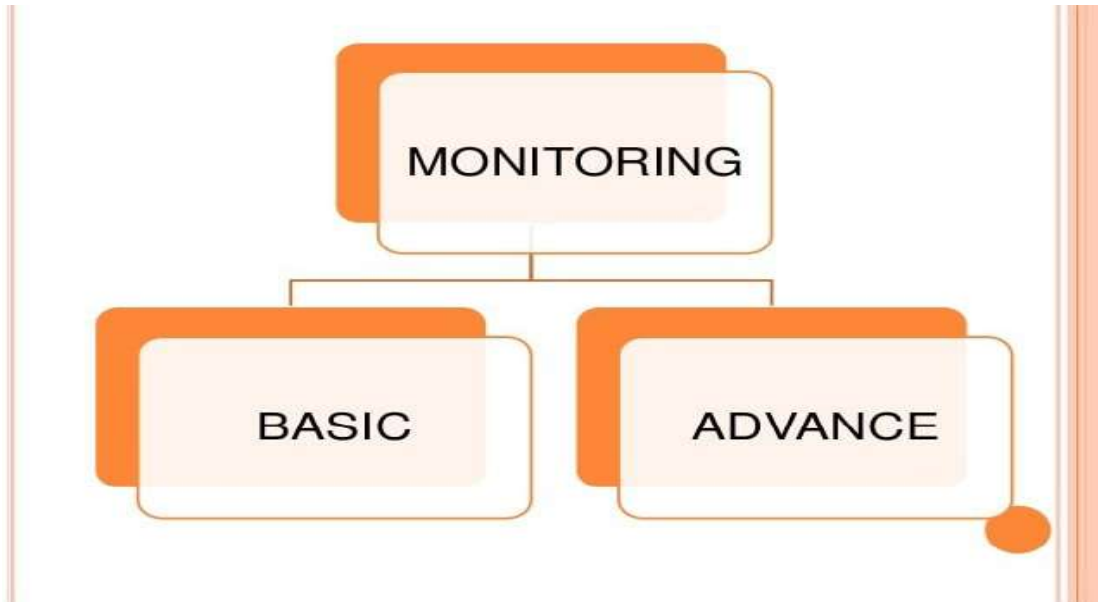
Hemoglobin saturation with a pulse oximeter and observation of skin color.

Ventilation: Capnography. Tracheal intubation must be verified clinically and by detection of exhaled CO₂. •

Circulation: ECG monitoring, blood pressure measurement at least every five minutes, and continuous monitoring of peripheral circulation by palpation, auscultation, plethysmography, or arterial pressure. •

Temperature: Thermometry if temp. changes are suspected

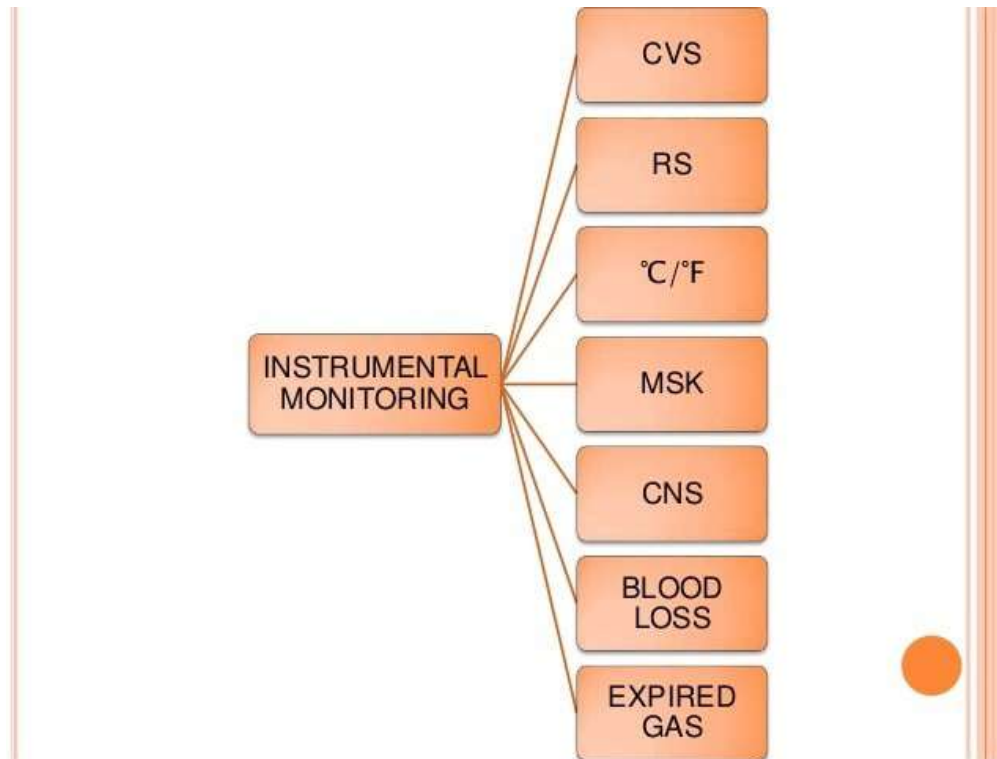
Monitoring can be divided into: BASIC and ADVANCE



BASIC MONITORING- (clinical monitoring): include:

1. Pulse rate
2. Color of skin
3. Blood pressure
4. Inflation of chest
5. Precordial and esophageal stethoscope
6. Signs of sympathetic over activity
7. Urine output ($>0.5\text{ml/min}$)

ADVANCE MONITORING-(instrumental monitoring):



1. Cardiovascular Monitoring

Cardiovascular monitoring can be:

- a) Non – invasive
- b) Invasive
- c) Semi - invasive

1. Non- invasive :

- a) Non-invasive ECG
- b) Non-invasive blood pressure - NIBP

ECG Mandatory monitor to detect : ' Arrhythmia ' Ischemia and cardiac arrest

Electrocardiogram ECG. This provides the clinician with three types of information:

- (1) heart rate,
- (2) cardiac rhythm
- (3) information about possible myocardial ischemia (via ST segment analysis)

The most common electrocardiographic system used during anesthesia is a 5-electrode lead system. This arrangement allows for the recording of any of the six limb leads plus a single precordial (V) lead

NIBP: Measure blood pressure at set intervals automatically by automated oscillometry. ' Cuff size should cover 2/3 of arm

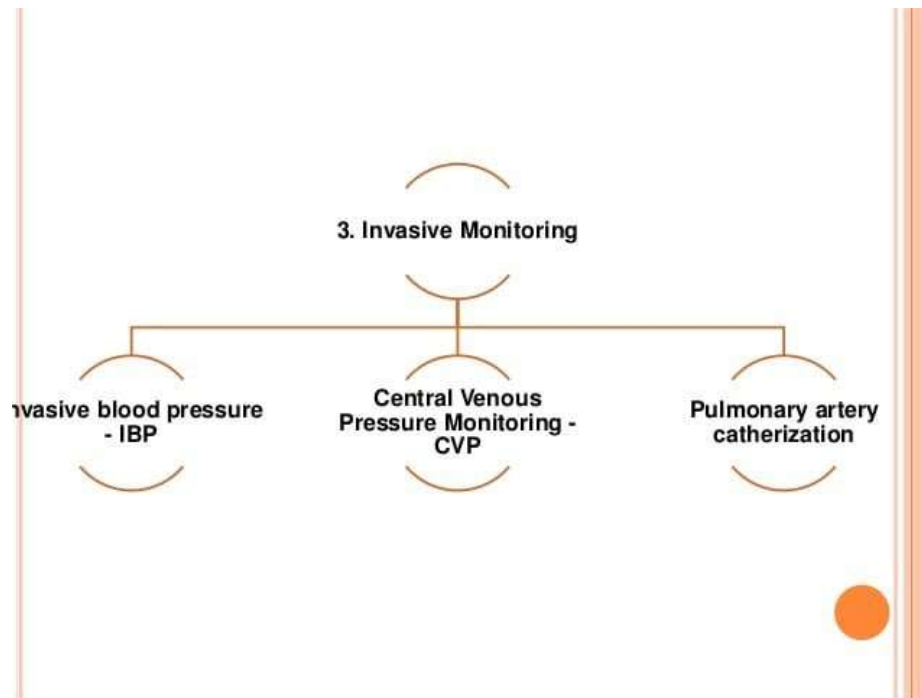
- Small cuff for children
- Too large (underestimate)
- Too small (over estimate)

Trans esophageal Echocardiography (Tee) ' Most sensitive to detect any wall motion abnormality

- ischemia ,
- valvular dysfunction,
- air embolism

Invasive Monitoring:

- a) invasive blood pressure - IBP
- b) Central Venous Pressure Monitoring – CVP
- c) Pulmonary artery catheterization



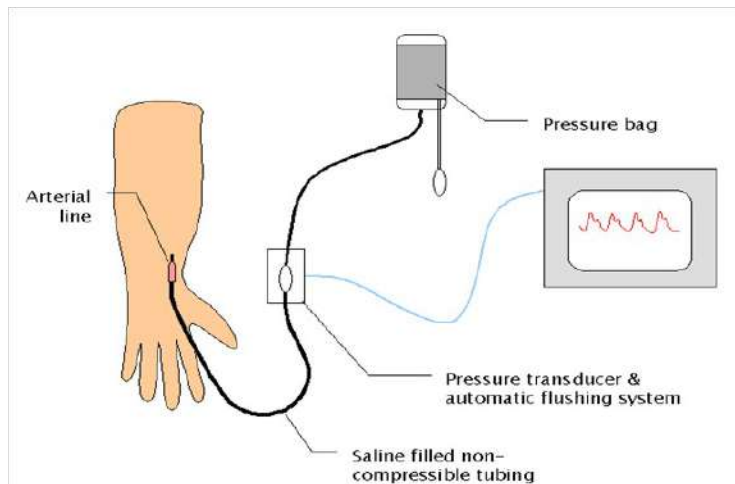
IBP ' Required in patient mandates for beat to beat monitoring '

Gold standard ' Accuracy

- measure the difference in IBP & NIBP not more than 5- 8mmHg '

Radial Artery ' Brachial Artery ' Femoral Artery ' Dorsalis Pedis Artery

The method requires the insertion of a short parallel-sided cannula into an artery. A continuous flow of either saline or heparinized saline at rates between 1 and 4 ml per hour is used to reduce clot formation in the cannula. The cannula is connected by a short length of narrow-bore, non-compliant plastic tubing containing saline to a pressure transducer



Indications for Arterial Cannulation:

1. Continuous, real-time blood pressure monitoring
2. Repeated blood sampling
3. Failure of indirect arterial blood pressure measurement
4. Supplementary diagnostic information from the arterial waveform
5. Determination of volume responsiveness from systolic pressure or pulse pressure variation

Complication of arterial Cannulation:

- 1- Arterial injury,
- 2- spasm, distal ischemia '
- 3- Thrombosis, embolization '
- 4-Sepsis ' Tissue necrosis ' Fistula
- 5- aneurysm formation '

prevention : continuous flush with/out heparin



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المرحلة / الرابع

محاضرة أجهزة (10)

د. نزار الحياي

Allen Test

The blood supply to your hand normally comes from two arteries: the radial artery and the ulnar artery. Before drawing blood for an arterial blood gas test, you will make sure that both arteries are open and working correctly. A procedure called the Allen test may be used to find out if the blood flow to your hand is normal.

Allen test, is done by apply pressure to the arteries in your wrist for several seconds. This will stop the blood flow to your hand, and your hand will become cool and pale. Blood is then allowed to flow through the artery that will not be used to collect the blood sample. This is usually the ulnar artery, which is found on the outer (little finger side) of

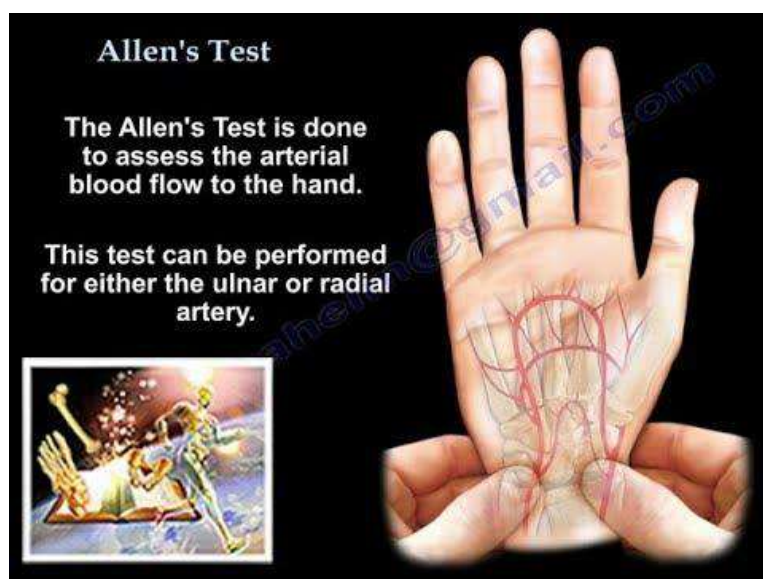
your wrist. Arterial blood gases are usually taken from the radial artery, which is found on the inner (thumb side) of the wrist.

Allen's Test: □ Normal - <7s □ Borderline – 7-14s □ >15s – contraindicated

Allen test

Normal (positive)	Your hand quickly becomes warm and returns to its normal color. This means that one artery alone will be enough to supply blood to your hand and fingers.
Abnormal (negative)	Your hand remains pale and cold. This means that one artery is not enough to supply blood to your hand and fingers. Blood will not be collected from an artery in this hand.

If your hand remains pale and cold, the Allen test will then be performed on your other hand. If your other hand also remains pale, the blood often will be collected from another artery, usually in the groin or elbow crease.



2. Central Venous Pressure Monitoring (CVP)

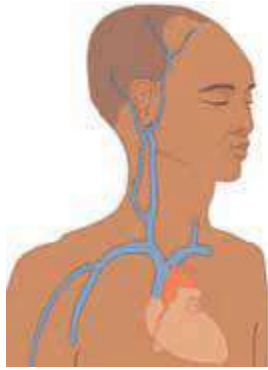
Blood from the systemic veins flows into right atrium (RA). The pressure in RA is CVP. Thus, a catheter is passed via Subclavian vein or Jugular vein into superior vena cava to determine venous return & Intravascular volume of RA.

DEFINITION : Central venous pressure (CVP) is the pressure of blood in the superior vena cava at the point where the superior vena cava meets the inferior vena cava prior to entry into the right atrium (RA) of the heart.

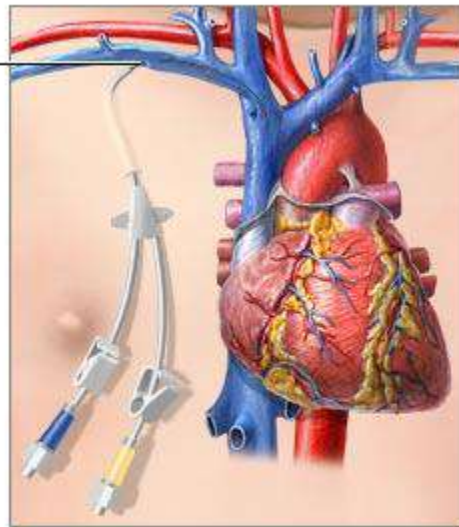
CVP reflects amount of blood returning to heart & the ability of heart to pump blood into arterial system.

A central venous catheter is a special IV line that is inserted into a large vein in the body. Several veins are used for central venous catheters including those located in the shoulder (subclavian vein), neck (jugular vein), and groin (femoral vein)

The right internal jugular vein is the preferred site for Cannulation because of a high success rate in both adults and children. The left-sided internal jugular vein is also available but is less desirable because of the potential for damaging the thoracic duct



Central venous catheter



ADAM.

Indication:

- 1- Major surgeries where large fluctuations in hemodynamics are expected. ' Open heart surgeries.
- 2- Fluid management in shock. ' As a venous access.
- 3- Parenteral nutrition.
- 4- Aspiration of air embolus

Normal CVP is 3 to 10 cm of H₂O (or 2-8 mmHg).

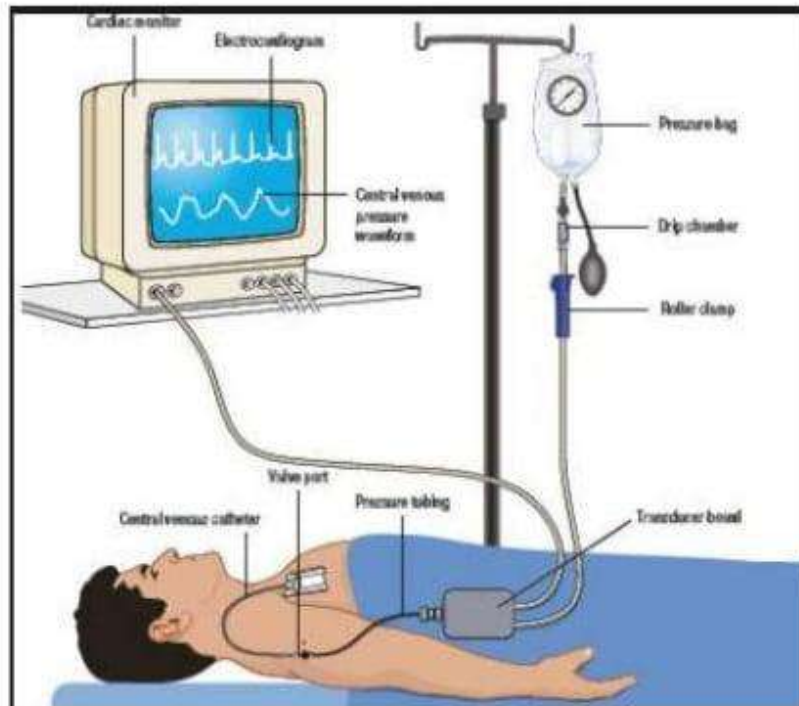
In children CVP is 3 to 6 cm of H₂O.

CVP more than 20 cm of H₂O indicates right heart failure.

Technique Of CVP Catheterization (Through Internal Jugular Vein) Seldinger Technique

1. Patient lies in Trendelenburg position – to decrease chance air embolism
2. The cannula with stylet is inserted at the tip of triangle formed by two heads of sternomastoid and clavicle. The direction of needle should be slightly lateral and towards the ipsilateral nipple.
3. Once the internal jugular vein is punctured. Stylet is removed and a J wire is passed through cannula
4. The tip of catheter should be at the junction of superior vena cava with right atrium – 15 cm from entry point

2.CENTRAL VENOUS PRESSURE MONITORING (CVP)



CVP is increased in : '

- 1- Fluid overloading '
- 2- Congestive cardiac failure.
- 3-' Pulmonary embolism '
- 4- Cardiac Tamponade '
- 5- Intermittent positive pressure ventilation with PEEP '
- 6- Constrictive pericarditis ' Pleural effusion ' Hemothorax ' Coughing and straining

CVP is decreased in :

- 1- Hypovolemia and shock
- 2- Venodilator
- 3- Spinal / epidural anaesthesia
- 4- General anesthesia – by causing vasodilatation

Low CVP + low BP = Hypovolemia

High CVP + low BP = pump failure

X ray chest is performed to check the position of catheter and to exclude pneumothorax

Complication

- 1- Air embolism
- 2- Thromboembolism
- 3- Cardiac arrhythmias
- 4- Pneumothorax, hemothorax
- 5- Cardiac perforation
- 6- Sepsis

CVP WAVEFORM

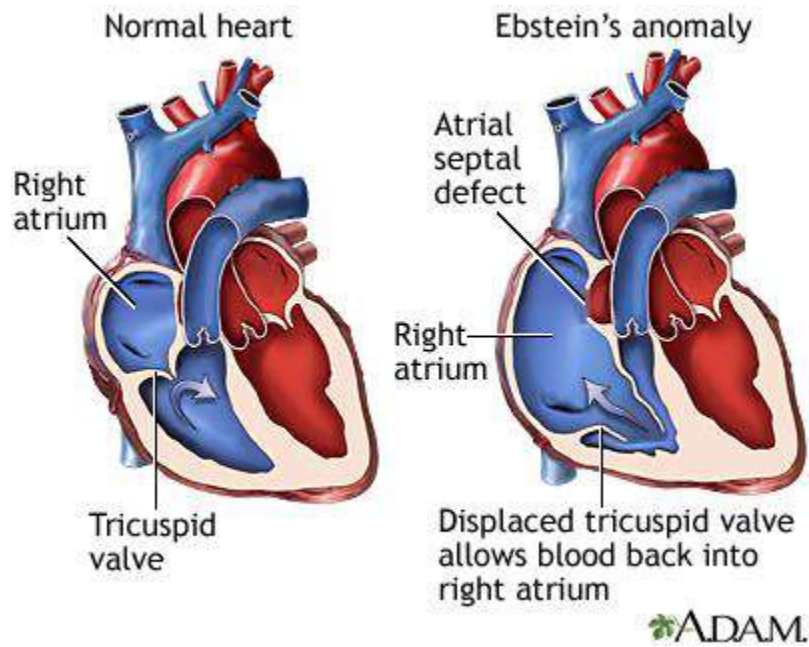
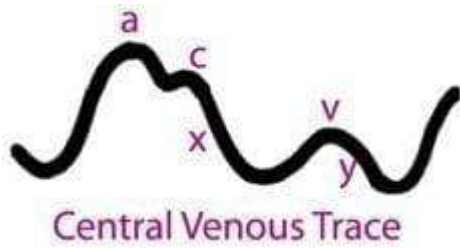
a = atrial contraction

c = closing and bulging of the tricuspid valve

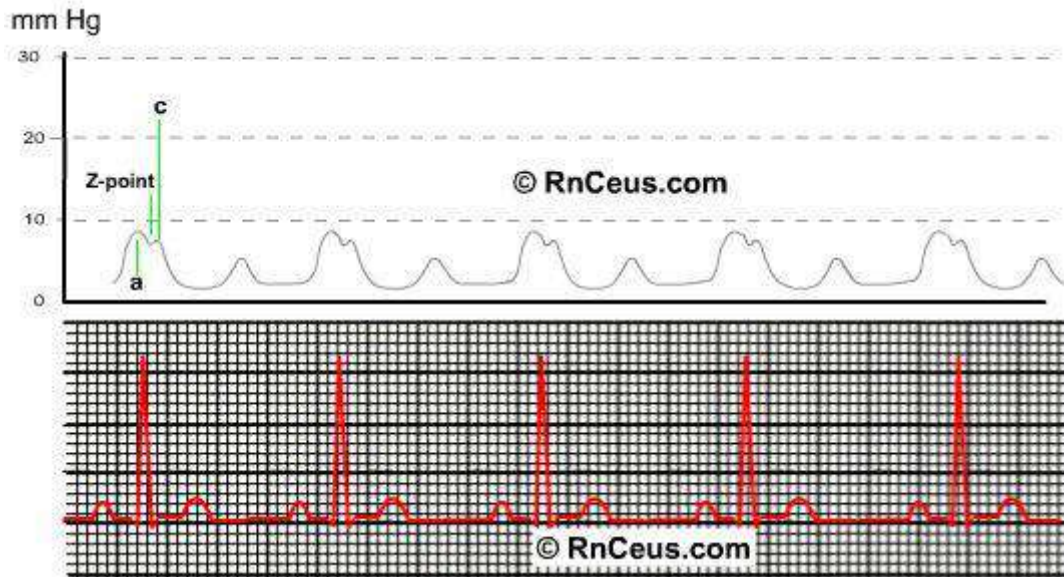
x = atrial relaxation

v = passive filling of atrium

y = opening of the tricuspid valve



There are two ways to read a CVP waveform:



1. Find the mean of the A wave.

- read the high point of the A wave
- read the low point of the A wave
- add the high point to the low point
- divide the sum by 2
- the result is the mean CVP

2. Find the Z-point.

- Find the Z-point which occurs mid to end QRS
- Read the Z-point

The Z-point coincides with the middle to end of the QRS wave. It occurs just before closure of the tricuspid valve.

Pulmonary Artery Catheterization '

It is indicated only for very major cases in severely compromised patients because cost, technical difficulty and complications

Pulmonary artery catheterization is a procedure using a long, thin tube called **Swan Ganz catheter**. The catheter is inserted into a pulmonary artery.

The pulmonary arteries are the two major arteries coming from the right ventricle of the heart which contains blood that is low in oxygen. The pulmonary arteries carry this blood to the lungs. There, the blood picks up more oxygen and releases carbon dioxide.

Pulmonary artery catheterization uses a catheter that has an inflatable balloon at its tip. The healthcare provider puts this tube through a large vein. The tube is then moved to the right atrium, one of the heart's upper chambers. It is then moved on through the right ventricle and out through a pulmonary artery. The healthcare provider then inflates the balloon and wedges it into a small pulmonary blood vessel. With the catheter in place, he can learn more about pressure in the right side of the heart and in the arteries of the lungs. Blood samples can also be taken at various sites within the heart to understand blood oxygen flow. The procedure can also tell other important details, such as heart output. The findings can help in treating many health conditions.

Indication :

- 1- Measuring cardiac chambers pressure (except left ventricle).
- 2- Calculating cardiac output ' Measuring pulmonary artery occlusion pressure (PAOP) '

3- Taking sample for mixed venous blood

4- Titration of fluid infusion

5-They use it to help diagnose many health problems. These include:

- Shock.
- Pulmonary edema. The test helps find the cause of fluid buildup in the lungs.
- Heart failure. This test evaluated heart pressures and blood flow in a weak heart.
- Congenital heart disease. This test may help understand the flow of blood within the heart.
- High blood pressure in the lungs (pulmonary hypertension)
- Fat embolism (clot that is blocking a blood vessel)

Complication:

1- Minor arrhythmias – most common

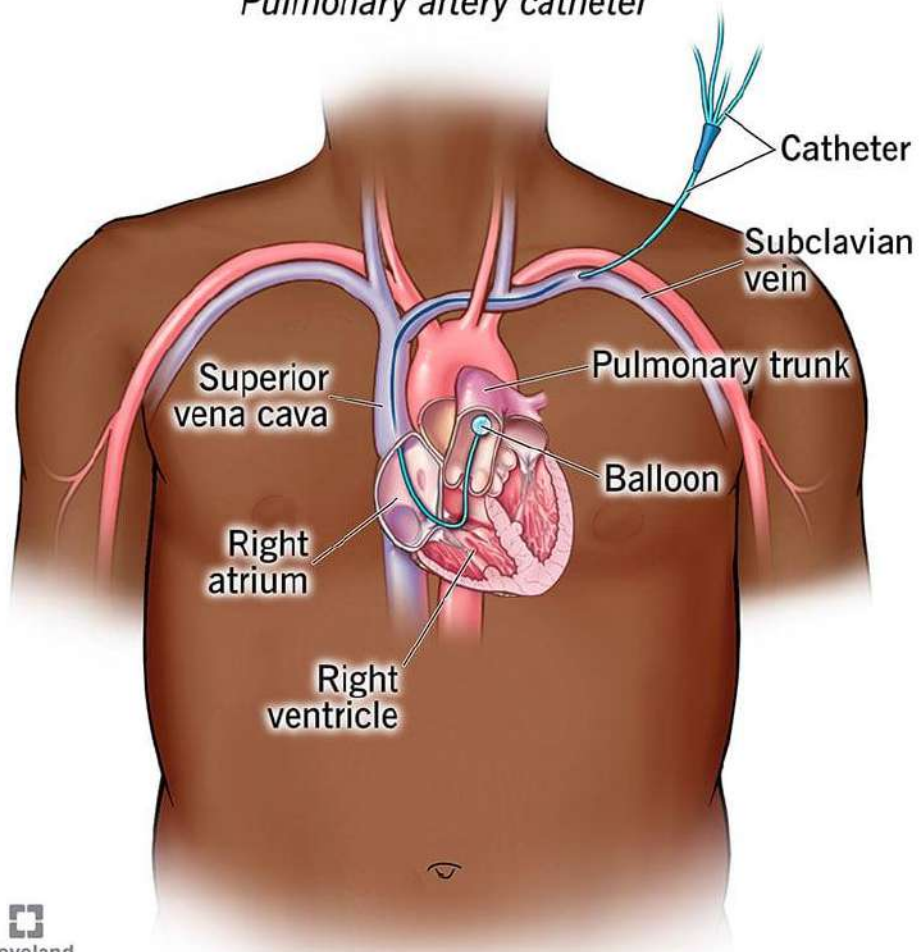
2- Pulmonary artery rupture

3- Infection of the heart valves (endocarditis

4- Severe arrhythmias ' Death

Swan-Ganz Catheterization

Pulmonary artery catheter





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المرحلة / الرابع

محاضرة أجهزة (11)

د. نزار الحياي

Respiratory Monitoring

The most essential function of the respiratory system is to deliver oxygen to arterial blood so it can be provided to body tissues.

Approximately 98–99% of the total oxygen content in arterial blood is bound to hemoglobin in the red blood cells. The remaining 1–2% is dissolved in plasma, producing a gas pressure referred to as *arterial oxygen tension* (PaO_2). It is this unbound oxygen that enters the body tissues, driven by the PaO_2 gradient. As dissolved oxygen enters the cells, it is replaced instantaneously by oxygen released from hemoglobin.

Therefore, there is a relationship between the degree to which hemoglobin is saturated with oxygen (SaO_2) and the tension produced by dissolved oxygen (PaO_2). This relationship is illustrated by the oxygen-

hemoglobin dissociation curve Under normal conditions, hemoglobin in arterial blood remains ~98% saturated and sustains a PaO_2 of ~95 mm Hg. At the tissue level, things change. Oxygen is delivered to the tissues and oxygen tension declines to ~40 mm Hg with a corresponding hemoglobin saturation of approximately 70–75%, normal values for venous blood. The respiratory monitoring includes:

1. Pulse Oximetry
2. Capnography
3. Blood gas analysis
4. Lung volumes
5. Oxygen analyzers
6. Airway pressure monitoring
7. Apnea monitoring

Pulse Oximetry

Oxygen saturation :— SpO_2

Normal SpO_2 - 97 – 98 %

Probe is applied at : □ finger nail bed, □ toe nail bed , □ ear lobule, □ tip of nose '

Uses : detection of hypoxia intra and post-operative

Errors :

- 1- Carboxyhaemoglobinemia ' Methhemoglobinemia
- 2- Anemia

- 3- Hypovolemia and vasoconstriction
- 4- Nail polish
- 5- Shivering
- 6- spO_2 below 60%
- 7- Skin pigmentation and Dyes

Capnography

Definition And Background

The term Capnography refers to the noninvasive measurement of the partial pressure of carbon dioxide (CO_2) in exhaled breath expressed as the CO_2 concentration over time. The relationship of CO_2 concentration to time is graphically represented by the CO_2 waveform, or capnogram. Changes in the shape of the capnogram are diagnostic of disease conditions, while changes in end-tidal CO_2 (EtCO_2), the maximum CO_2 concentration at the end of each tidal breath, can be used to assess disease severity and response to treatment.

Capnography is also the most reliable indicator that an endotracheal tube is placed in the trachea after intubation.

Oxygenation and ventilation must be assessed in both intubated and spontaneously breathing patients. Pulse Oximetry provides information about oxygenation while Capnography provides information about:

- 1- ventilation (how effectively CO₂ is being eliminated by the pulmonary system),
- 2- perfusion (how effectively CO₂ is being transported through the vascular system), and
- 3- metabolism (how effectively CO₂ is being produced by cellular metabolism).

Capnography became a routine part of anesthesia practice)

Types:

Carbon dioxide (CO₂) monitors measure gas concentration, or partial pressure, using one of two configurations: mainstream or sidestream.

1- Mainstream devices measure respiratory gas (in this case CO₂) directly from the airway, with the sensor located on the airway adapter at the hub of the endotracheal tube (ETT).

2- Sidestream devices measure respiratory gas via nasal or nasal-oral cannula by aspirating a small sample from the exhaled breath through the cannula tubing to a sensor located inside the monitor

Capnograph utilizes infrared technology (most commonly), or other techniques such as mass spectroscopy

Sidestream capnograph



Mainstream capnograph



Uses of Capnography:

Capnography is used for a number of important clinical situations:

1. Detecting when an anesthetic breathing circuit disconnects

2. Verification of endotracheal intubation (a sustained normal capnogram is not obtained when the endotracheal tube is in the esophagus)
- 3- Assessing tracheal tube and tracheostomy patency and position
- 4- Monitoring adequacy of ventilatory support: detection of hypoventilation (raised end-tidal CO₂ is often present) and hyperventilation (low end-tidal CO₂ is often present)
- 5- Detecting rebreathing of CO₂ (in which case the inspiratory CO₂ level is nonzero)
- 6- Monitoring CO₂ elimination during cardiac arrest and CPR
- 7- Monitoring patients with raised intracranial pressure: Cerebral blood flow varies considerably depending on the P_{aCO_2} in the blood: if the P_{aCO_2} rises, cerebral blood flow rises, resulting in increased ICP. Low P_{aCO_2} causes vasoconstriction of the cerebral blood vessels, reducing cerebral blood flow.

ETCO₂:

It is the continuous measurement of end tidal (expired) carbon dioxide (ETCO₂) and its waveform.

Normal ETCO₂ : 32 to 42 mmHg (3 to 4 mmHg less than arterial pCO₂ which is 35 to 45 mmHg). '

Principle : infrared light absorbed by carbon dioxide

What causes increased end tidal CO₂?

- 1-Problems with the anesthesia machine can cause increased expired carbon dioxide by increasing inspired carbon dioxide.
- 2- Exhausted soda lime,
- 3- faulty inspiratory or expiratory valve might increase the end-tidal carbon dioxide level

What happens to ETCO₂ during hypoventilation?

Elevated ETCO₂ (hypercapnia) occurs during hypoventilation, and a decrease in ETCO₂ (Hypocapnea) occurs with hyperventilation. Many Capnography also display a capnogram, or waveform which diagrams inspiration and exhalation over time

Capnography The Standard of Care

Terminology

Capnogram

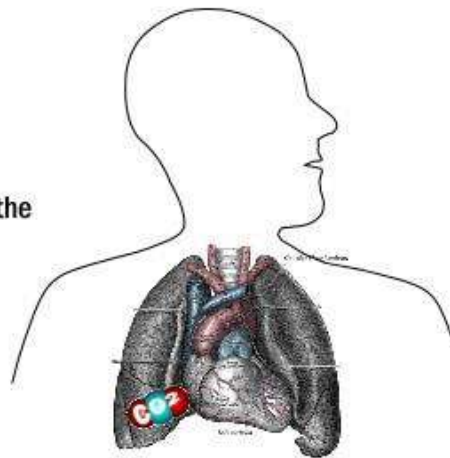


a real-time waveform record of the concentration of carbon dioxide in the respiratory gases

Capnograph



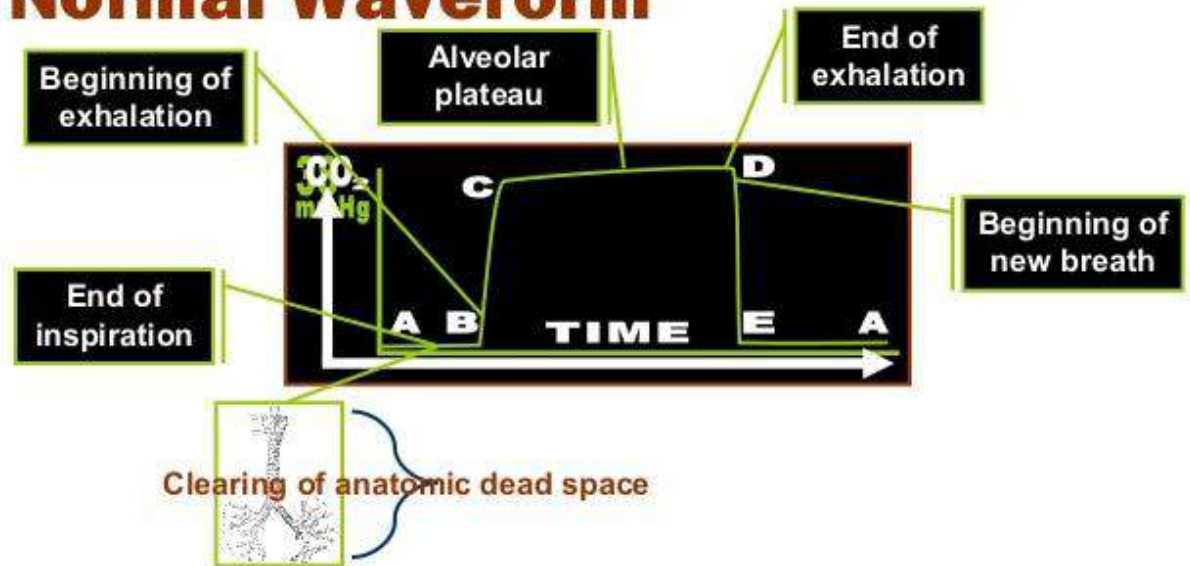
Capnogram waveform plus numerical value



Capnography

The Standard of Care

Normal Waveform



What are the phases of Capnography?

- Phase I: Respiratory Baseline.
- Phase II: Expiratory Upstroke.
- Phase III: Expiratory Plateau.
- ETCO_2 : Peak EtCO_2 level.
- Phase IV: Inspiratory Downstroke

A) A normal capnograph demonstrating the three phases of expiration:

phase I—dead space;

phase II—mixture of dead space and alveolar gas;

phase III—alveolar gas plateau.

(B) Capnograph of a patient with severe chronic obstructive pulmonary disease. No plateau is reached before the next inspiration.

(C) Depression during phase III indicates spontaneous respiratory effort.

(D) Failure of the inspired CO₂ to return to zero may represent an incompetent expiratory valve or exhausted CO₂ absorbent.



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المرحلة / الرابع

محاضرة أجهزة (12)

د. نزار الحياي

Blood Gas Analysis

Precaution:

- 1- Glass syringe is preferred for sampling '
- 2- Syringes should be heparinized '
- 3- Samples should be stored in ice

Sample from radial or femoral artery

Indication of Blood Gas Analysis :

- 1- Thoracic surgery
- 2- Hypothermia
- 3- Hypotensive anaesthesia

Normal Values On Room Air:

pH : 7.38 to 7.42

Partial pressure of oxygen (P_{O2}) : 96 to 98 mmHg

Partial pressure of carbon dioxide (P_{CO2}) : 35 to 45 mmHg

Bicarbonate (HCO_3) : 24 to 28 mEq/L

Oxygen saturation (SpO_2) : 95 to 98%

Lung Volumes

Spirometer:

A spirometer is a diagnostic device that measures the amount of air you're able to breathe in and out and the time it takes you to exhale completely after you take a deep breath. A spirometry test requires you to breathe into a tube attached to a machine called a spirometer



Uses of spirometry:

spirometry tests is used to diagnose these conditions:

1-COPD { chronic obstructive pulmonary disease }

2-asthma

3-restrictive lung disease, such as interstitial pulmonary fibrosis

4-other disorders affecting lung function

when you do spirometry test, you should keep in mind:

1-Wear loose clothing.

2-If you smoke, avoid smoking for at least 1 hour before the test.

3-If you drink alcohol, avoid consuming it for at least 4 hours before the test.

4-Avoid eating or drinking for at least 2 hours before the test.

5-Avoid heavy physical effort or exercise for at least 30 minutes before the test.

6-you should avoid any medications, such as inhalers, before the test, since they may interfere with the accuracy of the results.

Spirometry measures two key factors:

1- expiratory forced vital capacity (FVC) and

2- forced expiratory volume in one second (FEV1).

If you have obstructed airways, the amount of air you're able to quickly blow out of your lungs will be reduced. This translates to a lower FEV1 and FEV1/FVC ratio.

FVC measurement

The volume of air that can be forcefully exhaled after a maximal inhalation. • The majority of FVC can be exhaled in less than three seconds of exhalation in normal people, however it may be prolonged in people with obstructive lung diseases.

If your FVC is lower than expected, something is restricting your breathing.

Normal value is 80% or greater

An “abnormal” FVC could be due to restrictive or obstructive lung disease, and other types of spirometry measurements are required to determine which type of lung disease is present.

FEV1 measurement

This is the amount of air you can force out of your lungs in 1 second. • Normal subjects can exhale 75- 80% of their FVC in the first second, hence the FEV1/FVC ratio is an important determinant in assessing lung disease.

An FEV1 reading that's lower than expected shows you might have a significant breathing obstruction.

Normal----80% or greater

FEV1/FVC ratio

Doctors often analyze the FVC and FEV1 separately, then calculate your FEV1/FVC ratio. The FEV1/FVC ratio is a number that represents the percentage of your lung capacity you're able to exhale in 1 second.

In the absence of restrictive lung disease that causes a normal or elevated FEV1/FVC ratio, the higher the percentage gotten from your FEV1/FVC ratio means the healthier your lungs are.

A low ratio suggests that something is blocking your airways

Plethysmography:

Plethysmography:

Plethysmography measures changes in volume in different parts of the body. The test may be done to check for blood clots in the arms and legs. It is also done to measure how much air you can hold in your lungs.

Plethysmography measures changes in volume in different areas of your body. It measures these changes with blood pressure cuffs or other sensors.

Plethysmography is especially effective in detecting changes caused by blood flow. It can help your doctor determine if you have a blood clot in your arm or leg. It can also help your doctor calculate the volume of air in your lungs

Types of Plethysmography:

Limb Plethysmography

Lung Plethysmography

Uses of Plethysmography :

1- limb Plethysmography :

Most commonly, this test is performed to check blood flow in the arteries of the legs. This is done in people with conditions like atherosclerosis .

Atherosclerosis causes pain during exercise or poor healing of leg wounds.

Plethysmography is not as accurate as an arteriogram, which is more commonly used to identify blood clots. But it's noninvasive and less expensive

- 2- lung Plethysmography if you have symptoms of upper respiratory problems.
Your doctor can't diagnose the underlying cause of your problem from
Plethysmography alone

Procedure for a Plethysmography:

Limb Plethysmography:

Limb Plethysmography is a test that compares blood pressure in the legs and arms. You will be asked to lie with the upper part of your body slightly raised.

Three or four blood pressure cuffs are wrapped snugly around your arm and leg

Your doctor will then place blood pressure cuffs on your leg and arm.

checking your systolic blood pressure. That's the pressure of blood in your arm and leg when your heart contracts. The test usually lasts about 20 to 30 minutes.

Limb Plethysmography is not associated with any risks or side effects

Normally, the systolic blood pressure in your arm and leg are similar.

The ankle-brachial index (ABI) is a measurement used to check for potential problems. To calculate your ABI, divide the highest systolic blood pressure reading from your leg by the highest reading from your arm. A normal ABI falls between 0.90 and 1.30,

If your ABI falls outside this range, you may have a narrow or blocked artery



Lung or Body Plethysmography:

is a pulmonary function test that determines how much air is in your lungs after you take in a deep breath. It also measures the amount of air left in your lungs after you exhale as much as you can. This test gives information about how well your lungs are functioning .

How you prepare for body Plethysmography (pulmonary function test)?

- 1-Do not smoke at least 1 hour before.
- 2-Do not drink alcohol for at least 4 hours before the test.
- 3-Do not exercise heavily for at least 30 minutes before the test.
- 4-Do not wear tight clothes that make it difficult for you to breathe; this may alter the results.
- 5-Do not eat a large meal within 2 hours before the test.

6-Consult with your doctor about any medications that should not be taken the day of the test.

How is this body Plethysmography conducted?

During this test, you will be seated in an enclosed plastic box. You will then be asked to wear a nose clip and given instructions on how to breathe through a mouthpiece. This test typically takes 15 minutes to complete.



What is the difference between spirometry and Plethysmography

Although spirometry is the standard way to measure lung volumes, lung Plethysmography is more accurate. Measurements from this test are based on

Boyle's Law, a scientific principle that describes the relationship between the pressure and volume of a gas



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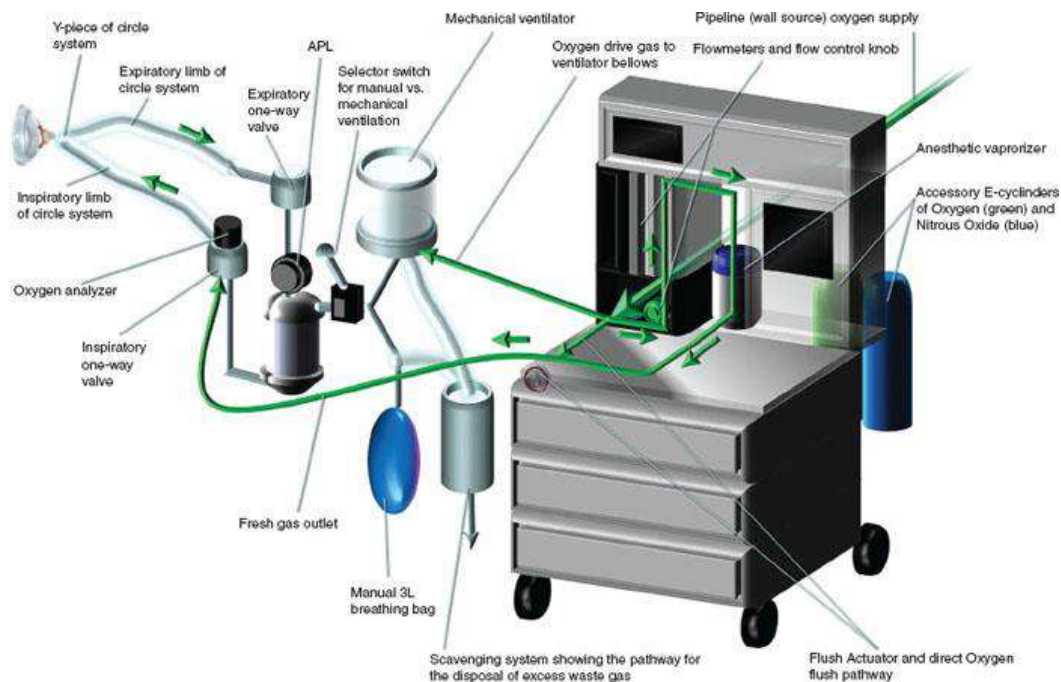
المرحلة / الرابع

محاضرة أجهزة (13)

د. نزار الحياي

Oxygen Analyzers :

- 1- Monitor actual value oxygen delivered
- 2- Fitted in inspiratory in limb of breathing circuit
- 3- Useful in closed circuit (use low flow oxygen)



Airway Pressure Monitoring

- 1- It should be less than 20 – 25cm H₂O
- 2- Low pressure – disconnection
- 3- High pressure – obstruction in tube or circuit and bronchospasm

Apnea Monitoring (Monitoring of Respiration) :

Apnea is cessation of respiration for more than 10s.

Intubated patients

- 1- Capnography - Most sensitive and effective to detect apnea
- 2- Airway pressure monitor

Non intubated patients :

- 1- Monitoring the airflow at nostrils (acoustic probe)

2- Detection of chest movements

3- Plethysmography – chest is encircled by a coil

For intubated and non-intubated patient ' Pulse oximeter

Temperature Monitoring

Continuous monitoring is recommended but every 15 minutes is acceptable •

Core temperature monitoring

Sites :-

1- Blood temp with thermistor of pulmonary artery catheter –

2- Oesophageal –

3- Tympanic membrane

4- Nasopharyngeal

5- Rectal

Peripheral monitoring sites :-

Axilla 0.5 °C less than core body temperature –

Skin(forehead) 1- 2 °C less than core body temperature 31

Normal core temperature in humans usually varies between 36.5 and 37.5°C .

Heat loss is due to impairment of thermoregulatory control by anesthetic agents combined with exposure to the cold operating room environment.

Hypothermia: is defined as a core body temperature of less than 35°C and may be classified as mild (32–35°C), moderate (28– 32°C), or severe (<28°C)

Hypothermia during anaesthesia is usually due to:

- 1- Most anaesthetic are vasodilators, causing heat loss and hypothermia
- 2- Cool room temperature
- 3- Cold intravenous fluids.
- 4- Evaporation

Core temperature can be measured with sensors in the nasopharynx, esophagus, pulmonary artery, tympanic membrane, or even in the rectum or urinary bladder. •

The ASA standards for patient monitoring require that every patient receiving anesthesia have temperature monitoring “when clinically significant changes in body temperature are intended, or suspected

Usually in ☐ Cardiac surgery ☐ Infant ☐ Children ☐ Adult with burns ☐ Febrile patient ☐ Malignant hyperthermia patient

Systemic Effects Of Hypothermia :

Bradycardia ,Hypotension ,Ventricular arrhythmias

if temperature is less than 28°C Respiratory arrest

Increased blood viscosity and platelet count

Acidosis – increased lactic acid production

Decreased GFR ' No urine output at 20°C

Endocrine system ' Decreased adrenaline and nor-adrenaline '

Hyperglycemia

Treatment Of Intraoperative Hypothermia :

Warm intravenous fluids ' Increase room temperature: The ideal operation theatre temperature for adults is 21°C and for the children 28°C ' Cover the patient with blankets ' Forced warm air by a special instrument (Bair Hugger airflow device)

Expired Gas Analysis:

There is multi-gas analyzer which measures concentration of anaesthetic vapors like nitrous oxide and inhalational agents like halothane, Isoflurane etc. ' These are mass spectrometers and Raman gas analyzers.

Monitoring Blood Loss:

Estimation of blood loss is done by weighing blood soaked swabs, sponges (Gravimetric method) and estimation of blood loss in suction bottle (Volumetric method). ' Most accurate method is colorimetric method. On an average (a rough guide): ' Fully soaked swab means 20 ml of loss. ' Fully soaked sponge means 100 to 120 ml of loss. ' A fist of clots means 200 to 300 ml of loss.

Electrocephalogram (EEG) :

measure depth of anesthesia , EEG also can assess cerebral ischemia during neurovascular surgeries –Effect of anesthetic agents and modalities on EEG ' All inhalational and intravenous anesthetic agents produces biphasic pattern on EEG ' Lower dose – causing excitation(high frequency and low amplitude waves). ' High dose - causing depression (high amplitude and low frequency waves)



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المرحلة / الرابع

محاضرة أجهزة (14)

د. نزار الحياي

Neuromuscular Monitoring

Objectives of NM Monitoring :

- 1- Monitoring onset of NM Blockade. •
- 2-To determine level of muscle relaxation during surgery. •
- 3- Assessing patients recovery from blockade to minimize risk of residual paralysis.

Indication: Who should be Monitored ?

- 1- Patients with severe renal, liver disease
- 2- Neuromuscular disorders like myasthenia gravis, myopathies, Patients with severe pulmonary disease or marked obesity •
- 3- Continuous infusion of NMBs or long acting NMBs •
- 4- Long surgeries or surgeries requiring elimination of sudden movement

Peripheral nerve stimulator: -

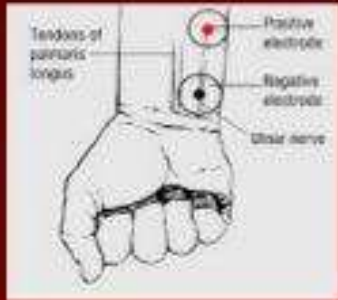
Electrodes • Surface electrodes for transmission of impulses to the nerves through the skin • Subcutaneous needles deliver impulse near the nerve

Electrode placement:

Ulnar nerve: place negative electrode (black) on wrist in line with the smallest digit 1-2cm below skin crease • positive electrode (red) 2-3cms proximal to the negative electrode • • Response: Adductor pollicis muscle – thumb adduction

Electrode placement:

- **Ulnar nerve:** place negative electrode (black) on wrist in line with the smallest digit 1-2cm below skin crease
- positive electrode (red) 2-3cms proximal to the negative electrode
- • Response: Adductor pollicis muscle – thumb adduction



The diagram illustrates the placement of two electrodes on a human hand and forearm. A red dot, labeled 'Positive electrode', is located on the forearm, approximately 2-3 cm proximal to the wrist. A black dot, labeled 'Negative electrode', is located on the wrist, in line with the smallest digit (pinky finger), approximately 1-2 cm below the skin crease. The 'Tendons of palmaris longus' are labeled on the palm side of the hand. The 'Ulnar nerve' is labeled near the elbow. The diagram shows the hand in a fist position, with the thumb adducted.

Facial nerve: place negative electrode (black) by ear lobe and the positive (red) 2cms from the eyebrow (along facial nerve inferior and lateral to eye) • •

Response: Orbicularis oculi muscle – eyelid twitching

- **Facial nerve:** place negative electrode (black) by ear lobe and the positive (red) 2cms from the eyebrow (along facial nerve inferior and lateral to eye)
- **Response:** Orbicularis oculi muscle – eyelid twitching



Posterior tibial nerve: place the negative electrode (black) over inferolateral aspect of medial malleolus (palpate posterior tibial pulse and place electrode there) and positive electrode (red) 2- 3cm proximal to the negative electrode •– planter flexion of big toe

- **Posterior tibial nerve:** place the negative electrode (black) over inferolateral aspect of medial malleolus (palpate posterior tibial pulse and place electrode there) and positive electrode (red) 2- 3cm proximal to the negative electrode
- **Response:** Flexor hallucis brevis muscle – planter flexion of big toe



Clinical tests of Postoperative Neuromuscular Recovery

- 1- Sustained head lift for 5 sec
- 2- Sustained eye opening
- 3- Sustained leg lift for 5 sec
- 4- Protrusion of tongue
- 5- Sustained handgrip for 5 sec
- 6- Arm lifted to the opposite shoulder Sustained “tongue depressor test”

Central Nervous System Monitoring

Monitoring Depth Of Anaesthesia :

Clinically : Signs and symptoms of light anaesthesia are:

- 1- Tachycardia.
- 2- Hypertension.
- 3- Lacrimation. ' Perspiration.
- 4- Movement response to painful stimuli.
- 5- Tachypnea, breath holding, coughing, laryngospasm, bronchospasm. '
- 6- Eye movements. ' Preserved reflexes

EEG ' Patient evoked response: detection of abnormalities in EEG at higher concentration of anaesthetic agents

Evoked Response Assessing the integrity of neuronal tissues during surgeries

Evoked potentials are used to measure the electrical activity in certain areas of the brain and spinal cord. Electrical activity is produced by stimulation of specific sensory nerve pathways. ... Evoked potentials test and record how quickly and completely the nerve signals reach the brain.

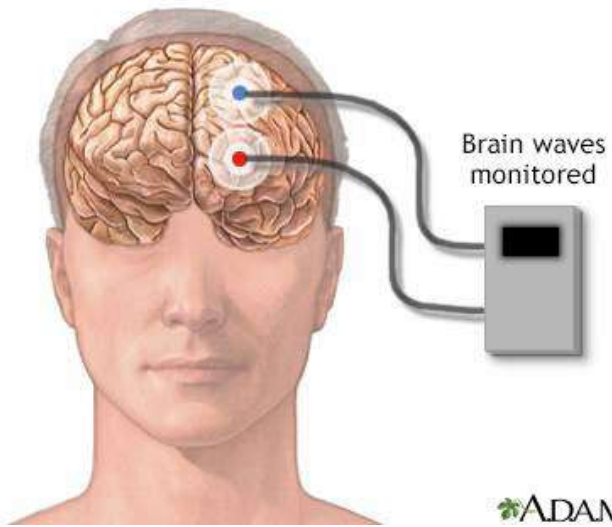
Evoked potentials are simple in concept, despite the sophistication of the equipment that is used. Just as the electroencephalogram (EEG) records the spontaneous electrical activity of the brain (cerebral cortex), evoked potentials record the electrical potentials produced after stimulation of specific neural tracts

Types of evoked Response (potential)

1- Somatosensory evoked potential (SSEP):

Spine surgeries, repair of thoracic and abdominal aorta aneurysm, exploration and surgery of brain area

2. Auditory evoked potential (AEP) : For procedures involving auditory pathways , Resection of acoustic neuroma and posterior fossa surgeries



3. Visual evoked potentials (VEP) : For procedures involving visual tracts □ Optic glioma, pituitary tumors



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المرحلة / الرابع

محاضرة أجهزة (15)

د. نزار الحياي

Operation Room Hazards

Hazard : A hazard is a situation that have a level of threat to life

Once a hazard becomes active, it can create an emergency situation. • A hazard does not exist when it is not happening.

Anesthesia and surgery are always potentially hazardous. • The most common hazards in operating room include fires and explosion, static electricity, electrical hazards, radiation injury, air pollution and power failure.

Fires & Explosions :

Both of these can cause death or injury to the patient in the theatre. • A fire can only occur if we have three things: spark or a hot surface, flammable substance and source of oxygen

Sources Of Spark: Heat, Static electricity • Faulty electrical switches and apparatus, • Foreign matter, e.g. dirt or grease in the oxygen or nitrous oxide cylinders • Diathermy

Flammable Substances : Flammable substances: Includes ether, ethyl chloride and sprits. • The addition of oxygen increased flammability.

Static Electricity : Electricity is present in the atmosphere. • A static electric charge occurs if two materials which conduct electricity poorly are brought into contact and then separated

If there is friction or movement between the two, a spark is produced and a spark, of course, can produce an explosion. • Examples of non-conductors which can spark if they touch each other include plastic, woolen fabrics, non- conducting rubber, and synthetic materials such as nylon.

These should always be avoided in the operating theatre, using special conducting rubber instead. • This rubber has graphite impregnated in it. It is black and has a yellow coding (either a yellow line or a stamp) to show it is antistatic.

Other Precautions Which Can Be Taken To Reduce The Incidence Of Static Electricity

- 1- The floors in the operating room should have a conductivity of the same order as the other items resting on them..
- 2-Clothing:. Avoid wool, plastic and nylon fabrics and wear cotton or other anti-static outer clothes instead. • Wear anti-static boots or conductive canvas overshoes.
- 3-Maintain humidity of 60% in the operating room. • Static sparks are more frequent when the air is dry.
- 4-Ventilation- Anesthetic gases are heavier than air and tend to collect at ground level. Air within one foot of the ground is the most dangerous. • Fresh air should enter at the top and stale air should be drawn out at the bottom. For the same reason switches should not be placed close to the ground.
- 5-Electric switches and electric apparatus should be inspected regularly by the electrician.
- 6- Firefighting equipment should always be available outside the operating theatre.
- 7- Smoking and open flames must be forbidden in the operating room.

Electrical Hazards :

They may occur when patients are: • Connected to or in contact with faulty electrically-operated medical equipment

1. Accidentally connected to electric circuits by spillage of blood or saline into equipment being used • Dependent on electrical equipment to replace or support vital organ functions
- 2-Undergoing treatment when safe levels of electrical energy are exceeded

Electric Shock :

Occurs when the body actually becomes part of an electrical circuit with significant current flowing in it. Lack of maintenance and misuse are the usual causes.

Macro Shock :

Macro shock is the most common form and occurs when the body conducts an electric current which does not pass directly through the heart. It varies in intensity from mild sensory stimulation at 5 to 10 mill amperes (mA), becoming more painful as the current increases. Somewhere above this level of current respiratory paralysis, cardiac arrest and severe burning occur.

Micro Shock :

Micro shock may occur when very tiny currents, such as $100\mu\text{A}$, are passed directly through the heart muscle; e.g. direct cardiac catheterization, measurement of cardiac output, etc.

High Frequency Currents :

High Frequency Currents i.e. alternating currents (AC) are less likely to produce electric shock but can cause burns

Direct Current :

Direct Current (DC) is less likely to cause ventricular fibrillation than high frequency alternating currents but can cause a more pronounced skeletal muscle contraction

Electro Surgical Units :

Electrosurgical Units e.g. diathermy are arranged so that current from the active electrode flows through the patient and back to the generator via the dispersive cable. • For example, with a broken dispersive cable, the current may return via ECG electrodes.

- Electric blankets have large surface areas but also many pressure points through which high current levels may pass, generating heat. Poor sitting of return electrode. It should be near the operation site and where sufficient soft tissue provides a large contact area. •.
- Skin preparation materials may impair the function of the skin as a return electrode region. If these preparations are flammable they may ignite.

Air Pollution In Operating theater

In places where the air is highly polluted, certain medical conditions occur more frequently. • Three of those conditions are spontaneous miscarriage, congenital abnormalities and liver disorders.

Therefore it is important that, we provide the cleanest air possible for patients and particularly for staff. • The patients spend only a short time in the operating theatre whereas the nursing and medical staffs spend many hours each day in this atmosphere and are at risk for health problems.

sources of air pollution are:

- 1- waste anesthetic gases which escape from: • Faulty valves • The ventilator • Poorly fitted components in the breathing circuit
- 2-Spilt anesthetic drugs • Expired gases from the spill valve of the anesthetic breathing system • Gases exhaled by the patient after anesthesia.

This pollution can be reduced by:

- 1- regular inspection of all anesthetic equipment
- 2-Employing anesthetic techniques which limit or avoid the use of inhalational gases and agents e.g., circle system, total intravenous anesthesia and regional techniques • An efficient scavenging system.

Power Failure

Critical areas employing electrically driven equipment such as some respirators (Ventilators) and dialysis machines require standby equipment (i.e. generators) to deal with this emergency.

Electrocardiography

Electrocardiogram ECG or EKG : is the graphic recording of the electrical activities of the heart •

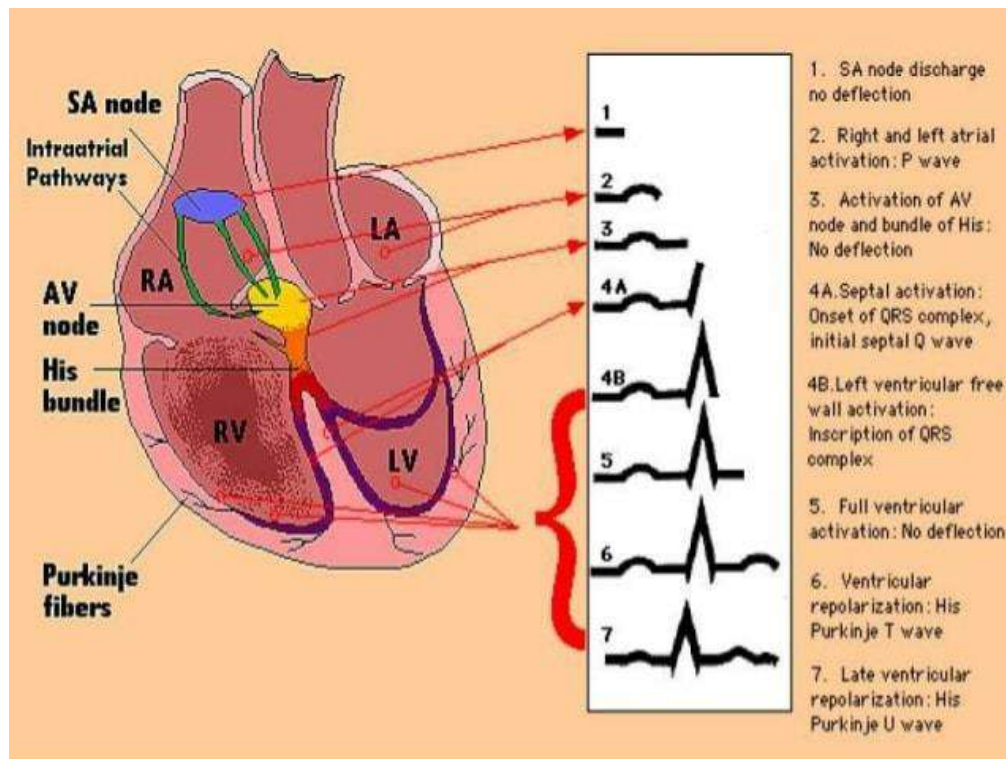
Electrocardiograph : is the machine that records the ECG • It is an important diagnostic & prognostic tool for assessment of cardiovascular function.

body fluids are good conductors of electricity • electrical changes occurring in the heart with each heart beat, are conducted all over the body & can be picked up from the body surface

The Electricity Of The Heart:

The contraction of any muscle is associated with electrical changes called “depolarization”& these changes can be detected by electrodes attached to the surface of the body.

The normal pacemaker site of the heart is the SA node. The conductivity of the heart normally follows an electrical pathway from the SA node through the interatrial pathway to the AV node to the Bundle of His down the bundle branches to the Purkinje fibers.



Indications of ECG:

- 1- Myocardial Infarction & other types of CAD such as angina
- 2- Cardiac dysrhythmias
- 3- Cardiac enlargement
- 4- Electrolyte disturbances
- 5- Inflammatory diseases of the heart
- 6- Effects on the heart by drugs, such as antiarrhythmic drugs

Requirements: – ECG machine – Cardiac jelly – ECG paper – ECG leads

ECG leads :

- 1- Direct leads – Leads applied directly to the surface of the heart – These leads are used to record cardiac activities during cardiac surgery or during an experiment •
- 2- Indirect leads – Leads applied away from the heart to record the cardiac activities – Different indirect leads are limb leads, chest leads

ECG Leads

Leads are electrodes which measure the difference in electrical potential between either:

1. Two different points on the body (bipolar leads)
2. One point on the body and a virtual reference point with zero electrical potential, located in the center of the heart (unipolar leads)

ECG Leads

The standard ECG has 12 leads:

- 3 Standard Limb Leads
- 3 Augmented Limb Leads
- 6 Precordial Leads

The axis of a particular lead represents the viewpoint from which it looks at the heart.

Limb leads (bipolar & unipolar) :

Bipolar limb leads : Bipolar standard limb leads are original leads selected by Einthoven to record electrical potential on frontal plane • electrodes are attached to right arm, left arm, & left foot – another electrode is applied to the right leg, which acts as a ground wire to prevent external disturbance during recording •

1- Lead I: between right arm (negative electrode) & left arm (positive electrode)

2- Lead II: between right arm (negative electrode) & left leg (positive electrode)

3- Lead III: between left arm (negative electrode) & left leg (positive electrode)

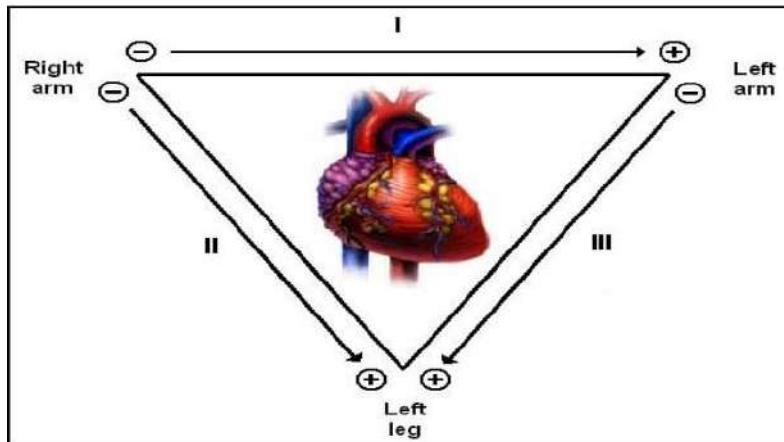
Augmented limb leads (unipolar limb leads) : positive electrode is connected to one limb, & negative electrode to the other two through high resistances • There are three augmented limb leads

aVR: between right arm (positive electrode) & left arm + left leg (negative electrode)

aVL: between left arm (positive electrode) & right arm + left leg (negative electrode)

aVF: between left leg (positive electrode) & right arm + left arm (negative electrode)

Standard Limb Leads



Unipolar chest leads : six chest leads are used routinely; V1 to V6

V1: in the right fourth intercostal space at the right border of the sternum •

V2: in the left fourth intercostal space at the left border of the sternum •

V3: at the midpoint between V2 & V4 •

V4: in the left fifth intercostal space on the midclavicular line •

V5: in the left fifth intercostal space on the anterior axillary line •

V6: in the left fifth intercostal space on the mid-axillary line •

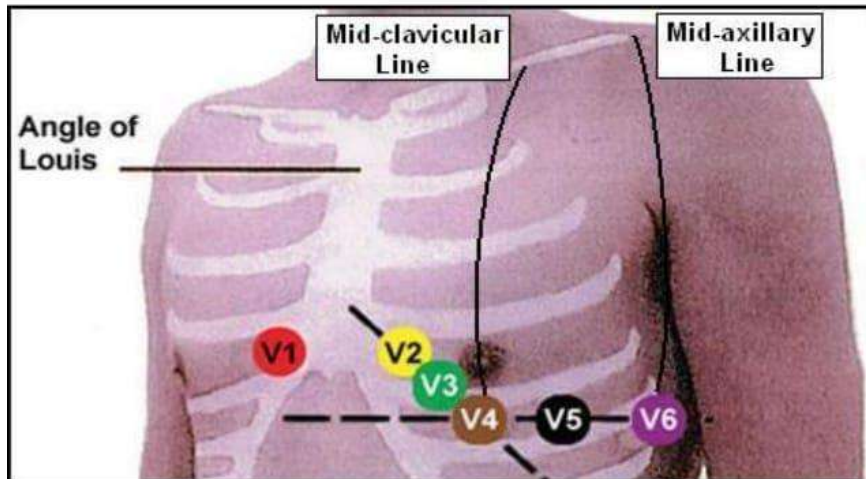
Precordial Lead Placement

- V_1 : 4th intercostal space, right sternal border
- V_2 : 4th intercostal space, left sternal border
- V_3 : midway between V_2 and V_4
- V_4 : 5th intercostal space, left midclavicular line
- V_5 : level with V_4 , anterior axillary line
- V_6 : level with V_4 , mid axillary line

Summary of Leads

	Limb Leads	Precordial Leads
Bipolar	I, II, III (standard limb leads)	-
Unipolar	aVR, aVL, aVF (augmented limb leads)	V_1 - V_6

Precordial Leads

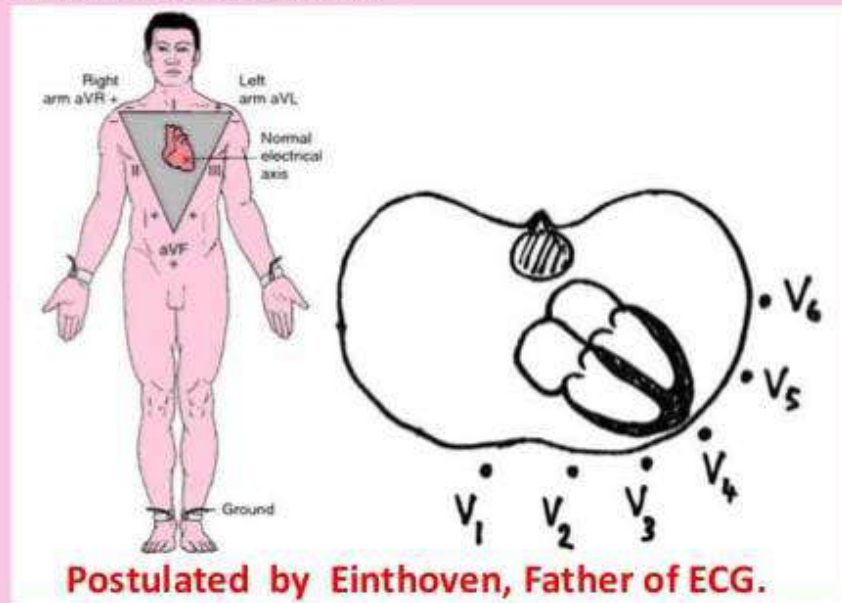


Einthoven's Triangle : is drawn around the area of the heart – this illustrates that the two arms & the left leg form apices of a triangle surrounding the heart

Einthoven's Law • if the electrical potentials of any two of the three bipolar limb electrocardiographic leads are known at any given instant, the third one can be determined mathematically by simply summing the first two

Einthoven's triangle

It is an imaginary equilateral triangle formed by connecting the points of junctions of the right & left superior extremities & the left inferior extremity.



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Normal ECG:

The electrical activity of the cardiac cycle is characterized by five primary wave deflections, designated by letters P, Q, R, S, T.

P wave Represents atrial contraction. Shape of the 'P' wave remains the same unless it is generated from a different focus.

QRS complex Represents ventricular depolarization and is composed of 3 waves, the Q, R & S.

Q wave is the first negative deflection. R wave is the first positive deflection after the P wave. S wave is the negative deflection following R wave. It is about 0.08 to 0.12 sec, represented by 3 small squares.

PR interval Measured from the beginning of P wave to the beginning of QRS complex. The normal PR interval is 0.12 - 0.2 sec, represented by 3-5 small squares. The time it takes for the impulse to spread from atria to ventricles.

ST segment An isoelectric line representing early ventricular repolarization. Normally not elevated $>1\text{mm}$ or depressed $>0.5\text{mm}$.

T wave Represents ventricular repolarization. Usually positive, rounded, & slightly Asymmetric.

U wave Results from slow repolarization of ventricular Purkinje fibers.
More common in lead V3. Hypokalemia.

QT interval Represents total time required for ventricular depolarization & repolarization. From the beginning of QRS complex to the end of T wave. Normal QT interval is 0.36 to 0.45 sec. A prolonged QT interval may lead to ventricular tachycardia.

Heart rate :As per speed of the paper, one minute is equal to 1500 small squares or 300 big squares.

So Heart rate = $1500 / \text{No: of small squares in one RR interval}$

OR $300 / \text{No: of big square}$

Rhythm Whether the waves are repeated at regular interval in consecutive beats.

Usually Normal Sinus Rhythm. One 'p' in front of every QRS, regular, all look alike. 3mm in height & a duration of 0.04 to 0.11 sec.

It is replaced by fibrillary wave in Atrial fibrillation & saw toothed wave in Atrial flutter.

Normal 'p' wave indicates the impulse is originating in SA node impulse is travelling normally along atria

PR interval Measured by counting the no. of small squares and multiplying by 0.04. Must be normal & constant

QRS complex Examined for

a) Duration- 0.08 to 0.12 sec. Prolonged in ventricular hypertrophy and bundle branch block.

b) Q wave - Normal in V5, V6 & it is due to septal depolarization. Q is always absent in lead II, V1, V2. Presence of a large Q wave >5mm is abnormal, usually signifies myocardial infarction.

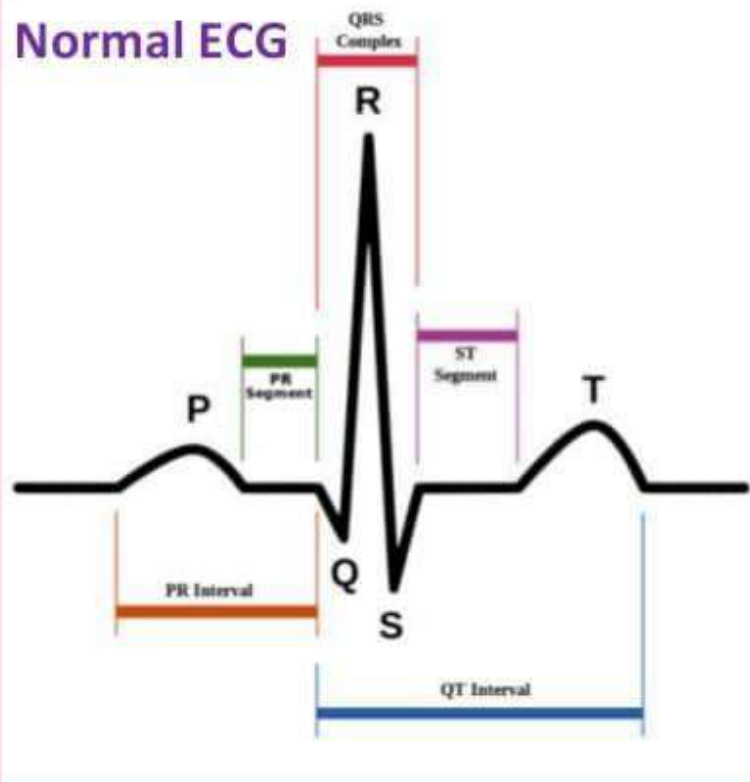
c) R waves & S waves- R waves are tall in V5 & V6, but in V1 & V2, the S waves are deep.

ST segment ST depression in ischemia & ST elevation in acute myocardial infarction.

T wave Positive except in aVR. Inverted T wave is found in ischemia, Tall 'T' wave in moderate hyperkalemia.

QT interval Changes with variation of plasma potassium & calcium concentration, drugs like quinidine prolongs QT interval. Normal QT interval is 0.42 seconds.

Normal ECG



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1. Heart rate

As per speed of the paper, one minute is equal to 1500 small squares or 300 big squares.

So Heart rate = $\frac{1500}{\text{-----}}$

No: of small squares in one RR interval

OR

$\frac{300}{\text{-----}}$

No: of big squares

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We can identify the side or wall of the heart affected by identifying the changes in particular leads.

Anterior wall- V2, V3, V4

Inferior wall - aVF, II, III

Lateral wall - I, aVL, V5, V6

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Abnormalities of rhythm

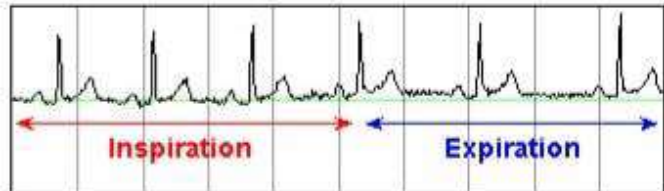
- Tachycardia
 - fast heart rate (>100 bpm)



- Bradycardia
 - slow heart rate (<60 bpm)



- Sinus arrhythmia
 - \uparrow heart rate during inspiration & \downarrow during expiration



- Ventricular extrasystole
 - It may occurs because a papillary muscle may fire an impulse before normal impulse reaches the ventricles, leading to premature contraction (extrasystole) of ventricles.

Ventricular Extrasystole

