

Endotracheal Tube (Et Tube)

Tracheal intubation is a procedure done to insure a patent passage of air to the trachea and lungs .

Intubation of trachea is useful in cases other than anesthesia;1)to preserve the airway in any patient who is unconscious as a result of head injury, drug overdose , cardiac arrest, .. 2)In cases of hypoxia , 3) to facilitate bronchial and tracheal suction , 4)to overcome any obstruction due to tumor or inflammation ,5)in case of artificial ventilation .

Endotracheal tubes are curved tubes used for intubation• Tubes were previously made up of latex (Indian rubber) and those still available ,currently plastic tubes (PVC) are preferred because of following advantages :

- 1- Disposable (less chances of infection)
- 2- Less allergic (latex allergy is fairly common)
- 3- Transparent (easy visualization of blockage ETT due to blood , pus ,secretions.

Components of ET

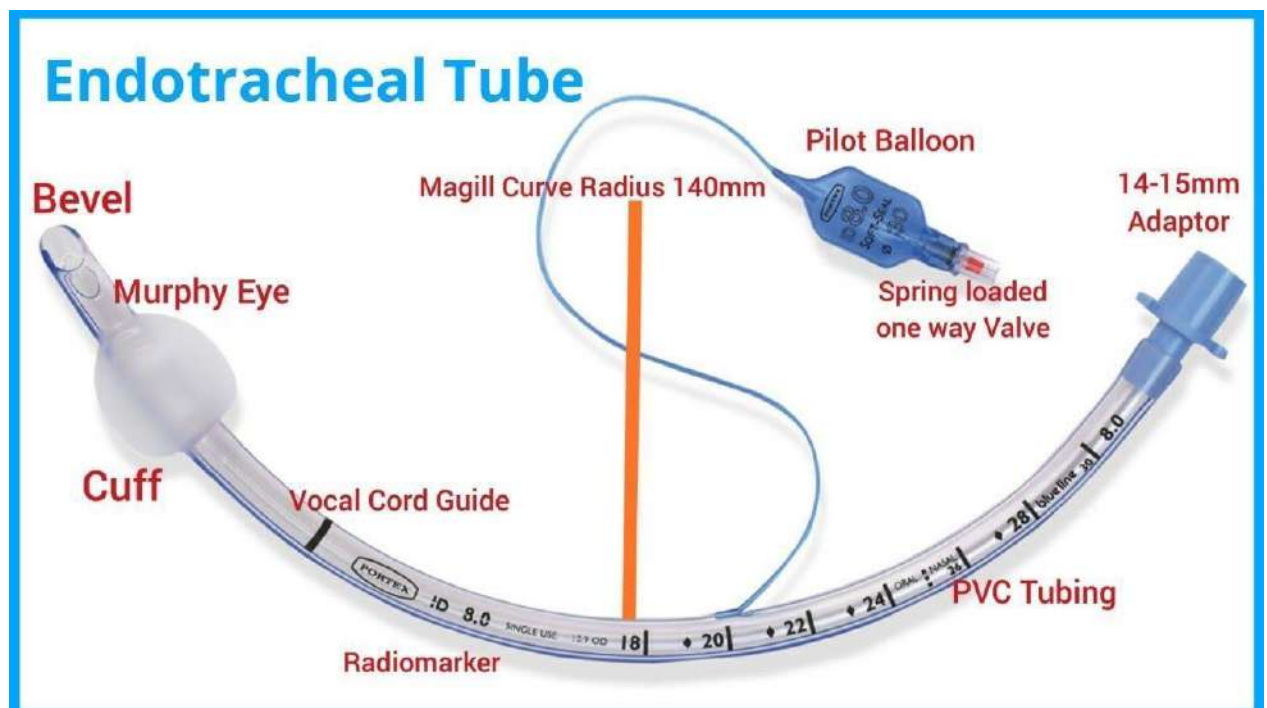
It has the following components :

1-Proximal End – 15mm adapter (connector) which fits to ventilator or ambu bag

2-Central Portion –

- a) A vocal cord guide (black line) which should be placed at the level of the opening of the vocal cords so that the tip of the ET tube is positioned above the bifurcation of the trachea.
- b) A radio-opaque marker which is essential for accurate visualization of the position of the ET tube within the trachea by means of an X-ray
- c) The distance indicator (marked in centimeters) which facilitates placement of ET tube.
- d) A cuff- in case of cuff ET tube

Distal End – has Murphy's eye (opening in the lateral wall) which prevents complete blockage of ET tube in case the distal end is impacted with secretion , blood , etc.



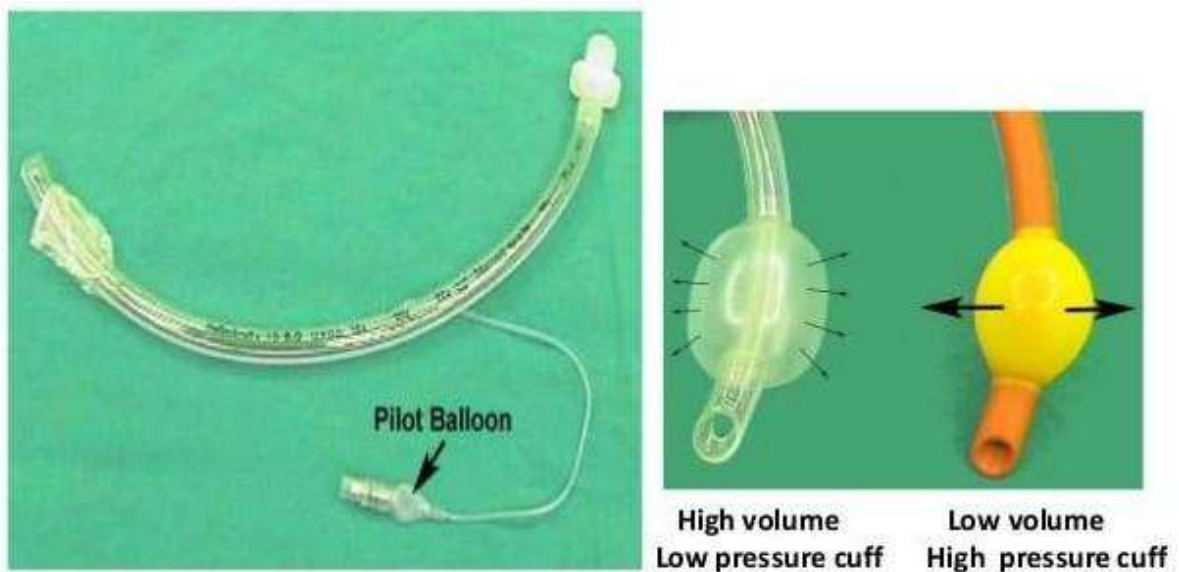
TYPES:

ET tubes can be : - cuffed or uncuffed tube

Cuffed ET tubes are used in children > 8 years• The cuff when inflated maintains the ET tube in proper position and prevents aspiration of contents from GI tract into respiratory tract•

In children < 8 uncuffed ET tubes are used because the narrow subglottic area performs the function of a cuff and prevents the ET tube from slipping. The cuff is either:

- a) High volume Low pressure cuff
- b) Low volume High pressure cuff



SIZE:

- 1) 0-1 yrs. 2.5 to 3.5 mm (plain)
- 2) 1-3 yrs. 4. to 5 mm

- 3) 4-6 yrs. 5 to 6 mm
- 4) 6-10 yrs. 6 to 7 mm (cuffed)
- 5) adult female. 7 to 8 mm
- 6) adult male. 8 to 9 mm

The size of the tube children below 5 years can be determined by –
 internal diameter of ETT(mm) = age in years /4 + 4

Roughly the diameter of the child's little finger is the same as that required for the ETT.

Indication of ET:

Endotracheal intubation is the placement of a special tube in trachea

- 1-To secure airway

- 2- to supply oxygen

- 3- general Anesthesia

- 4- Cardio pulmonary resuscitation

- 5- ventilatory therapy in ICU

Complication:

- 1- Mechanical trauma to tongue, teeth , palate , pharynx & larynx during intubation procedure

- 2- Stimulation of posterior pharyngeal wall leading to coughing , vomiting or vasovagal episode with resultant hypoxia , bradycardia.

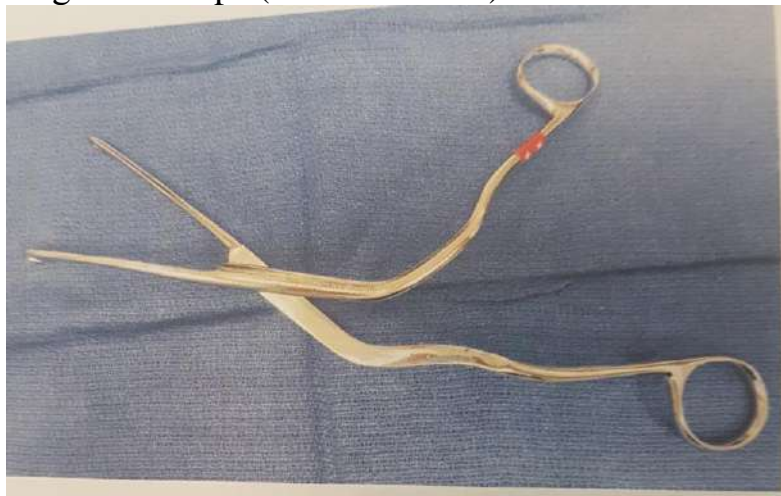
- 3- tube in oesophagus

- 4- Right intubation: the tube is in the right main bronchus

- 5- Prolonged intubation may cause pressure necrosis of laryngeal structures leading to persistent hoarseness (hence tracheostomy) is indicated in patients requiring long-term mechanical ventilation)
- 6- Pneumothorax.

Equipment's used for Endotracheal intubation

1. Different sizes of ETT
2. Laryngoscope: There are many types of laryngoscopes used for visualization of the larynx and vocal cords so that insertion of the ET is facilitated .The most commonly used laryngoscopes are ;the Macintosh and the miller type
3. Magill's forceps (different sizes)



4. Syringe to inflate cuff
5. suction
6. Stethoscope

difficult intubation

An intubation is called difficult if a normally trained anesthesiologist needs more than 3 attempts or more than 10 min for a successful endotracheal intubation

causes difficult intubation:

- 1-patients with a small mouth opening, and protruding upper teeth,
- 2- stiff neck,
- 3-engorgement of the tongue.
- 4- patients with an unstable cervical spine. and cervical joint rigidity in elderly patients
- 5- low Mallampati score : if the soft palate cannot be visualized (Mallampati classification)
- 6- narrow Interincisor gap

Handling: General handling of difficult intubation, use of special material including a portable unit, and confirmation of the endotracheal position

Fibero-optic bronchoscopy, direct visualization of the trans laryngeal position of the tube).

The laryngeal mask airway, trans tracheal jet ventilation

With better preoperative evaluation and clear guidelines and training for difficult intubation, anaesthetic morbidity and mortality can be reduced.



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محاظرة ١

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Lec 1

Operating room (theater)

Operating room design consideration :

The principle of designing the operating room are :

- 1- Ideally located near to surgical wards or intensive care
- 2- The design should allow for one way traffic and prevent return flow of contaminants into clean area
- 3-The prime requirements in the design are the control of infections
- 4- control the risk of fire, explosion, and chemical and electrical hazards

structure of operation theatre :

- 1-The wall should be hard and easily washable material
- 2- Pipes and central oxygen , nitrous oxide, suction should be fitted to the walls.
- 3- Adequate air conditioning should be provided
- 4-In the absence of window adequate light should provide.
- 5- Fire extinguisher should be adequate

Several operating rooms are part of the operating suite. Besides the operating rooms and their wash rooms, it contains rooms for personnel to change, wash, and rest, preparation and recovery rooms(s), storage and cleaning facilities, offices, dedicated corridors, and possibly other supportive units. In larger facilities, the operating suite is climate- and air-controlled, and separated from other departments so that only authorized personnel have access.

Traffic Flow

Traffic Patterns in the Surgical Suite, a **three-zone** designation of areas within the surgical suite facilitates appropriate movement of patients and personnel.

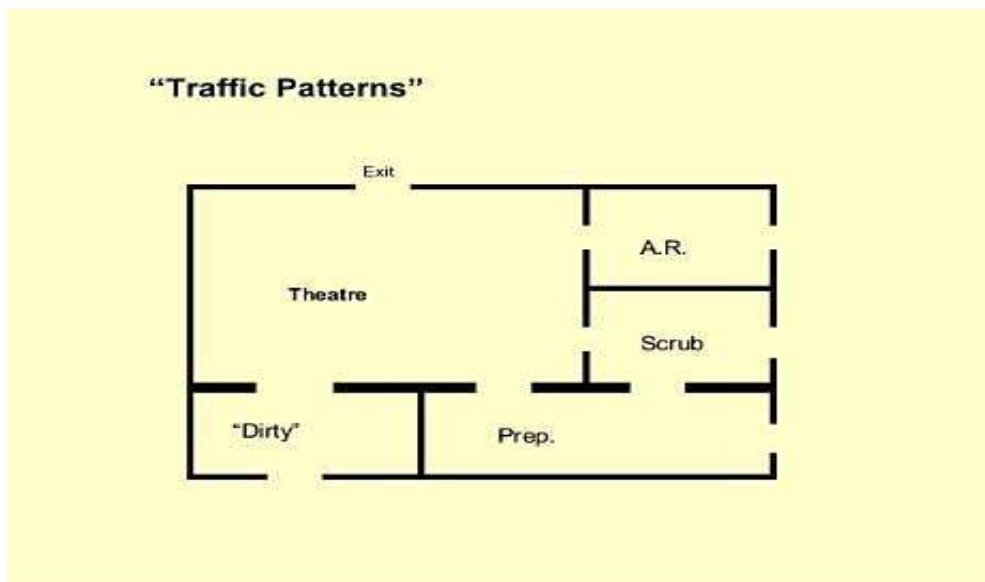
Traffic Flow

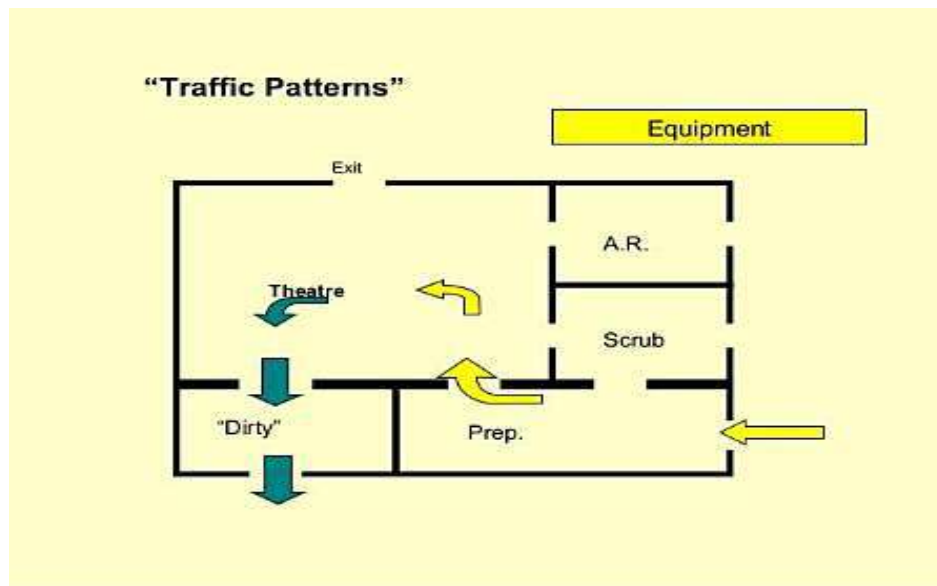
1. **Unrestricted areas** are those in which personnel may wear street clothes, and traffic is not limited.
2. **In semi-restricted areas**, such as processing and storage areas for instruments and supplies, as well as corridors leading to the restricted areas of the surgical suite, personnel must wear surgical attire and patients must wear gowns and hair coverings.

3. **Restricted areas** include operating rooms and clean core and scrub sink areas. Surgical attire and masks are required in these areas when there are open sterile supplies or scrubbed persons in the area.

Soiled materials should not re-enter the clean core area.

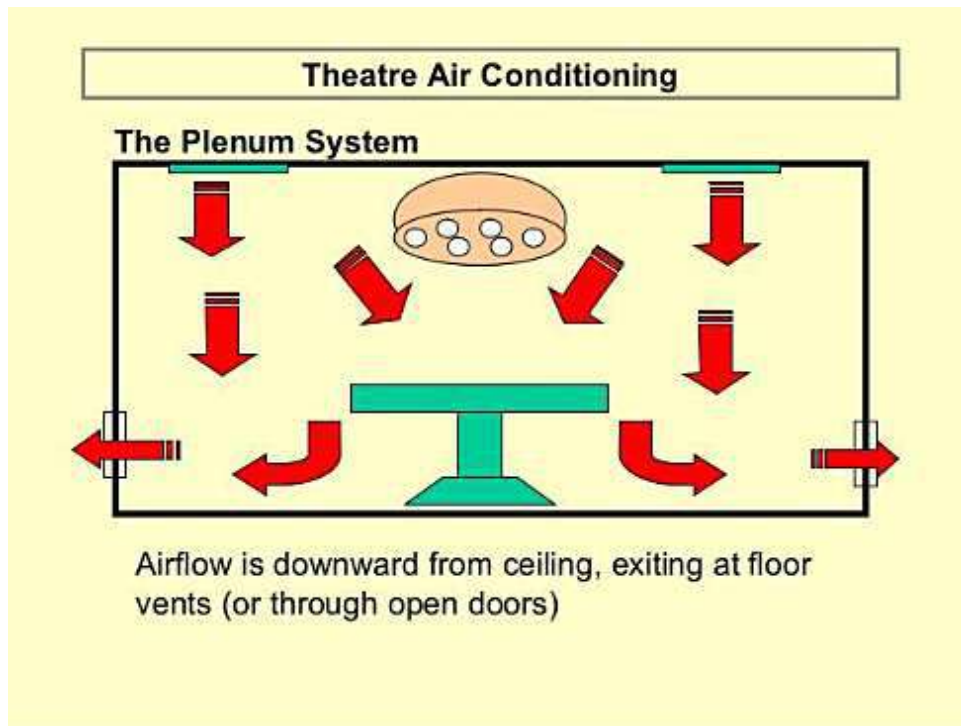
All journeys within the department are made from clean to dirty areas, never the other way round





Ventilation :

- 1- Appropriate ventilation systems aid in the control of infection by minimizing microbial contamination.
- 2- Temperatures in an operating room should be maintained between (20° to 23° C), with relative humidity of 30% to 60% to reduce bacterial growth and suppress static electricity.
- 3- Temperatures in that range allow for comfort of the surgical team and are tolerated by most patients.
- 4- Each operating room should have individual temperature controls to accommodate patient safety, as when increased warmth is required for patients at high risk for inadvertent hypothermia during operative procedures.



Emergency Signals

Every surgical suite should have an emergency signal system that can be activated inside each operating room.

A light should appear outside the door of the room involved, and bell should sound in a central nursing or anaesthesia area.

Operating Department comprises

- 1- Rest rooms
- 2- Changing rooms : a room is provided for theatre personnel to change into OT clothes from their sweat clothes, foot wear, sterile caps and mask also kept in this room
- 3-Teaching rooms
- 4- Storage
- 5- Reception areas
- 6- Operating suite

Operating Suite

Is one functioning unit of a department, it includes :

- 1- An anesthetic room
- 2- Clean preparation room
- 3- Scrub-up area
- 4- Operating theatre
- 5- Sluice room

Anaesthesia room : it should contain

- 1- The anesthetic machine and mechanical ventilators
- 2- Suction apparatus
- 3- The drug cupboard
- 4- Intravenous solution and connecting tubes

Anaesthetic Room



- Reception & preparation of patient
- Induction of anaesthesia

Store room:

Cylinder of O₂ and nitrous oxide, additional equipment, infusion fluid bag, syringes, needles, drugs, and operation instrument are kept in this room

Changing room :

a room is provided for theatre personnel to change into OT clothes from their sweat clothes, foot wear, sterile caps and mask also kept in this room.

Scrub room:

the surgeon and the nurses scrub in this room and this room open into the OT.

Sterilizer room :

a sterilizer room should be built adjacent to the OT with a window. The equipment can be passed between the rooms without repeatedly opening



The Operating Theatre

The operating table – center piece of the room, It has to be in order to accommodate the great variety of different operating positions.

The Operating Lights :

- 1- There are usually two operating lights in a theatre attached to the ceiling.
- 2- The lights are easily maneuvered, necessary to accommodate the needs of surgery.
- 3- Good lighting is needed to carry out an operation, and lighting a wound from two converging angles is designed to eliminate shadows.

Recovery room

the main purpose of recovery room is to given nursing care to the post-operative patient .

Carried out in the corridor outside the operating theatre.

Normally made up of several bed spaces, each with necessary equipment to facilitate recovery e.g. oxygen, suction apparatus, pulse oximetry, emergency trolley necessary to deal with cardiac arrests or anesthetic emergencies etc.



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Clean and Dirty

Patients

Will enter the department from the hospital corridor via a transfer bay. Here they are usually lifted on to a theatre trolley, leaving the ward bed outside.

Next they enter directly to the anesthetic room.

Finally they enter the theatre itself where surgery is to be performed

The journey has been one through progressively **cleaner** areas, arriving finally at the **cleanest** of all.

Once the wound has been closed and covered with dressing, it is safe for the patient to return to the ward via progressively more dirty areas: through the exit bay, recovery and the hospital corridor.

Instrument and Equipment

Are brought from outside the department into clean store rooms. Instruments are often supplied in pre-packed sterilized trays Finally, they enter the theatre ready for use on the scrub nurse's trolley.

At the end of an operation, dirty instruments, linen and rubbish are removed to the sluice room,.

Theatre Personnel

Enter the department via a changing room where outdoor clothing is left.

Here they enter via the clean preparation room or the scrub-area, and like the patient, leave through the exit bay.

Anesthetic Scavenging

A long length of corrugated plastic tubing connected to the anesthetic circuit at one end, while the other connects to a vent in the ceiling or wall.

The system draws out of the theatre any anesthetic gases or agents leaking from the circuit and which pollute the atmosphere.

The Swab Rack

This is a metal piece of furniture used for hanging up swabs during an operation for ease counting.

The Swab Board

1- This is for recording the amount of blood loss during the operation especially major operation.

2- The nurses record this information for anesthetist's benefit, who will instigate replacement therapy.

3- The board is usually marked in two columns; one for blood loss from the swabs and one for loss from the suction.

Weighing Scale: estimating blood loss

You should find a list of known dry weights of each different type of swab.

To estimate blood loss, you weigh the blood-soaked swab, and from that weight subtract the known dry weight.

This leaves you with the weight of blood lost, which is the amount you record, adding it to the running total.

e.g.; Dry Large swab = 20g, Soaked in blood = 90g

: $90\text{g} - 20\text{g} = 70\text{g}$ is the weight of the blood loss

(1g = 1ml)

X-ray Screens

This is vital as some operations are conducted with close reference to a patient's x-rays throughout. e.g. orthopedic surgery, tumor surgery and operations such as cholecystectomy

Theatre cleaning.

1. Daily routine cleaning-the operation theatre is cleaned at least 1 hr before operation are started. the floor is cleaned whenever it gets dirty. it also cleaned at the end of the day's work.

2. Cleaning between cases-Area which is contaminated or dirty have to clean between cases.

४. Weekly cleaning- the floor is wshed after removing all equipment and furniture from the theatre.

5.Cleaning after an infected cases- Routine cleaning is carried out. Fumigation should be done either with the formalin vapor or hypo chloride spray.in case the patient have an infection that can be transmitted through blood, all linen and instrument are soaked in 1%hypochloride solution before washing.

Preparation of equipment's for sterilization- instrument are prepared on a metal tray which is covered by a large drape which is secured to the rim of the tray. Cleaning and care of -instrument must be thoroughly washed either by hand or by using a sonic washer.

Operating room equipment:

1-The operating table in the center of the room can be raised, lowered, and tilted in any direction.

2- The operating room lights are over the table to provide bright light, without shadows, during surgery.

3- The anesthesia machine is at the head of the operating table. This machine has tubes that connect to the patient to assist them in breathing

during surgery, and built-in monitors that help control the mixture of gases in the breathing circuit.

4- The anesthesia cart is next to the anesthesia machine. It contains the medications, equipment, and other supplies that the anesthesiologist may need.

5- Sterile instruments to be used during surgery are arranged on a stainless steel table.

6- An electronic monitor (which records the heart rate and respiratory rate by adhesive patches that are placed on the patient's chest).

7- The pulse oximetry machine attaches to the patient's finger with an elastic band aid. It measures the amount of oxygen contained in the blood.

8- Automated blood pressure measuring machine that automatically inflates the blood pressure cuff on patient's arm.

9- An electro cautery machine uses high frequency electrical signals to cauterize or seal off blood vessels and may also be used to cut through tissue with a minimal amount of bleeding.

10- If surgery requires, a heart-lung machine or other specialized equipment may be brought into the room.

11- Advances in technology now support hybrid operating rooms, which integrate diagnostic imaging systems such as MRI and cardiac catheterization into the operating room to assist surgeons in specialized neurological and cardiac procedures

.

Surgeon and assistants' equipment:

People in the operating room wear PPE (personal protective equipment) to help prevent bacteria from infecting the surgical incision. This PPE includes the following:

- 1- A protective cap covering their hair
- 2- Masks over their lower face, covering their mouths and noses with minimal gaps to prevent inhalation of plume or airborne microbes
- 3- Shades or glasses over their eyes, including specialized colored glasses for use with different lasers. a fiber-optic headlight may be attached for greater visibility
- 4- Sterile gloves; usually latex-free due to latex sensitivity which affects some health care workers and patients.
- 5- Protective covers on their shoes
- 6- If x-rays are expected to be used, lead aprons/neck covers are used to prevent overexposure to radiation

7- The surgeon may also wear special glasses that help him/her to see more clearly. The circulating nurse and anesthesiologist will not wear a gown in the OR because they are not a part of the sterile team. They must keep a distance of 12-16 inches from any sterile object, person, or field



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محاضرة اجهزة (3)

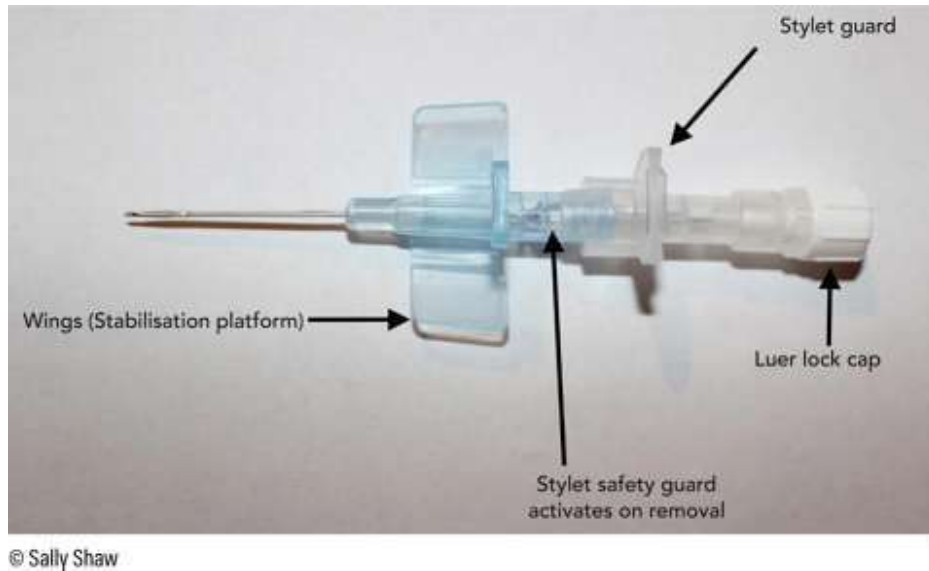
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Peripheral intravenous cannula (PIC)

Cannula:

flexible plastic tubing which has been inserted into the vein using a needle; the tubing has been taped to the patient's arm to prevent it coming out when the patient moves, and a sterile dressing has been placed over the punctured place in the skin where the cannula has been

inserted to prevent bacteria that commonly exist on the skin's surface from getting into the bloodstream.



.Indications:

- 1- Administration of anaesthesia.
- 2- Administration of fluids.
- 3- Administration of medications.
- 4- Administration of blood or blood products.
- 5- Allow sampling of the blood
- 6- Radiological imaging using IV contrast

Contraindication:

- 1- Sites close to infection
- 2- Veins of fractured limbs

3- Where there is an A-V fistula present

4- Oedema

5- Affected side of CVA and side of Mastectomy

Site Vein Selection:

1- Back of hand

2 – Forearm

3 - Antecubital fossa

Which vein is chosen?

Patent - Palpable - Distal - Straight - Avoid bifurcations

Areas to Be Avoided:

1- Areas of joint flexion

2- Hardened/sclerosed veins

3- Major veins near arteries

4- Veins in lower extremities

5- Areas of surgery

6- Previously cannulated veins

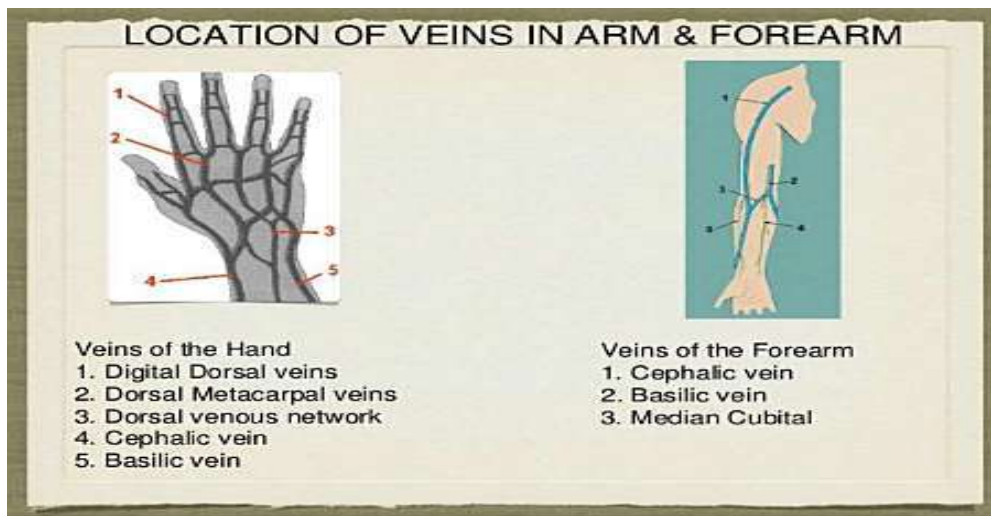
Location of Veins in Arm & Forearm

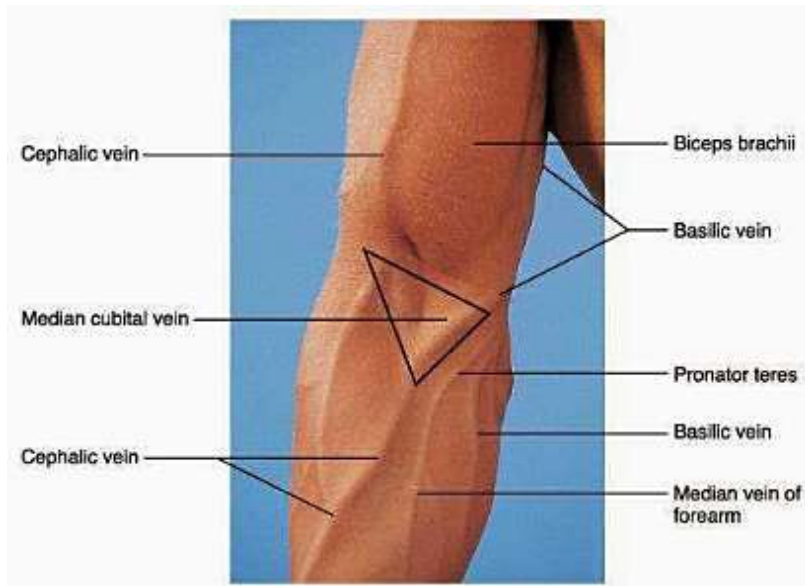
Veins of the Hand:

1. Digital Dorsal veins
2. Dorsal Metacarpal veins
3. Dorsal venous network
4. Cephalic vein
5. Basilic vein

Veins of the Forearm:

1. Cephalic vein
2. Basilic vein
3. Median Cubital





Types of cannula:

Size Color Coding, Flow Rate, Uses

- 1) 14G Orange: it is used in Trauma Patients. Rapid, Large-volume replacement
- 2) 16G Grey: Trauma Patients, used in Major Surgery, , GI bleeds, Multiple blood transfers, High volume of fluids
- 3) 17 G White
- 4) 18G Green: Blood products, delivery of irritant medications, major surgery,
- 5) 20G Pink: General use, IV maintenance, IV antibiotics, IV analgesia
- 6) 22G Blue: Small or Fragile veins, cytotoxic therapy

7) 24G: Yellow 20ml/min for pediatric usage

8) 26G Violet 13ml/min newly added



Butterfly Cannula:

A Butterfly cannula is a device specialized for venipuncture. It is used to access a superficial vein for IV injections. Used in children



Procedure of IV. Cannulation:

- 1- Explain procedure to the patient.
- 2- Wear personal protection equipment's, i.e. gloves
- 3-Select the location according to the procedure
- 4-Apply tourniquet
- 5- Make the selected vein prominent & clean the area with betadine solution. Clean the area with alcohol swab
- 6-Stretch the skin and fix the vein distally and tell the patient to expect a sharp scratch.
- 7- Insert the needle, bevel upwards at about 30 degrees. Advance the needle until you observe blood at the back of the cannula.
- 8- Once bloods appear, progress the entire cannula a further 2mm, and then fix the needle.
- 9- Release the tourniquet, apply pressure to the vein at the tip of the cannula and remove the needle fully. Remove the cap from the needle and put this on the end of the cannula.
- 10- Apply the dressing to the cannula to fix it in place.
- 11- Fill the syringe with saline and flush it through the cannula to check for patency.

Complications of IV cannula:

1- Hematoma

2- Hemorrhage

3- Infection

4- Extravasation

5- Infiltration

6- Thrombophlebitis

7- Puncturing an artery

8- Puncturing a nerve



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محاضرة 4

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محاضرة اجهزة (4)

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IV Setup

It is used when we want to give a large amount of fluid, or when we need to dilute a medication in a lot of fluid to make less irritant. Also, because IV administration generally involves larger quantities of fluid, the medication given by IV is usually infused over a longer period of time.

Structure of IV Setup :

It consist of bag and tubing

The standard sizes of the bags can range from 50 mL to 1000 mL. and IV tubing is attached to the bottom of the bag.

The IV tubing contains several important parts:

a)The **drip chamber** is located just below the IV bag; inside this chamber we can see the fluid drip down from the bag into the IV tubing. **This is where we measure the speed of a manual IV setup; we look at this chamber and count the number of drops we see per minute.** So, for example, if we count 25 drops over the period of 60 seconds, we would say that the IV is infusing at a rate of 25 drops per minute, or 25 gtt/min. (In reality, we may not count the number of drops in a full minute; we can, for example, count the number of drops we see over a period of 15 seconds, and then multiply that number by 4 to get the number of drops in a full minute.)

The drip chamber must always be half full. If the drip chamber is too full, we will not be able to see the drops to count them and If the drip chamber is not full enough, then this will allow air to get into the IV tubing, which means that air would get into the patient's circulatory system, which could be very dangerous, blocking a blood vessel or stopping the heart.

b)The **roller clamp** used to control the rate at which the IV fluid infuses. If we roll it one way, it squeezes the IV tubing more tightly, making it more narrow and therefore making the fluid flow through the tubing more slowly; if we roll it the other way, it loosens its pinching of the IV tubing, making the tubing less narrow, and allowing the IV fluid to flow through at a faster rate. All roller clamps on a set of IV tubing should be closed before we attach a bag of IV fluid to the top of the tubing; this ensures that no air gets into the tubing.

Every IV medication will be ordered to infuse at a specific rate, and one of the major tasks of hospital nurses is to set up the IV so that it infuses at this rate and to adjust the IV periodically if the rate has changed so that it remains at the ordered rate. The rate at which an IV fluid infuses is referred to as the IV **infusion rate** or **flow rate**.

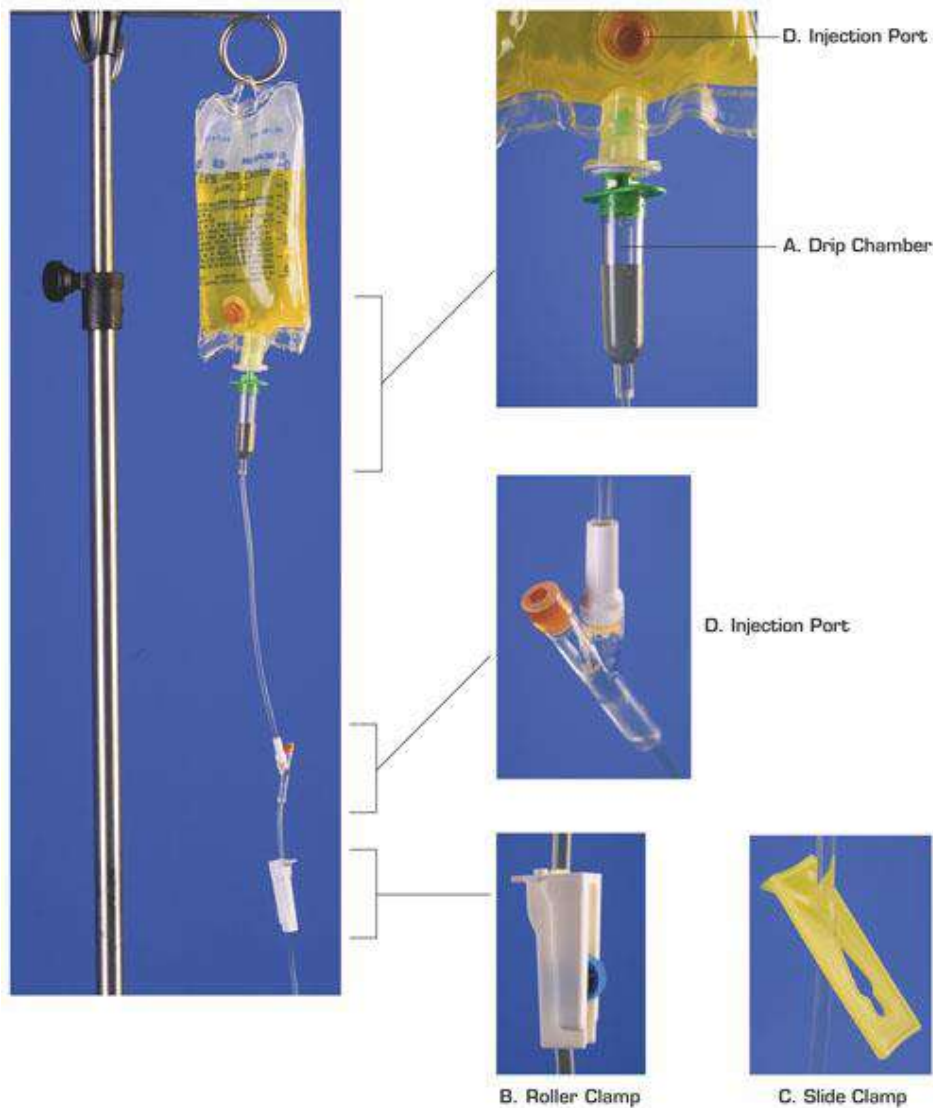
c)The **slide clamp** is used **when we want to completely stop the IV from flowing**, without having to adjust the roller clamp. This is handy if we want to stop the IV for a moment, but we don't want to have to reset the flow rate by readjusting the roller clamp all over again once we start the IV up again. This works by pinching the tubing completely shut when we slide the tubing into the narrowest part of the clamp.

d)The **injection port** is a place **where medicine or fluids other than those in the current IV bag can be injected so that they will infuse into the patient's vein through the IV tubing**. On the photo below we

can see two ports: one on the IV bag itself and one below the drip chamber. There is also usually an injection port close to where the needle goes into the patient's vein;

The injection port on the actual IV bag is used if we want to mix some kind of medication with the fluid that is in the IV bag; if we inject the medication into this port and then roll the bag a little to mix the medication into the fluid in the bag, then the patient will receive both the medication and the IV fluid at the same time

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How the Height of the IV Bag Affects the Infusion Rate

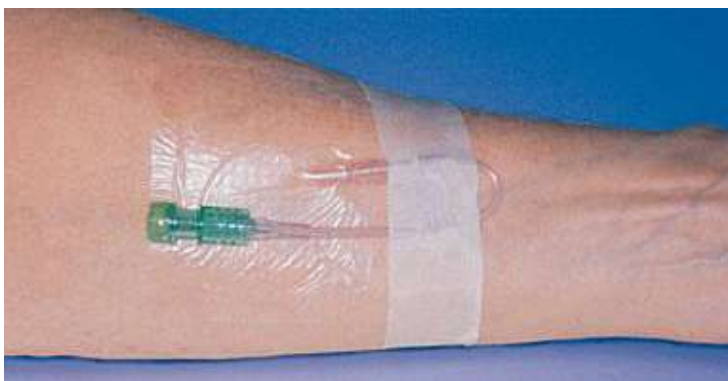
IV infusion works because gravity pushes the fluid down through the IV tubing into the patient's vein. **The higher the bag is hung, the greater the gravitational pressure on the IV fluid to go downward through the tubing. So, all IV bags must be hung above the patient's heart**

and it is standard procedure to **hang the IV bag at least 3 feet above an adult patient's heart**

Continuous IV infusion : when an IV medication or fluid is given continuously, or all the time.

Intermittent IV Infusion : when we want to administer an IV fluid and/or medication to a patient only at specific times; this is called an intermittent IV infusion.

A patient who is to receive a continuous IV infusion , the IV setup connected to them all the time, but for a patient who should receive only intermittent IVs, we can't leave them permanently attached to an IV setup. What we do instead is insert a cannula like the one in the picture below to the patient, which allows us to connect an IV only when the patient is actually receiving an infusion and to disconnect it in between doses:



This is a length of IV tubing with an injection port attached to one end; this special injection port is called an **infusion port adapter**,

Secondary IV or IV Piggyback

If a patient is receiving continuous IV fluids and in addition must receive a second kind of intermittent infusion, or if a patient's current IV infusion must be interrupted in order to administer a second IV medication or fluid that is more pressing, then we will need to hang a **secondary IV** for the patient. A **secondary IV**, also known as **IV Piggyback**, and abbreviated **IVPB**, is a second IV medication or fluid that is hung alongside the first and which is attached to the first set of IV tubing through one of the injection ports that is below the drip chamber of the primary IV (if we were to connect it through the injection port inside the primary IV bag, the contents of the primary and secondary IVs would mix and infuse at the same time, which is not what we want).

The picture below shows a secondary IV set up to the left and the primary IV hung to the right:



Notice that in this picture, the secondary IV bag is above the primary IV bag; this means that the pressure on the secondary IV bag will be greater than the pressure on the primary IV bag, and so this pressure will push it down into the tubing and prevent any of the fluid from the primary IV from entering the tubing until the secondary IV has emptied. Then, once the secondary IV has finished infusing, the primary IV will be able to go down into the tubing again, and the infusion of the primary IV will resume.



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محاضرة اجهزة (5)

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Physical property

All matter is made from atoms. Every substance (oxygen, lead, silver) has a unique number of protons, neutrons, and electrons. Oxygen, for example, has 8 protons, 8 neutrons, and 8 electrons. Hydrogen has 1 proton and 1 electron. Individual atoms can combine with other atoms to

form molecules. Water molecules contain two atoms of hydrogen **H** and one atom of oxygen **O** and is chemically called **H₂O**.

Phases of matter :

matter normally exists as either a **solid, a liquid, or a gas**. We call this property of matter the **phase** of the matter..

1- Solid

In the **solid phase** the molecules are closely bound to one another by molecular forces. A solid holds its shape and the volume of a solid is fixed by the shape of the solid.

2-Liquid :

In the **liquid phase** the molecular forces are weaker than in a solid. A liquid will take the shape of its container and the liquid has a fixed volume.

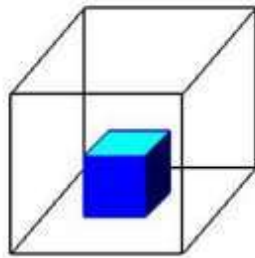
3- Gas

In the **gas phase** the molecular forces are very weak. A gas fills its container, taking both the shape and the volume of the container.



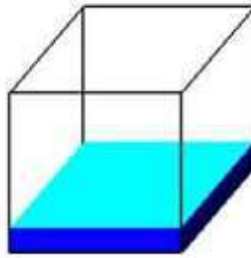
Phases of Matter

Glenn
Research
Center



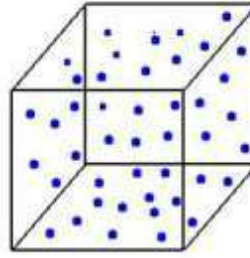
Solid

Holds Shape
Fixed Volume



Liquid

Shape of Container
Free Surface
Fixed Volume



Gas

Shape of Container
Volume of Container

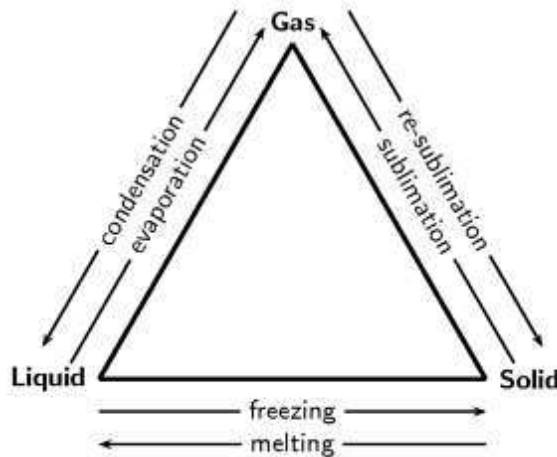
Fluids (Liquids and Gases)

Liquids and gases are called **fluids** because they can be made to flow, or move. In any fluid, the molecules themselves are in constant, random motion, colliding with each other and with the walls of any container..

Physical change of matter :

Any substance can occur in any phase. Under standard atmospheric conditions ‘ water exists as a liquid. But if we lower the temperature below 0 degrees Celsius, or 32 degrees Fahrenheit, water changes its phase into a solid called ice. Similarly, if we heat a volume of water above 100 degrees Celsius, or 212 degrees Fahrenheit, water changes its phase into a gas called water vapor. Changes in the phase of matter

are physical changes, not chemical changes. A molecule of water vapor has the same chemical composition, **H₂O**, as a molecule of liquid water or a molecule of ice.



Plasma - the "fourth phase"

The three normal phases of matter (solid, gas, liquid)have been known for many years. In recent times, we have begun to study matter at the very high temperatures and pressures which typically occur on the Sun, or during re-entry from space. Under these conditions, the atoms themselves begin to break down; electrons are stripped from their orbit around the nucleus leaving a positively charged **ion** behind. The resulting mixture of neutral atoms, free electrons, and charged ions is called a **plasma**. ("fourth phase" of matter).

kinetic molecular theory :

The kinetic molecular theory of matter states that:

- 1- Matter is made up of particles that are constantly moving.
- 2- All particles have energy, but the energy varies depending on the temperature. This in turn determines whether the substance exists in the solid, liquid, or gaseous state. Molecules in the solid phase have the least amount of energy, while gas particles have the greatest amount of energy.
- 3- The temperature of a substance is a measure of the average kinetic energy of the particles.
- 4- A change in phase may occur when the energy of the particles is changed.
- 5- There are spaces between particles of matter. The average amount of empty space between molecules gets progressively larger as a sample of matter moves from the solid to the liquid and gas phases.
- 6- There are attractive forces between atoms/molecules, and these become stronger as the particles move closer together. These attractive forces are called intermolecular forces.



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محاظرة 6

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محاضرة اجهزة (5)

د. نزار الحياي

Liquid State :

a solid begins to liquefy at the melting point as the particles gain enough energy to overcome their ordered arrangement

Energy required to reach the melting point is called the heat of fusion .
Liquid particles have more space between them allowing them to flow and take the shape of their container

Gaseous State :

particles have enough energy to escape the attractive forces of the other particles in liquid

Heat Of Vaporization :

is the energy required for a liquid to change to a gas At the Boiling Point the pressure of the liquid's vapor is equal to the pressure of the atmosphere and that liquid becomes a gas

Thermal Expansion:

increase in the Size of a substance when the temperature increases The size of the substance will then decrease when the temperature decreases
Expansion and contraction occur in most solids liquids and gases

WATER is an exception because it expands as it becomes a solid

Behavior of Gases

PRESSURE- is measured in units called Pascal (Pa) P

A collisions of particles in air result in **atmospheric pressure**

Moving particles colliding with the inside walls of a container result in **gas pressure**

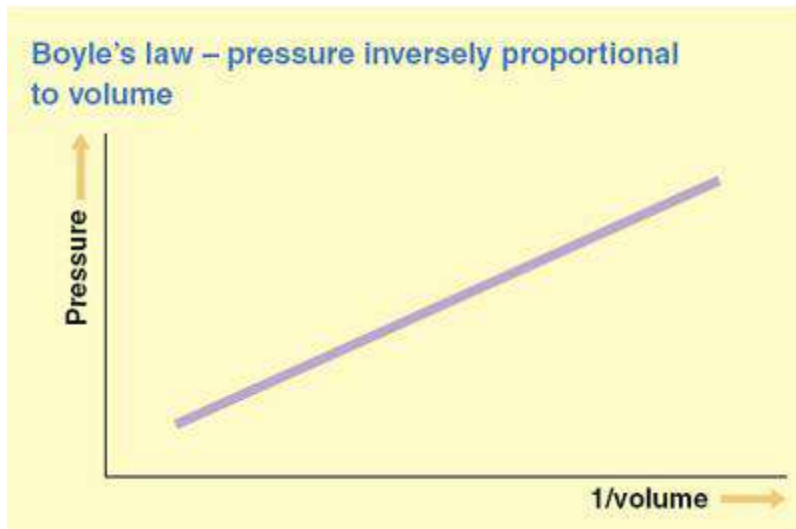
gas laws

1- Boyle's Law :

at a constant temperature, the volume of a mass of gas is inversely proportional to the pressure ($PV = \text{Constant}$).

Volume decreases as pressure increases Pressure decreases as volume increases

Pressure multiplied by volume is always equal to a constant if the temperature is constant Weather Balloons



Example of the application of Boyles law :

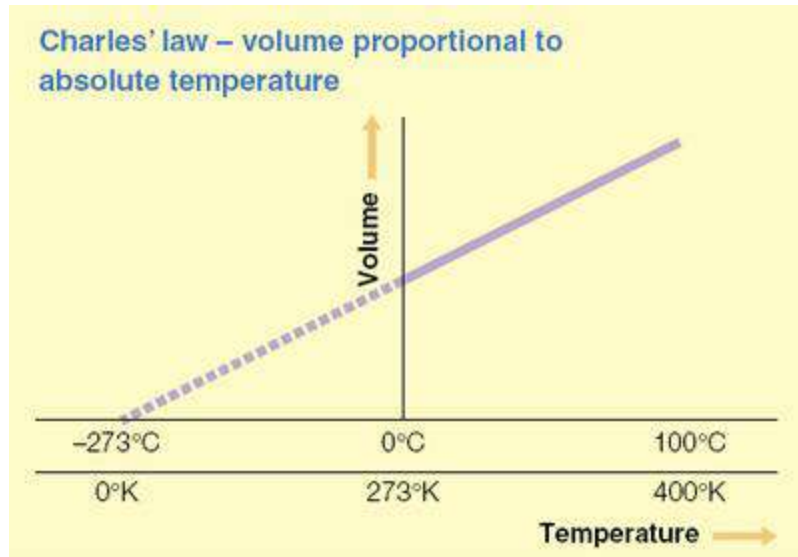
A typical large oxygen cylinder such as used in oxygen therapy, How much oxygen will be available at atmospheric pressure ?

The internal capacity of the cylinder is about 10 liters and when full it has a gauge pressure of 137 bar or 13700 kPa. If the atmospheric pressure is 100 kPa , the total or absolute pressure of the oxygen will be 13800 kPa , since absolute pressure is gauge pressure plus atmospheric pressure .

The total volume of oxygen = 1380 liters , as 10 liters is retained in the empty oxygen cylinder , 1300 liters is available for delivery at atmospheric pressure

Charles's Law :

at a constant pressure the volume of a gas is directly proportional to its absolute temperature ($V/T = \text{Constant}$). Volume is proportional to temperature. Gases expand when they are heated and become less dense, thus hot air rises.

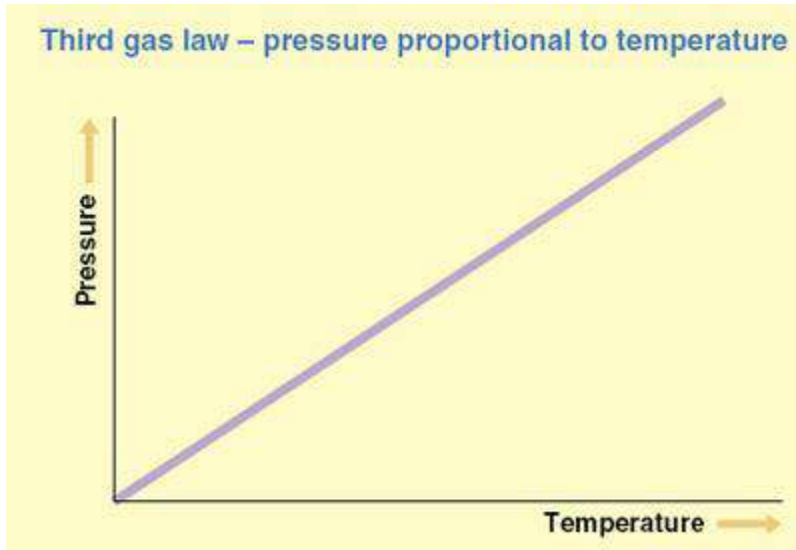


example of this law :

this law shows that gas expand when they are heated and so become less dense . it means that warm air tends to rise and this cause convection currents

Gay Lussac's Law :

at constant volume the absolute pressure varies directly with absolute temperature ($P/T = \text{Constant}$). Pressure is proportional to temperature. An example is the hydrogen thermometer. A constant volume of hydrogen when heated produces a change in pressure.



an example of this law :

consider an oxygen cylinder full to an absolute pressure of 138 bar at an ambient temperature of 290K (17C). cylinders are tested to withstand pressure of up to 210 bar . if the cylinder is dropped accidentally into an incinerator at 580 K (307C), there is a danger of explosion of the cylinder from the pressure increase . a doubling of the absolute temperature doubles the pressure , thus the pressure in the cylinder increase to over 210 bar . The cylinder is likely to explode

Standard temperature and pressure (STP) – it is important to specify the temperature and pressure at which the measurement of a volume is made. increased temperature reduces the density of fluids

- increased temperature reduces the viscosity of liquids
- increased temperature increases the viscosity of gases (increased molecular activity).

The standard temperature used is 273.15K (0c)

The standard pressure used is 101.325KPa (760mmHg)

This standard temperature and pressure is known as s.t.p.

Temperature, however, requires a scale that starts at absolute zero, therefore Kelvin must be used.

T Molybdenum steel can withstand pressure till 210 bars. Weakening of metal in damaged cylinders are at a greater risk of explosion due to rise in temperature.



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محاظرة 7

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محاضرة اجهزة (7)

د. نزار الحياي

Gas laws in anesthesia and its Applications

What is gas?

A gas is a substance that is in its gaseous phase, but is above its critical temperature

What is pressure?

It is defined as the force per unit area acting at right angles to the surface under consideration

What is temperature?

This is a measure of the average kinetic energy in a system and translates to the degree of hotness or coldness of that system

Convert pressure values from kPa units to psi pressure units using the following method:

1. $1 \text{ psi} = 6894.76 \text{ Pascals (Pa)}$
2. $1 \text{ kPa} = 1000 \text{ Pascals (Pa)}$
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4. $\text{psi value} = \text{kPa value} \times 0.145038$

$1 \text{ kPa to PSI} = 0.145 \text{ PSI}$

$10 \text{ kPa to PSI} = 1.450 \text{ PSI}$

$1 \text{ psi} = 6.89 \text{ kPa}$

Boyle's Law :

At a constant temperature, the volume of a given mass of gas is inversely proportional to the absolute pressure.

The volume of an E type cylinder is approximately 5 Litres. The service pressure at which the cylinder is filled is 2000psig (when it is full)

What is the gas law applied to know the volume of oxygen in a full “E” type of cylinder available for use at 15 psig (pressure at common gas outlet)?

$$P_1V_1 = P_2V_2$$

$$2000 \times 5 = 15 \times V_2$$

$V_2 = 2000 \times 5 / 15 = 665$ litres So if we use 3 litres of oxygen, the E type full cylinder will last for about 220 mins.

$$665 / 3 = 220$$

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At constant pressure, volume of a gas is directly proportional to the temperature.

Application:

- i. Respiratory gas measurements of tidal volume & vital capacity etc. are done at ambient temperature while these exchanges actually take place in the body at 37 OC.
- ii. One way of heat loss from the body is that air next to the body surface gets warmer and moves up and thus our patient loses heat this way (esp. important in Paediatric anaesthesia) .

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At constant volume, the absolute pressure of the given mass of gas is directly proportional to the temperature.

Application:

- i. Medical gases are stored in cylinders having a constant volume and high pressures (138 Barr in a full oxygen / air cylinder). If these are stored at high temperatures, pressures will rise causing explosions.
- ii. Molybdenum steel can withstand pressures till 210 bars. Weakening of metal in damaged cylinders are at a greater risk of explosion due to rise in temperature.

Gas contents in a cylinder From ideal gas equation,

the pressure exerted by any gas is dependent on the number of moles present. Therefore in a fixed volume such as cylinder, the pressure is a measure of amount of gas contained. This is only applies to gas (e.g. O₂ or CO₂ cylinder) but not to vapour like full nitrous, where liquid and gas phases are present..

Avogadro's hypothesis

Equal volumes of gases at the same temperature and pressure contain equal numbers of molecules. the number of molecules present is expressed as a mole. A mole is the quantity of a substance containing the

same number of particles One mole of gas at standard temperature and pressure is contained in a volume of 22.4 litres.

A clinical application would be to calculate the volume of nitrous oxide in a cylinder. A nitrous oxide cylinder contains 2.2 kg of nitrous oxide. The molecular weight of nitrous oxide is 44. One mole is 44 g. At STP we know that 44 g occupies 22.4 litres, therefore 2200 g occupies $22.4 \times 2200/44 = 1120$ litres.

From known cylinder wt. and measured wt. the amount of N₂O is found out using Avogadro's hypothesis

The universal gas equation (the ideal gas law)

If the perfect gas laws and Avogadro's hypothesis are combined:

$PV/T = \text{Constant}$. For one mole of gas, PV/T equals the universal gas constant R . The equation can be rearranged to $PV = nRT$ (the universal gas equation) where n equals the number of moles present. The practical application of this law is the use of pressure gauges to assess the contents of a cylinder. The volume, temperature and gas constant remain the same and pressure is therefore proportional to n , the number of moles.

Adiabatic changes in a gas

Applying the three gas laws, for a change to occur in the state of a gas, heat energy is either added or taken away from the gas. If the state of a gas is altered without a change in heat energy it is said to undergo adiabatic change. If a compressed gas expands adiabatically, cooling occurs as seen in the cryoprobe. (when a gas is allowed to escape through a narrow opening, there is a sudden temperature drop). Energy is required as the gas expands to overcome van der Waal's forces. No heat exchange occurs between the gas and its surroundings because the source of energy is from the molecule's own kinetic energy, thus the gas cools as it expands. Conversely, if a gas is rapidly compressed its temperature rises (the Joule–Kelvin principle). When a cylinder connected to an anaesthetic machine is turned on too quickly the temperature rises in gauges and pipelines and in the presence of oil or grease may lead to a fire or explosion.

Dalton's law of partial pressures :

states that if a mixture of gases is placed in a container then the pressure exerted by each gas (partial pressure) is equal to that which it would exert if it alone occupied the container.- Thus in any mixture of gases

(alveolar, fresh inspired gases, air) the partial pressure exerted by each gas is proportional to its fractional concentration . $P = P_1 + P_2 + P_3$

If a pressure exerted by a gas is 50 % of the total pressure exerted by all gases in that container, then it will occupy exactly 50 % of its volume.

Critical temperature:

gases can be liquefied by increasing the pressure or cooling. However , there is a temperature above which any gas cannot be liquefied by increasing pressure. This is critical temperature.

The pressure of the gas at the critical temperature is called the critical pressure and the volume occupied by the gas is called the critical volume

O₂ – -118 c, 50bar

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CO₂ –31 c, 73bar

Therefore one can define a gas as a substance in the gaseous phase above its critical temperature.

Vapour is the term applied to a substance in the gaseous phase below its critical temperature. Thus, simply increasing the pressure can liquefy a vapour, but not a gas.



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محاضرة 8

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Vapours and gases :

Gas: Substance which is normally in gaseous state at room temperature and atmospheric pressure.

Vapour: gaseous substance which is normally in liquid form at room temperature and atmospheric pressure, since its critical temperature is above the room temperature

Vapour formed from liquid by evaporation occurs at surface of liquid and the concentration of vapour increases and Continues till there is a equilibrium when no further increase in vapour concentration is possible. This is called **saturated vapour pressure.(SVP)**

Boiling point :

SVP increases with temperature. The temp at which SVP is equal to atm pressure it is called boiling point. It is important to know that the Vapour pressure depends only on the liquid and temperature. Not affected by ambient pressure. (and is practically independent of total environmental pressure)

Heat and temperature :

Heat : The form of energy that passes between two samples owing to the difference in their temperatures.

Temperature : The property of matter which determines whether the heat energy will flow to or from another object of a different temperature

Temperature scales – the triple point of water

Different thermometers use particular thermometric properties. For example, a mercury-in-glass thermometer uses the change in length of a column of mercury confined to a capillary tube of uniform bore; a platinum thermometer uses the increase in resistance with increasing temperature.

To establish a temperature scale it is necessary to make use of fixed points: a fixed point is the single temperature at which it can be confidently expected that a particular physical event always takes place.

The ice point is the temperature at which pure ice can exist in equilibrium with water at standard atmospheric pressure.

The steam point is the temperature at which pure water is in equilibrium with its vapour at standard atmospheric pressure.

The triple point of water is that unique temperature at which pure ice, pure water and pure water vapour can exist together at equilibrium. The triple point is particularly useful, because there is only one pressure at which all three phases (solid, liquid and gas) can be in equilibrium with each other.

Flow of fluid through and orifice :

We have 2 types of flow :

there are two types of flows: a **laminar flow** and a **turbulent flow**

1- laminar flow

Laminar flow or streamline flow in pipes (or tubes) occurs when a fluid flows in parallel layers, with no disruption between the layers. At low velocities, the fluid tends to flow without lateral mixing, and adjacent layers slide past one another like playing cards. There are no cross-currents perpendicular to the direction of flow, nor eddies or swirls of fluids. In laminar flow, the motion of the particles of the fluid is very orderly with all particles moving in straight lines parallel to the pipe walls. Any lateral mixing (mixing at right angles to the flow direction) occurs by the action of diffusion between layers of the liquid. Diffusion mixing can be slow however if the diameter of the pipe or tube is small then this diffusive mixing can be very significant.

Turbulent flow

The fluid flow in which the adjacent layers of the fluid cross each other and do not move parallel to each other is called turbulent flow.

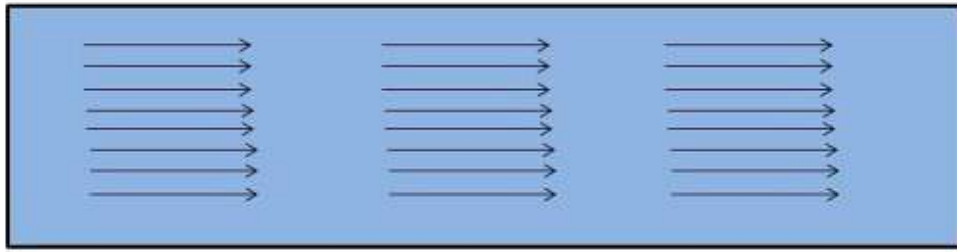
In turbulent flow the fluid layers do not move in a straight line. They move randomly in a zigzag manner.

The turbulent flow occurs when the velocity of the fluid is high and it flows through larger diameter pipes.

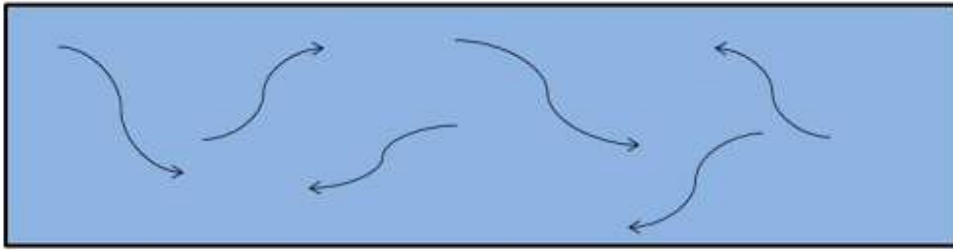
The fluid flow having Reynolds number greater than 4000 is called turbulent flow.

The fluid does not flow in a definite order. There is a mixing of different layers and they do not move parallel to each other but cross each other.

The shear stress in turbulent flow depends upon its density.



Laminar Flow



Turbulent Flow

The type of flow will depend on 4 factors :

- 1- Diameter of the tube
- 2- Speed of the fluid
- 3- Density of the fluid
- 4- Dynamic viscosity of the fluid

The factors combined provide the so called **Reynolds number (Re)**.

The Reynolds number is used to determine whether a fluid is in laminar or turbulent flow, it is assumed that a Reynolds number less than or equal to 2100 indicates laminar flow, and a Reynolds number greater than 2100 indicates turbulent flow.



أجهزة عملي

محاضرة 9

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Gas laws in anesthesia and its Applications

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أجهزة عملي

محاضرة 10

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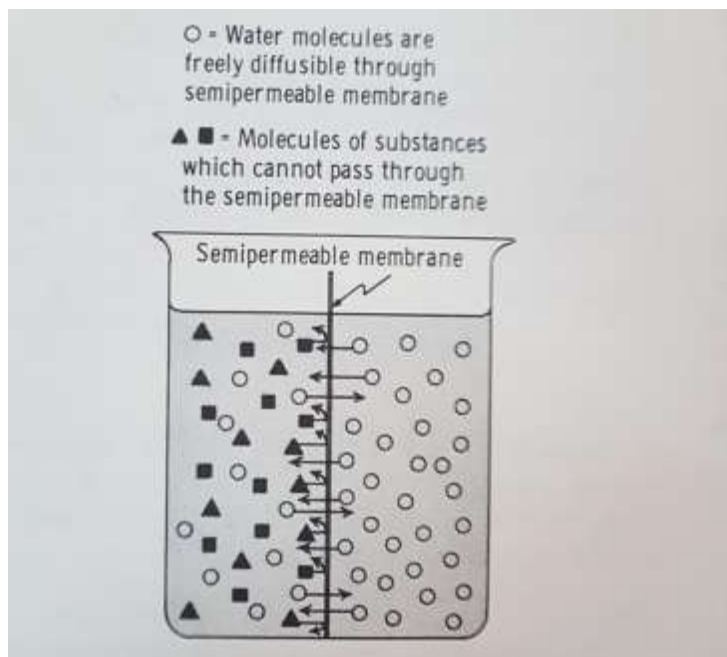
Intravenous therapy

Diffusion:

When a soluble substance such as sodium chloride is added to water, it quickly dissolves and distributes itself equally throughout the liquid. This process of diffusion is produced by the constant movement of the ions of the salt when in solution.

Osmosis:

If, however, a semipermeable membrane is interposed between a solution and its pure solvent (eg, water and a solution of NaCl), or between 2 solutions differing in concentrations of solute, the water molecules will diffuse through the membrane more rapidly than the salt molecules, if the salt solution is enclosed within the membrane, water will diffuse across the membrane into the salt solution.



Osmotic pressure:

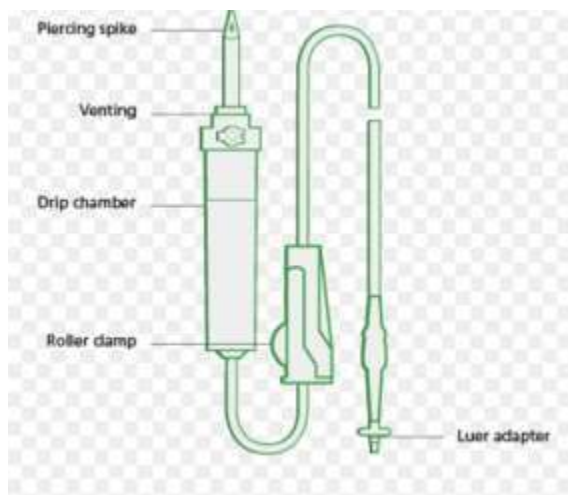
This movement of water (osmosis) results in the building up of a definite pressure (osmotic pressure) within the membrane-enclosed area. The amount of excess pressure which must be imposed on a solution in order to prevent the passage of solvent into it through a semipermeable membrane is the osmotic pressure.

So different solution are having different osmotic pressures or the so called different tonicity. Any solution having the same tonicity of plasma is called isotonic solution, other solution are either hypertonic or hypotonic solution. example of isotonic solution 0.9% sodium chloride (saline), 5% dextrose, 1/5 dextrose saline and lactated ringer solution.

Examples of hypertonic solution are 3% sodium chloride and 10% dextrose solution.

IV fluid

For intravenous therapy we should have an open vein (intravenous line) by cannula or other way and an intravenous giving set which is composed of a trocar to be inserted in the fluid bag and a drip chamber and tub to be connected to the cannula, along the tube there is a flow controller by which we can control the flow of the fluid.



Procedure of intravenous therapy:

1. Connect the intravenous set to the fluid bag by inserting the trocar in to the proper side of the bag by non-touch technique
2. Allow the fluid to fill half of the chamber
3. Let the tubes free of air by filling it with fluid
4. Connect the tube to the cannula and adjust the flow according to the need of patient

Forced or controlled intravenous therapy:

Usually we use the flow controller present on the intravenous set to adjust the favored rate but sometimes we need a very fast flow or very low flow in this case we have methods:

1. Squeezing bag



2. Infusion pump: an infusion pump is a medical device used to deliver fluids, such as nutrients and medications, into a patient's body in controlled amounts. In general, an infusion pump is operated by a trained user, who programs the rate and duration

of fluid by a built- in software interface. Infusion pumps offer significant advantages over manual administration of fluids, including the ability to deliver fluids in very small volumes, and the ability to deliver fluids at precisely programmed rate.

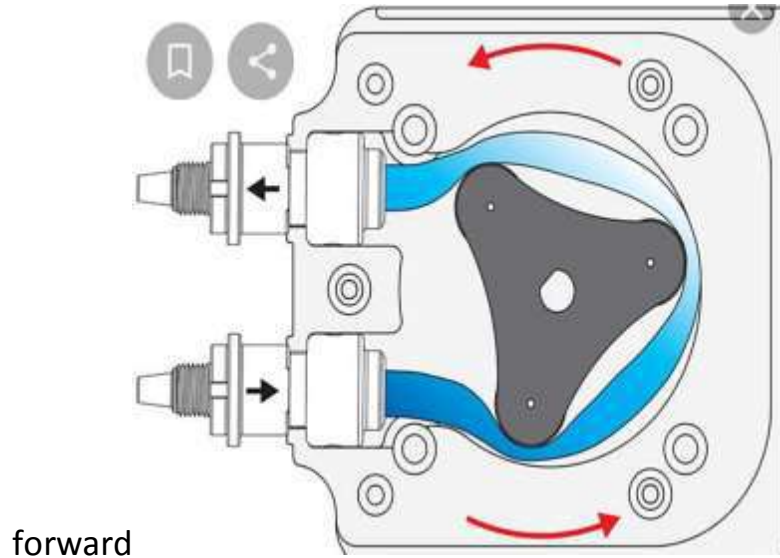
Infusion pump may be powered electrically or mechanically.

Different pumps operate in different ways for example:

- In a syringe pump, fluid is held in the reservoir of a syringe, and a moveable piston controls fluid delivery.



- In an elastomeric pump, fluid is held in a stretchable balloon reservoir, and pressure from the elastic walls of the balloon drives fluid delivery.
- In a peristaltic pump, a set of rollers pinches down on a length of flexible tubing, pushing fluid



Uses of intravenous fluid:

1. Fluid deficiency whether the patient can take oral or not.
2. Electrolyte imbalance
3. Nutrient supplement.
4. Blood transfusion.
5. Drug administration
6. Keep an open vein.



أجهزة عملي

محاظرة 11

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Blood transfusion

Frequently we need to give blood or one of its component during anesthesia to treat shock or bleeding patient. One of the most important principal is to avoid the production of antibodies by the recipient, this is difficult with white cell, platelet and plasma protein antigens. Antibodies produced to these are responsible for reactions in patients who have had multiple transfusions. Antibodies to red blood cells antigens are much more dangerous as they may cause fatal intravascular haemolysis (most commonly ABO incompatibility) .

Selection of donors; Blood is collected from donors .They are excluded if they are found to be anaemic or to have hepatitis B ,positive syphilis serology or malaria. Donors are also excluded if they are having TB ,epilepsy, hypertension, renal disease , sever atopy, malignant disease, or jaundice.

Collection and preservation; Blood is collected in plastic bags containing preservative and stored at 4°C .Blood should never be frozen as this causes haemolysis which can result in sever transfusion reactions.

The preservative solutions in common use are acid citrate dextrose (ACD) and citrate phosphate dextrose (CPD). Heparin is occasionally used if the blood is to be given within 12 hrs.

The limit of storage in ACD is 21 days ,and in CPD is 32 days .

Cross –matching; The serum of the patient is added to red cells of the donor and are incubated at 37°C for 2 hrs . Incompatibility is indicated by lysis or agglutination of red blood cells.

Indication of blood transfusion during anesthesia is either bleeding during surgery or expected bleeding. Usually blood is given when the blood loss exceeds 10% of the patient's blood volume. If the blood loss is

less than 10% of patient's blood volume usually we can give plasma expander (Normal saline, Ringer lactate, dextan, or heamacele. The giving set of blood is a special one (a mesh in the chamber of the giving set).

Autotransfusion; Is a process where in a person receives their own blood for a transfusion, instead of banked allogenic (separate-donor) blood. Autotransfusion also refers to the natural presses where (during fetal delivery) the uterus naturally contracts, shunting blood back in to the maternal circulation this is important in pregnancy , because the uterus can hold as much as 16% of mother's blood supply.

There are two main kinds of autotransfusion;

- Collection of blood before surgery; this collection can be conducted in two ways;
 - a) Elective preoperative blood collection, storage and retransfusion during surgery. Usually one donations per week is done. In 5 weeks we can have 5 units of blood, care should be taken to not put the patient in anaemic state. Time interval between the last donation and the surgery should be more than 72 hours.
 - b) Immediate preoperative phlebotomy with simultaneous artificial hemodilution and later reinfusion of the collected blood. This method has many advantages: 1- high level of 2,3-DPG, 2- normothermic, 3- relatively normal Ph , 4- low risk of infectious diseases, 5- high level of cells, 6- low potassium (compare to stored blood), 7- quickly available
- Intraoperative blood salvage and retransfusion : blood lost by the patient is collected into an apparatus designed for this purpose (e.g. the cell –saver), anticoagulated, and immediately returned to the circulation. This type of autotransfusion is most useful in cases

of massive bleeding. It may be lifesaving when compatible blood unavailable .

ADVANTAGES

1. less risk of the immune phenomenon
2. supply of allogeneic blood.
3. Less risk of infection.
4. Patients with rare blood types or incompatibilities.
5. Religious considerations.

Contraindication:

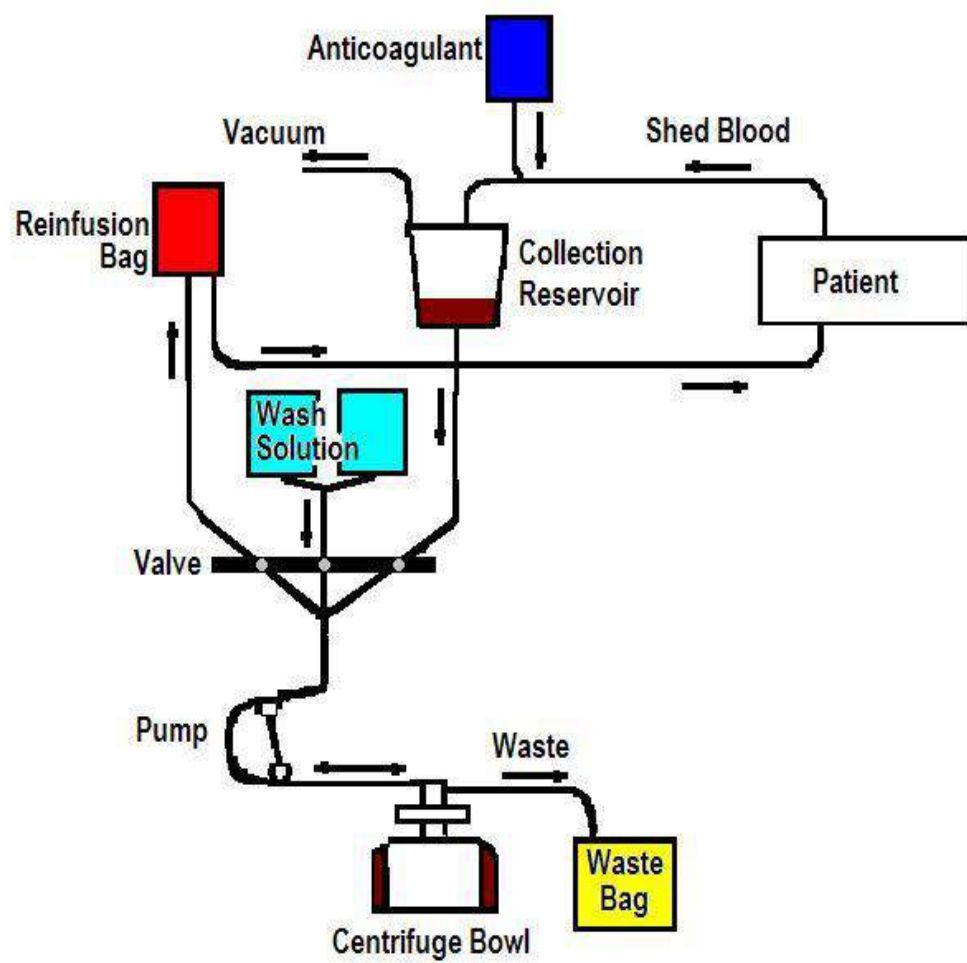
- 1) blood contamination : by intestinal contain in case of penetrating abdominal wound, or by chemicals used during operation.
- 2) If there is evidence of coagulopathy or evidence of disseminated intravascular coagulopathy (DIC).
- 3) the avoidance of autotransfusion in sickle cell disease and cesarean delivery as a relative contraindication.

Complications:

1. The most common complication of autotransfusion is blood loss if not properly collected.
2. The more serious complication includes blood contamination resulting in infection.
3. Other less common complications include hemodilution, hemolysis due to suction.
4. Air and fat embolism.

5. Dissemination of malignant cells.

Autotransfusion Process Diagram





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محاضرة 14

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Steps for oral tracheal intubation:

Step 1: check the equipment (laryngoscope, curved (Macintosh type) and straight (Miller type) blades of an appropriate size for patient and assure that the light works, check ETT cuff for leaks).

Step 2: Assemble all materials close at hand (Laryngoscope, ET tube size, 10 ml syringe, water-soluble lubricant, suction equipment, stethoscope).

Step 3: position of patient: unless contraindicated-i.e Truma.

If there is no contraindication elevating the patient's head about 5-10 cm with pads under the occiput and extension of the head into the sniffing position this position permits better visualization of the glottis and vocal cords and allows easier passage of the endotracheal tube.

Step 4: Curved blade technique: (Macintosh Laryngoscope)

- a. Hyper-oxygenate the patient with 100% oxygen for 2 minutes.
- b. Open the patient's mouth with the right hand, and remove any dentures.
- c. Grasp the laryngoscope in the left hand.
- d. Spread the patient's lips, and insert the blade between the teeth, being careful not to break a tooth.
- e. Pass the blade to the right of the tongue, and advance the blade into the hypopharynx, pushing the tongue to the left.
- f. Lift the laryngoscope upward and forward, without changing the angle of the blade, to expose the vocal cords. The cricoid pressure is used to lower the Larynx to facilitate tube passage and compress the epiglottis and prevent aspiration. A gentle downward pressure on cricoid cartilage, start slowly and then gradually increase the downward force.
- g. Pass the tube through the vocal cords.

Straight blade technique: (Miller laryngoscope)

Follow the steps outlined above. But advance the blade down the hypopharynx, and lift the epiglottis with the tip of the blade to expose the vocal cords.

Step 5: Sometimes we need to use a stylet to direct the tube toward the larynx. If we do it remove Stylet.

Step 6: connect the bag-valve mask and begin ventilation with 100% oxygen.

Step 7: check the placement by:

1. Visualize tube passing through the cords.
2. Movement of the chest with respirations.
3. Auscultation of the chest (You should hear breath sound on both sides of the chest).
4. Auscultation of the stomach (You should not hear gurgles here when bagging).
5. Rising or stable O₂ saturation.
6. Clinical improvement of the patient.

Size of endotracheal tube

- A cuffed ETT with an internal diameter of 3.0 mm may be used for infant. Up to 1 year of age.
- Uncuffed tube with an internal diameter of 3.5 mm for infants up to 1 year of age.

Endotracheal tube size for children (age 1 to 8 years)

Uncuffed endotracheal tube size = $4 + (\text{Age} / 4)$

Cuffed endotracheal tube size = $3.5 + (\text{Age} / 4)$

Adult Male----- 8.5-9 mm

Adult female----- 7.5-8 mm

Measure the air pressure in the ETT tube

Measuring the pressure created in the airway will help prevent damage to the trachea and lungs.

A safe pressure at the cuff of the ET tube is between 20 and 30 cmH₂O.

Adult:

Estimation of ideal ETT placement length is roughly 21 cm in women and 23 cm in men, “tube taped at the teeth”

Measuring the length of endotracheal tube:

Length = internal diameter (size ×3)

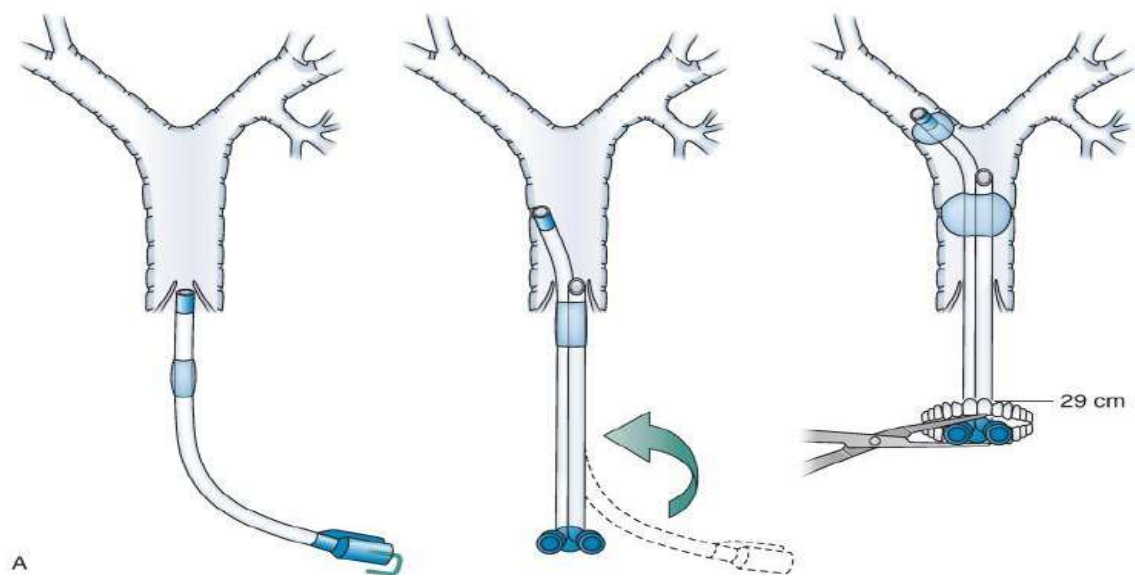
So for example, a 4-year-old child would get intubated with a 5-0 ETT inserted depth of 15 cm (3× ETT).

Double- Lumen Endotracheal tube:

Double-Lumen endotracheal tube (DLT) is the most common technique to achieve lung separation. Isolation of one side from another may be required to:

1. Visualization for certain surgical procedure within the thoracic cavity, such as operations on the lung tissue, esophagus.
2. Lung isolation also allows for management of certain pathological conditions of the lung including unilateral lung hemorrhage, trauma, or bronchopleural fistula.

The DLT, comprising two parallel lumen terminating in the trachea, and a second longer lumen extending into either the left or right main bronchus. Each lumen has a cuff that is inflated to create a seal.



A





أجهزة عملي

محاظرة 15

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محاضرة اجهزة ثاني (١٥)

د.رضوان البكري

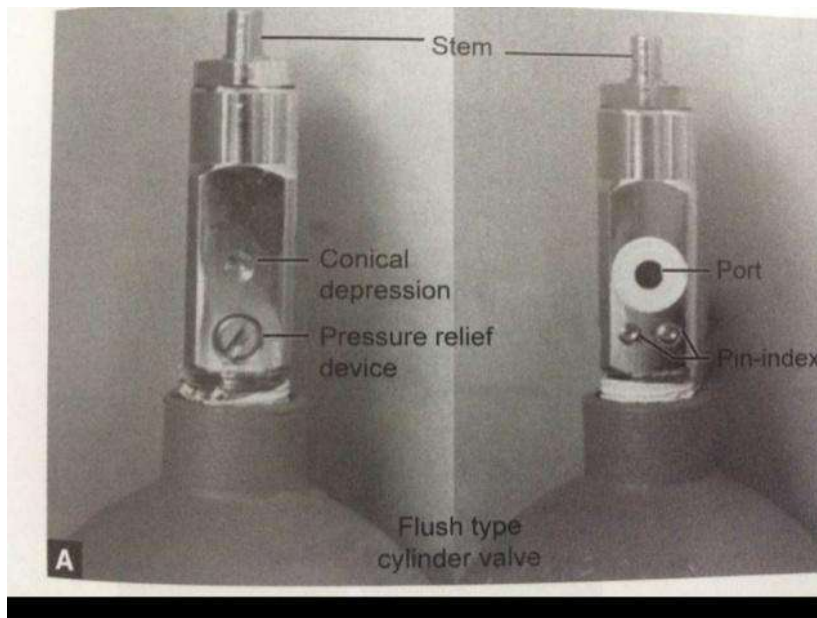
Medical gas supply

either cylinders or a piped gas system, depending on the requirements of the hospital.

Cylinders :

Cylinders Consists of:

- 1– Body
- 2– Valve
- 3 – Port
- 4– Stem
- 5 – Pressure relief devices



1. Cylinders are made of thin walled seamless molybdenum steel in which gases and vapours are stored under pressure. They are designed to withstand considerable internal pressure

. 2. The top end of the cylinder is called the neck, and this ends in a tapered screw thread into which the valve is fitted. The thread is sealed with a material that melts if the cylinder is exposed to intense heat. This allows the gas to escape so reducing the risk of an explosion

3. There is a plastic disc around the neck of the cylinder. The year when the cylinder was last examined can be identified from the shape and colour of the disc.

4. Cylinders are manufactured in different sizes (A to J

Cylinders attached to the anaesthetic machine are usually size E while size J cylinders are commonly used for cylinder manifolds.

Size E oxygen cylinder contains 680 litres, whereas size E nitrous oxide can release 1800 litres

Gas exists in the gaseous state at room temperature. Its liquefaction at room temperature is impossible, since the room temperature is above its critical temperature.

Vapour is the gaseous state of a substance below its critical temperature. At room temperature and atmospheric pressure, the substance is liquid.

Critical temperature : is the temperature above which a substance cannot be liquefied no matter how much pressure is applied.

The critical temperatures for nitrous oxide and oxygen are 36.5 and -118°C respectively.

Cylinders are colour-coded to reduce accidental use of the wrong gas or vapour

Gas Cylinders

Oxygen cylinders contain gas whereas nitrous oxide cylinders contain a mixture of liquid and vapour. In the UK nitrous oxide cylinders are 75% filled with liquid nitrous oxide (filling ratio

At a constant temperature, the pressure in a gas cylinder decreases linearly and proportionally as it empties. This is not true in cylinder containing liquid/vapour

Oxygen is stored as a gas at a pressure of 13 700 kPa whereas nitrous oxide is stored in a liquid phase with its vapour on top at a pressure of 4400 kPa. As the liquid is less compressible than the gas, this means that the cylinder should be only partially filled. The amount of filling is

called the filling ratio. Partially filling the cylinders with liquid minimizes the risk of dangerous increases in pressure with any increase in the ambient temperature that can lead to an explosion. In the UK, the filling ratio for nitrous oxide and carbon dioxide is 0.75. In hotter climates, the filling ratio is reduced to 0.67.

The filling ratio : is the weight of the fluid in the cylinder divided by the weight of water required to fill the cylinder. A full oxygen cylinder at atmospheric pressure can deliver 130 times its capacity of oxygen.

At constant temperature, a gas-containing cylinder shows a linear and proportional reduction in cylinder pressure as it empties.

For a cylinder that contains liquid and vapour, initially the pressure remains constant as more vapour is produced to replace that used. Once all the liquid has been evaporated, the pressure in the cylinder decreases. The temperature in such a cylinder can decrease because of the loss of the latent heat of vaporization leading to the formation of ice on the outside of the cylinder.

The marks engraved on the cylinders are:

1. Test pressure.
2. Dates of test performed.
3. Chemical formula of the cylinder's content.

4. Tare weight (weight of nitrous oxide cylinder when empty)

Cylinders in use are checked and tested by manufacturers at regular intervals, usually 5 years:

1- Internal endoscopic examination.

2- Pressure test: the cylinder is subjected to high pressures of about 22 000 kPa, which is more than 50% above their normal working pressure.

3- Tensile test where strips of the cylinder are cut and stretched. This test is carried out on at least one cylinder in every hundred

Labeling

The cylinder label includes the following details:

1- name, chemical symbol, pharmaceutical form

3- hazard warnings and safety instructions

4- cylinder size code

5- nominal cylinder contents (litres)

6- maximum cylinder pressure (bars)

7- filling date, and expiry date

8- directions for use

9 - storage and handling precautions.



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محاظرة 16

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Central Medical Gas Distribution System

Medical Gas Distribution System is a central supply system to supply a medical gas (O₂, N₂O, N₂), medical air, and medical vacuum to each ward of hospital safely and conveniently through a central supply piping from medical gas supply sources.

Advantages Of Centralized Medical Gas Delivery System :

- 1- No distressing sign of oxygen cylinder at bed side.
- 2- Elimination of noise produced by their movement.
- 3- Protection of sterile areas from contamination caused by use and movement of cylinder
- 4- Uninterrupted and clean gas supply at each work station.
- 5- Effective use of space. Additionally it is economically

Types Of Medical Gases

Oxygen : used for respiratory therapy and life-support and is used in anaesthetic procedures.

Medical air :-This is supplied by a specialized air compressor to patient care areas. Used extensively in the ICU, to reduce the risk of excess oxygen in the lung. During surgical procedures. • Surgical air is used, at a higher pressure, to power a variety of surgical tools and other devices . **Nitrous oxide** : is used for anaesthetic and analgesic purposes. •

Helium/oxygen mixture : is used to treat patients with respiratory or airway obstruction.

Carbon dioxide : in used in the medical world to aid laparoscopic examination. The carbon dioxide inflates the stomach slightly which simplifies internal visibility inside the abdomen

Piped vacuum or Suction is provided by means of centrally sited vacuum pumps & supports evacuation procedures.

Components Of Medical Gas Pipeline System :

1. Medical Oxygen plant.
2. Medical Nitrous oxide plant.
3. Medical compressed air plant
4. Vacuum plant.
5. Medical gas pipeline.
6. Terminal units.
7. Pressure Regulators
- . 8. Shutoff valves
- . 9. Monitoring and alarm system

Piped gas supply

Piped gas supply (piped medical gas and vacuum –) PMGV) is a system where gases are delivered from central supply points to different sites in the hospital at a pressure of about 400 kPa. Special outlet valves supply the various needs throughout the hospital. Oxygen, nitrous oxide, Entonox, compressed air and medical vacuum are commonly supplied through the pipeline system

.

Components

1. Central supply points such as cylinder banks or liquid oxygen storage tank.
2. Pipework made of special high quality copper alloy, which both prevents degradation of the gases ,and has bacteriostatic properties.
- . 3. The size of the pipes differs according to the demand that they carry. Pipes with a 42 mm diameter are usually used for leaving the manifold. Smaller diameter tubes, such as 15 mm, are used after repeated branching.
4. Outlets which are identified by gas colour-coding, gas name and by shape . They accept matching quick connect/ disconnect probes, Schrader sockets, with an indexing collar specific for each gas



5. Flexible colour-coded hoses connect the outlets to the anaesthetic machine

The anaesthetic machine end should be permanently fixed using a nut and liner union where the thread is gas specific and non-interchangeable screw thread, NIST.

Sources of gas supply

The source of supply can be cylinder manifold(s) and, in the case of oxygen, a liquid oxygen storage tank or oxygen concentrator.

Manifolds are used to supply nitrous oxide, Entonox and oxygen

Gas Manifold:

Gas manifolds are designed to supply the pipeline system with sufficient quantity of gas by cylinders and/or tanks. The typical manifold for medical gases usually consists of a two-sided cylinder supply with automatic changeover between the empty and full side, and an additional third source for emergency supply.

Components

1. Large cylinders (e.g. size J each with 6800 litres capacity) are usually divided into two groups, primary and secondary. The two groups alternate in supplying the pipelines. The number of cylinders depends on the expected demand.
2. All cylinders in each group are connected through non-return valves to a common pipe. This in turn is connected to the pipeline through pressure regulators.
- 3- pressure regulators reduce gas/vapor pressure to 400 kPa, (the standard pipeline pressure).
- 4- As nitrous oxide is only available in cylinders (in contrast to liquid oxygen) its manifold is larger than that of oxygen.

MANIFOLD ROOM



Dr A.K.Khandelwal

Mechanism of action:

1. In either group, all the cylinders' valves are opened. This allows them to empty simultaneously.
2. The supply is automatically changed to the secondary group when the primary group is nearly empty. The changeover is achieved through a pressure sensitive device that detects when the cylinders are nearly empty.
3. The changeover activates an electrical signaling system to alert staff to the need to change the cylinders

Problems in practice and safety features

1. The manifold should be housed in a well-ventilated away from the main buildings of the hospital
2. The manifold room should not be used as a general cylinder store
3. All empty cylinders should be removed immediately from the manifold room.



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محاظرة 17

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OXYGEN

Oxygen may be stored either as a cryogenic liquid at low pressures or as compressed gas in cylinders.

Source of supply:

1- Cylinder manifold: banks of large cylinders, usually size J, are used. 2- Liquid oxygen: a thermally insulated vessel at a temperature of -150° to -170°C and at a pressure of 5–10 atmospheres is used.

3- Oxygen concentrator: a zeolite molecular sieve is used.

When large amounts of oxygen are required, it is less expensive and more convenient to store it as a liquid.

Liquid Oxygen :

is a pale Blue, transparent liquid.

Oxygen can be made liquid by lowering the temperature to below -183°C or by placing gaseous oxygen under pressure.

special container is used to store and transport liquid oxygen.

It uses an evacuated, double-walled insulation design to keep the liquid oxygen under pressure at a very low temperature

Uses:-

A small quantity of Liquid oxygen can be converted to an enormous amount of gaseous oxygen, resulting in the use of very little storage space compared to that needed for high-pressure gaseous oxygen

cylinders.



The cold oxygen gas is warmed once outside the vessel in a coil of copper tubing. The increase in temperature causes an increase in pressure

At a temperature of 15°C and atmospheric pressure, liquid oxygen can give 842 times its volume as gas.

Reserve banks of cylinders are kept in case of supply failure

A liquid oxygen storage vessel should be housed away from main buildings due to the fire hazard Spillage of cryogenic liquid can cause cold burns, frostbite and hypothermia

Oxygen concentrator :

Oxygen concentrators extract oxygen from air by differential absorption. These devices may be small, designed to supply oxygen to a single patient , or they can be large enough to supply oxygen for a medical gas pipeline system .

Entonox :





This is a compressed gas mixture containing 50% oxygen and 50% nitrous oxide by volume. It is commonly used in the casualty and labour ward to provide analgesia.

Entonox is compressed into cylinders to a pressure of 13 700 kPa. If the temperature of the Entonox cylinder is decreased to below -5.5°C , liquefaction and separation of the two components occur. This results in:

1. a liquid mixture containing mostly nitrous oxide with about 20% oxygen dissolved in it
2. above the liquid, a gas mixture of high oxygen concentration. This means that when used at a constant flow rate, a gas with a high concentration of oxygen is supplied first. This is followed by a gas of decreasing oxygen concentration as the liquid evaporates. This may lead to the supply of hypoxic mixtures, with less than

20% oxygen, as the cylinder is nearly empty. Rewarming and mixing of both the cylinder and its contents reverses the separation and liquefaction

Problems in practice and safety features

1. Liquefaction and separation of the components can be prevented by:
 - a) cylinders being stored horizontally for about 24 hours at temperatures of or above 5°C before use. The horizontal position increases the area for diffusion. If the contents are well mixed by repeated inversion, cylinders can be used earlier than 24 hours
 - b) large cylinders are equipped with a dip tube with its tip ending in the liquid phase. This results in the liquid being used first, preventing the delivery of an oxygen concentration of less than 20%.
2. Prolonged use of Entonox should be avoided because of the effect of nitrous oxide on the bone marrow especially in the critically

Compressed air:

Medical air is supplied in a hospital for clinical uses or to drive power tools. The former is supplied at a pressure of 400 kPa and the latter at 700 kPa. The anaesthetic machines and most intensive care ventilator blenders accept a 400 kPa supply. The terminal outlets for the two

pressures are different to prevent misconnection. Air may be supplied from cylinder manifolds, or more economically from a compressor. Oil-free medical air is cleaned by filters and separators and then dried before use.

Centralized vacuum system

This system consists of : a pump, receiver and a filter. The pump is capable of creating a negative pressure of -53 kPa (-400 mmHg) and can accommodate an air flow of 40 L/min . It is recommended that there are at least two vacuum outlets per operating theatre, one per anaesthetic room and one per recovery room .

Vacuum Unit : It is used in OT, Surgery ,laboratory It consist of electrically driven vacuum pump to create a pressure much lower than atmospheric pressure in reservoir tank This vacuum creates a suction effect at out lets unit



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محاضرة 18

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Hypoxia and oxygen therapy

Oxygen

Is a colorless, odorless, tasteless gas that is essential for the body to function properly and to survive?

Hypoxia: low level of oxygen at tissue level

Hypoxemia: low levels of oxygen in blood

Partial pressure: the pressure exerted on a surface by the molecules of individual gases. The partial pressure of oxygen can be calculated for a given atmospheric pressure, by multiplying concentration of a gas by the atmospheric or barometric pressure

Eg: $760 \text{ mm Hg} \times 21\% = 160 \text{ mm Hg}$

What is meaning of O₂ therapy

Oxygen therapy is the administration of oxygen at a concentration of pressure greater than that found in the environmental atmosphere .The air that we breathe contain approximately 21% oxygen

Purpose of Oxygen therapy

To increase oxygen saturation in tissues where the saturation levels are too low due to illness or injury.

What are the signs that a person needs oxygen?

- 1- Shortness of breath.
- 2- Headache.
- 3- Confusion restlessness and dizziness
- 4- Rapid breathing.
- 5- Chest pain.
- 6- High blood pressure.

Indications of Oxygen Therapy:

- 1- during anaesthesia for surgery
- 2- Acute respiratory failure
- 3- Acute myocardial infarction and cardiac failure
- 4- Shock
- 5- Hyper metabolic state induced by trauma, burns or sepsis
- 6- Other indication include: anaemia • cyanide poisoning and during CPR.

Delivery Devices for Oxygen Therapy

The oxygen delivery devices are grouped into two:

Low flow oxygen delivery system

High flow oxygen delivery system

Low flow oxygen delivery systems are those that the exact fraction of oxygen in the inspired air (FiO_2) will be based on the patient's anatomic reservoir and minute ventilation. They are:

1- Nasal Cannula

2- Simple Mask

3- Partial Rebreather

4- Nonrebreather

High flow oxygen delivery systems deliver a prescribed gas mixture (either high or low) at flow rates that exceed patient demand.

1- Venturi Mask

2- Aerosol masks, tracheostomy collars, , and face tents can be used with high-flow supplemental oxygen systems but not all aerosol generators can deliver high oxygen concentration at the needed flows rate

Nasal cannula (prongs):

It is a disposable, plastic device with two protruding prongs for insertion into the nostrils, connected to an oxygen source.

Used for low-medium concentrations of Oxygen (24-44%).



Amount Delivered Fio₂ (Fraction Inspired Oxygen) Low flow- 24-44

Advantages:

- 1- patient able to talk and eat with oxygen in place
- 2- Easily used in home setting
- 3- Safe and simple
- 4- Easily tolerated
- 5- Delivers low concentrations

Disadvantages:

- 1- Unable to use with nasal obstruction
- 2- Drying to mucous membranes, so flow greater than 4 L/min needs to be humidified
- 3- Can dislodge from nares easily
- 4- Causes skin irritation or breakdown over ears or at nares
- 5- Not good for mouth breathers

Face Mask:

The Simple Oxygen Mask

The Partial Re-Breather Mask

The Non Re- Breather Mask

The Venturi Mask

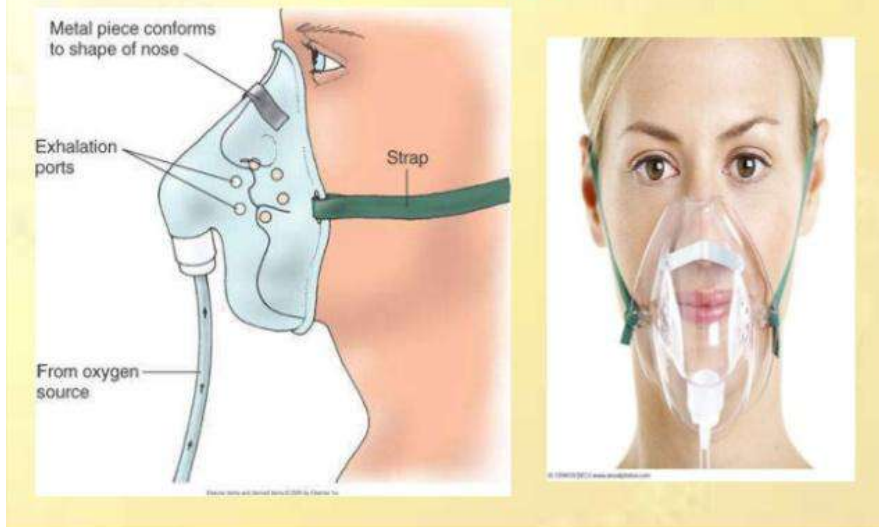
The simple Oxygen mask

Simple mask is made of clear, flexible, plastic or rubber that can be molded to fit the face.

It is held to the head with elastic bands.

Some have a metal clip that can be bent over the bridge of the nose for a comfortable fit.

The simple Oxygen mask



The simple Oxygen mask delivers 35% to 60% oxygen. A flow rate of 6 to 10 liters per minute. It has vents on its sides which allow room air to leak in at many places, thereby diluting the source oxygen. Often it is used when an increased delivery of oxygen is needed for short periods (i.e., less than 12 hours).

Advantages:

Can provide increased delivery of oxygen for short period of time

Disadvantages:

Difficult to keep mask in position over nose and mouth

Potential for skin breakdown (pressure, moisture)

Uncomfortable for patient while eating or talking



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محاضرة 19

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The Partial Re Breather Mask:

The mask is with a reservoir bag that must remain inflated during both inspiration & expiration

It collects part of the patients' exhaled air.

It is used to deliver oxygen concentrations up to 80%.

The oxygen flow rate must be maintained at a minimum of 6 L/min to ensure that the patient does not re-breathe large amounts of exhaled air.

The remaining exhaled air exits through vents.

Advantages:

Patient can inhale room air through openings in mask if oxygen supply is briefly interrupted

Disadvantages:

Requires tight seal (eating and talking difficult, uncomfortable)

The non rebreather mask:

This mask provides the highest concentration of \rightarrow oxygen (95-100%) at a flow rate 6-15L/min. \rightarrow It is similar to the partial rebreather mask except two:

1-one-way valves prevent conservation of exhaled air.

2-The bag is an oxygen reservoir

Advantages:

Delivers the highest possible oxygen concentration

Suitable for patient breathing spontaneously with sever hypoxemia

Non rebreathing mask with reservoir mask:



Disadvantages:

Impractical for long term Therapy

Malfunction can cause CO₂ buildup

Suffocation

Expensive and uncomfortable

Venturi Mask

It is high flow oxygen delivery device. Oxygen from 40 - 50% at liters flow of 4 to 15 L/min. The mask is constructed so that there is a constant flow of room air blended with a fixed concentration of oxygen

Oxygen toxicity:

is lung damage that happens from breathing in too much extra (supplemental) oxygen. It's also called oxygen poisoning. It can cause coughing and trouble breathing. In severe cases it can even cause death.

Risks of Oxygen Therapy (O₂ toxicity)

Determining factors of O₂ toxicity

1- PO₂

2- Time of exposure

i.e., higher the PO₂ & exposure time the greater the toxicity.

CNS effects occur with Hyperbaric Pressures

High PO₂ damages capillary endothelium 'Followed by interstitial edema & alveolar-capillary membrane thickening

Depression of ventilation:

It is seen in COPD patients with chronic carbon dioxide (CO₂) retention who have hypoxic respiratory drive to

Hyperbaric oxygen toxicity:

Long term hyperbaric O₂ therapy can lead to pulmonary, optic and central nervous system toxicity

Absorption atelectasis:

Given only pure oxygen results in the collapse of the dependent part of the lungs as it quickly taken up from the alveoli. It is also a risk in general anaesthesia induction

Retinopathy of prematurity (ROP):

It usually occurs in low birth weight, very premature infant.

Pulmonary toxicity:

Patients exposed to high oxygen levels for a prolonged period of time have lung damage. The extent of lung damage is dependent on FiO₂ and duration of exposure.

Symptoms of oxygen toxicity

1-Coughing.

2-Mild throat irritation.

3-Chest pain.

- 4-Trouble breathing.
- 5-Muscle twitching in face and hands.
- 6-Blurred vision.
- 7-Nausea.

A drop in oxygen saturation to less than 86% to 90% during activity indicates that the patient needs supplemental oxygen

How does hypoxia relate to oxygenation?

Without oxygen, your brain, liver, and other organs can be damaged just minutes after symptoms start. Hypoxemia (low oxygen in your blood) can cause hypoxia (low oxygen in your tissues) when your blood doesn't carry enough oxygen to your tissues to meet your body's needs

How does hypoxia kill?

If severe or prolonged it could lead to cell death. In most tissues of the body, the response to hypoxia is vasodilation. By widening the blood vessels, the tissue allows greater perfusion. By contrast, in the lungs, the response to hypoxia is vasoconstriction

What are the effects of oxygen toxicity?

Central nervous system oxygen toxicity can cause seizures; brief periods of rigidity followed by convulsions and unconsciousness.

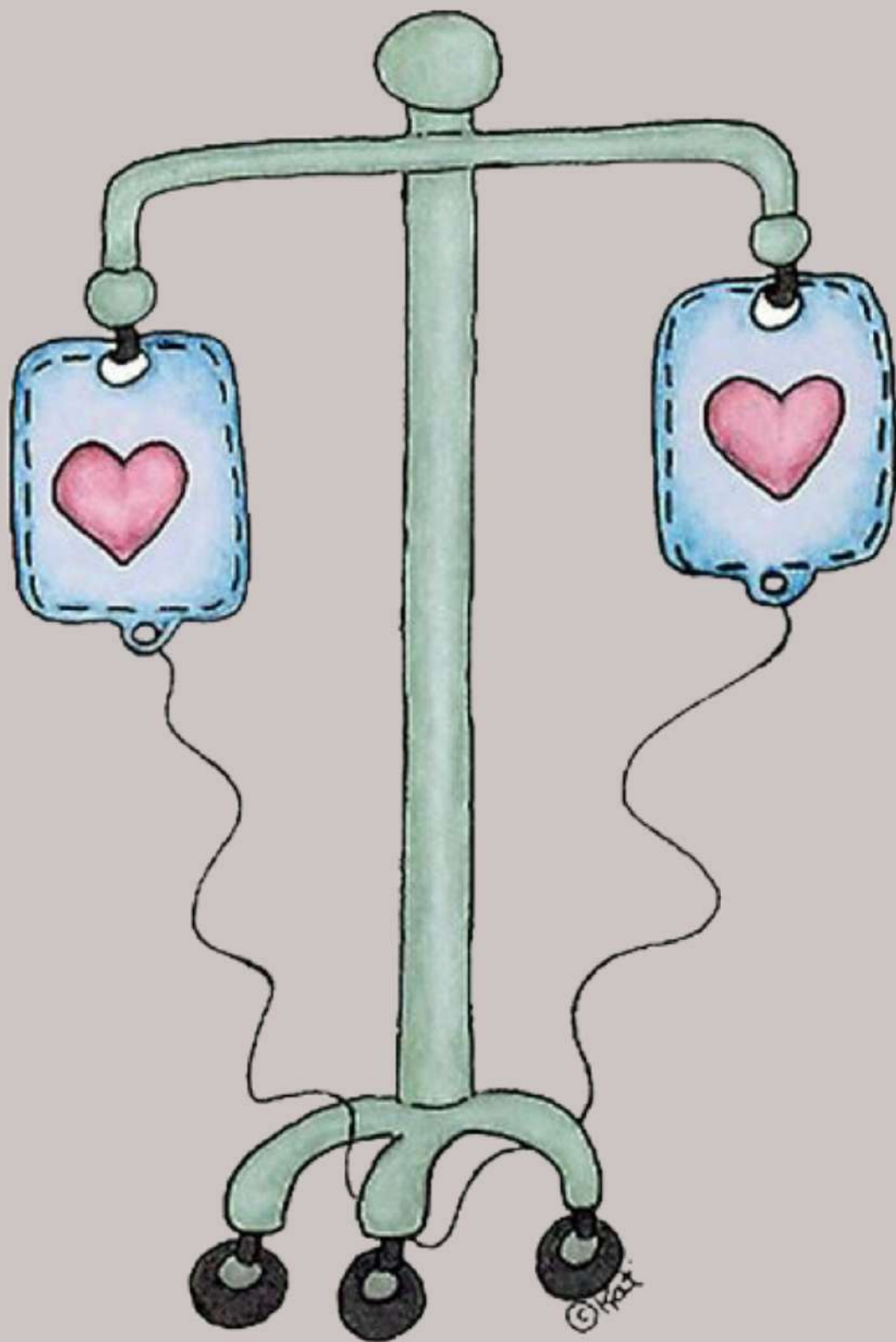
Pulmonary oxygen toxicity results in damage to the lungs, causing pain and difficulty in breathing.

At what level does oxygen become toxic?

Oxygen is toxic to the lungs when high FIO_2 (>0.60) is administered over extended exposure time (≥ 24 hours) at normal barometric pressure (1 atmospheres absolute (ATA)). This type of exposure is referred to as low pressure O_2 poisoning, pulmonary toxicity, or the Lorraine Smith effect.

What are examples of oxygen toxicity?

Oxygen toxicity occurs in three major forms: neurologic, pulmonary, and ocular. Central nervous system oxygen toxicity is the most common manifestation of oxygen toxicity and manifests itself as a generalized tonic-clonic seizure (“grand mal” type).



أجهزة نظري

محافظة 1

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Al – Noor University College

Department of anesthesiology

المرحلة / الثانية

محاضرة اجهزة (1)

د. نزار عبد الكريم الحياي

Operating room (theater)

An operating theater is a **facility within a hospital where surgical operations are carried out in an aseptic environment.**

Operating room design consideration :

The principle of designing the operating room are :

- 1- Ideally located near to surgical wards or intensive care
- 2- The design should allow for one way traffic and prevent return flow of contaminants into clean area
- 3- The prime requirements in the design are the control of infections
- 4- control the risk of fire, explosion, and chemical and electrical hazards

Structure of operation theatre :

- 1-The wall should be hard and easily washable material
- 2- Pipes and central oxygen , nitrous oxide, suction should be fitted to the walls.
- 3- Adequate air conditioning should be provided
- 4-In the absence of window adequate light should provide.
- 5- Fire extinguisher should be adequate

Several operating rooms are part of the operating suite Besides the operating rooms and their wash rooms, it contains rooms for personnel to change, wash, and rest, preparation and recovery rooms(s), storage and cleaning facilities, offices, dedicated corridors, and possibly other supportive units. In larger facilities, the operating suite is climate- and air-controlled, and separated from other departments so that only authorized personnel have access.

Traffic Flow

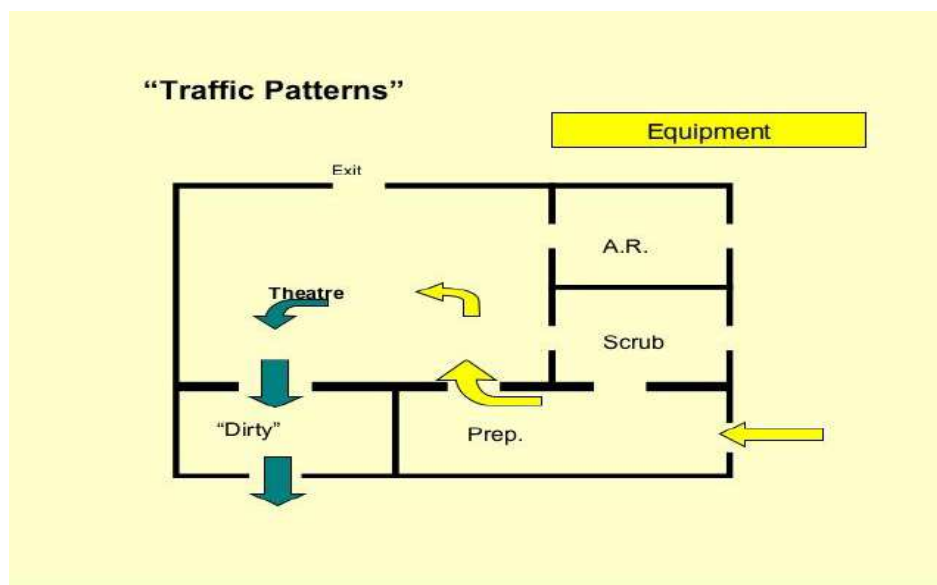
Traffic Patterns in the Surgical Suite, a **three-zone** designation of areas within the surgical suite facilitates appropriate movement of patients and personnel.

Traffic Flow include:

1. **Unrestricted areas** are those in which personnel may wear street clothes, and traffic is not limited.
2. **In semi-restricted areas**, such as processing and storage areas for instruments and supplies, as well as corridors leading to the restricted areas of the surgical suite, personnel must wear surgical attire and patients must wear gowns and hair coverings.
3. **Restricted areas** include operating rooms and clean core and scrub sink areas. Surgical attire and masks are required in these areas when there are open sterile supplies or scrubbed persons in the area.

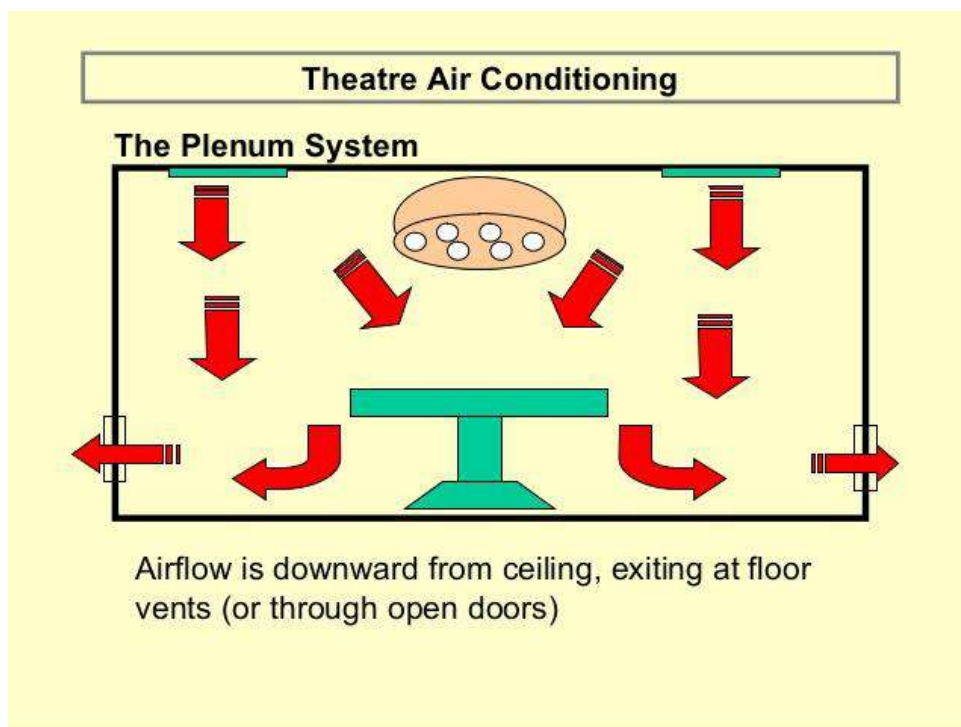
Soiled materials should not re-enter the clean core area.

All journeys within the department are made from clean to dirty areas, never the other way round



Ventilation :

- 1- Appropriate ventilation systems aid in the control of infection by minimizing microbial contamination.
- 2- Temperatures in an operating room should be maintained between (20° to 23° C), with relative humidity of 30% to 60% to reduce bacterial growth and suppress static electricity.
- 3- Temperatures in that range allow for comfort of the surgical team and are tolerated by most patients.
- 4- Each operating room should have individual temperature controls to accommodate patient safety, as when increased warmth is required for patients at high risk for inadvertent hypothermia during operative procedures.



Emergency Signals

Every surgical suite should have an emergency signal system that can be activated inside each operating room.

A light should appear outside the door of the room involved, and bell should sound in a central nursing or anaesthesia area.

Operating Department comprises

- 1- Rest rooms
- 2- Changing rooms : a room is provided for theatre personnel to change into OT clothes from their sweat clothes, foot wear, sterile caps and mask also kept in this room
- 3-Teaching rooms
- 4- Storage
- 5- Reception areas
- 6- Operating suite

Operating Suite

Is one functioning unit of a department, it includes :

- 1- An anesthetic room
- 2- Clean preparation room
- 3- Scrub-up area
- 4- Operating theatre
- 5- Sluice room

Anaesthesia room : it should contain

- 1- The anesthetic machine and mechanical ventilators
- 2- Suction apparatus
- 3- The drug cupboard
- 4- Intravenous solution and connecting tubes

Anaesthetic Room



- Reception & preparation of patient
- Induction of anaesthesia

Store room:

Cylinder of O₂ and nitrous oxide, additional equipment, infusion fluid bag , syringes, needles, drugs, and operation instrument are kept in this room

Changing room :

a room is provided for theatre personnel to change into OT clothes from their sweat clothes, foot wear, sterile caps and mask also kept in this room.

Scrub room:

the surgeon and the nurses scrub in this room and this room open into the OT.

Sterilizer room :

a sterilizer room should be built adjacent to the OT with a window. The equipment can be passed between the rooms without repeatedly opening



The Operating Theatre

The operating table : center piece of the room, It has to be in order to accommodate the great variety of different operating positions.

The Operating Lights :

- 1- There are usually two operating lights in a theatre attached to the ceiling.
- 2- The lights are easily maneuvered, necessary to accommodate the needs of surgery.

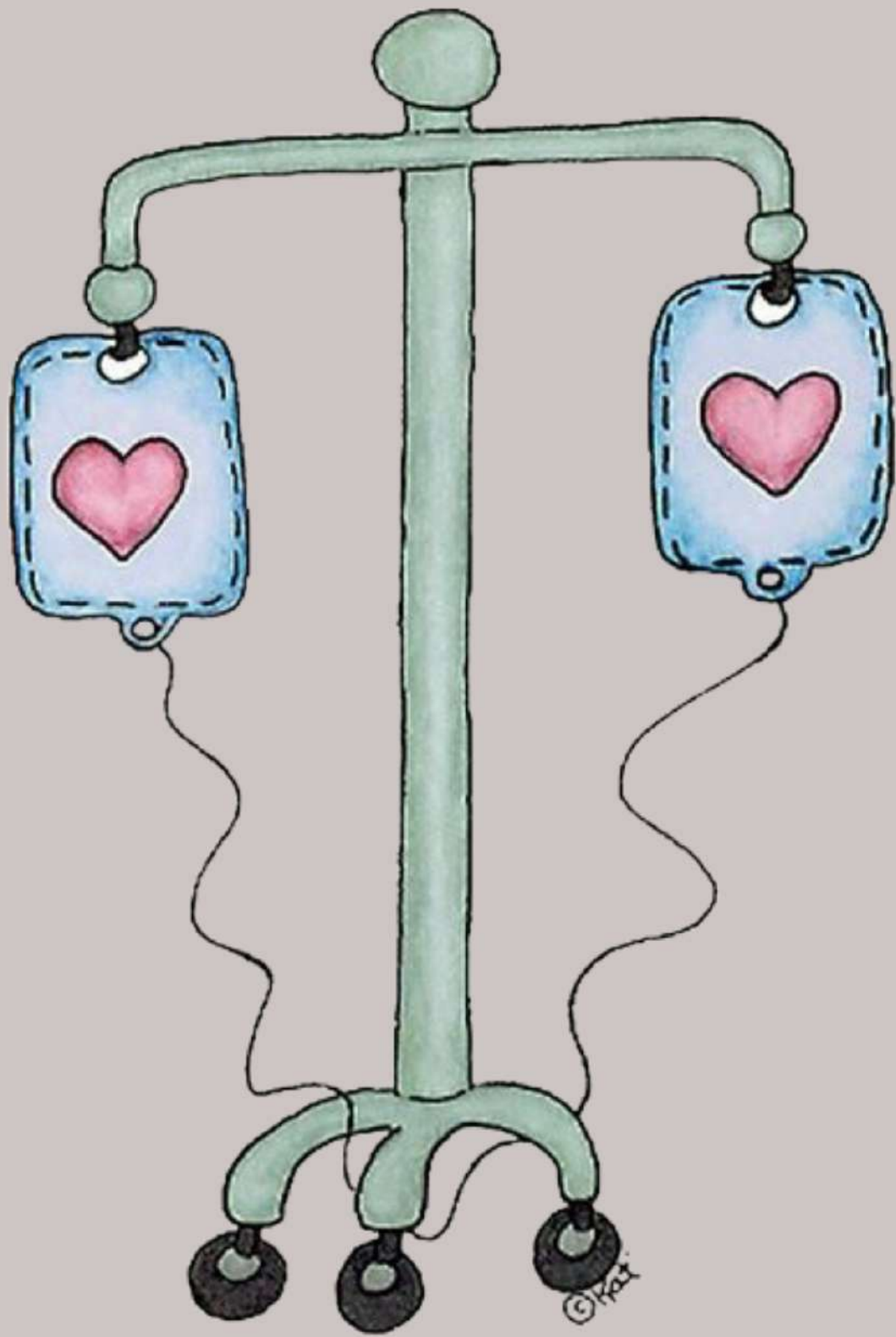
3- Good lighting is needed to carry out an operation, and lighting a wound from two converging angles is designed to eliminate shadows.

Recovery room

the main purpose of recovery room is to given nursing care to the post-operative patient .

Carried out in the corridor outside the operating theatre.

Normally made up of several bed spaces, each with necessary equipment to facilitate recovery e.g. oxygen, suction apparatus, pulse oximetry, emergency trolley necessary to deal with cardiac arrests or anesthetic emergencies etc.



أجهزة نظري

محاظرة 2

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محاضرة اجهزة (2)

د. نزار الحياي

Clean and Dirty

Patients

Will enter the department from the hospital corridor via a transfer bay.
leaving the ward bed outside.

Next they enter directly to the anesthetic room.

Finally they enter the theatre itself where surgery is to be performed

The journey has been one through progressively **cleaner** areas, arriving finally at the **cleanest** of all.

Once the wound has been closed and covered with dressing, it is safe for the patient to return to the ward via progressively more dirty areas: through the exit bay, recovery and the hospital corridor.

Instrument and Equipment

Are brought from outside the department into clean store rooms. Instruments are often supplied in pre-packed sterilized trays. Finally, they enter the theatre ready for use on the scrub nurse's trolley.

At the end of an operation, dirty instruments, linen and rubbish are removed to the sluice room,.

Theatre Personnel

Enter the department via a changing room where outdoor clothing is left. Then they enter via the clean preparation room or the scrub-area

Anesthetic Scavenging

A long corrugated plastic tube connected to the anesthetic circuit at one end, while the other connects to a vent in the ceiling or wall.

The system draws out of the theatre any anesthetic gases or agents leaking from the circuit and which pollute the atmosphere.

The Swab Rack : This is a metal piece of furniture used for hanging up swabs during an operation for ease counting.

The Swab Board

- 1- This is for recording the amount of blood loss during the operation especially major operation.
- 2- The nurses record this information for anesthetist's benefit, who will start replacement therapy.
- 3- The board is usually marked in two columns; one for blood loss from the swabs and one for loss from the suction.

Weighing Scale: (estimating blood loss)

You should find a list of known dry weights of each different type of swab.

To estimate blood loss, you weigh the blood-soaked swab, and from that weight subtract the known dry weight.

This give you the weight of blood lost,

e.g.; Dry Large swab = 20g, Soaked in blood = 90g

: $90\text{g} - 20\text{g} = 70\text{g}$ is the weight of the blood loss (1g = 1ml)

X-ray Screens

This is vital as some operations are conducted with close reference to a patient's x-rays throughout. e.g. orthopedic surgery, tumor surgery and operations such as removal of foreign boby.

Theatre cleaning.:

1. Daily routine cleaning:- The operating theatre should be cleaned at least 1 hr. before operation are started. the floor is cleaned whenever it gets dirty. it also cleaned at the end of the day's work.

2. Cleaning between cases:- Area which is contaminated or dirty have to clean between cases.

3. Weekly cleaning:- the floor is washed after removing all equipment and furniture from the theatre.

4- Cleaning after an infected cases:- Routine cleaning is carried out. Fumigation should be done either with the formalin vapor or hypo chloride spray.in case the patient have an infection that can be transmitted through blood, all linen and instrument are soaked in 1% hypo chloride solution before washing.

Preparation of equipment's for sterilization

Cleaning and care of instrument must be thoroughly washed either by hand or by using a sonic washer.

Operating room equipment:

1-The operating table in the center of the room can be raised, lowered, and tilted in any direction.

2- The operating room lights are over the table to provide bright light, without shadows, during surgery.

3- The anesthesia machine is at the head of the operating table. This machine has tubes that connect to the patient to assist them in breathing during surgery, and built-in monitors that help control the mixture of gases in the breathing circuit.

4- The anesthesia cart is next to the anesthesia machine. It contains the medications, equipment, and other supplies that the anesthesiologist may need.

5- Sterile instruments to be used during surgery are arranged on a stainless steel table.

6- An electronic monitor (which records the heart rate and respiratory rate by adhesive patches that are placed on the patient's chest).

7- The pulse oximetry machine attaches to the patient's finger with an elastic band aid

8- Automated blood pressure measuring machine that automatically inflates the blood pressure cuff on patient's arm.

9- An electro cautery machine used to cauterize or seal off blood vessels and may also be used to cut through tissue with a minimal amount of bleeding.

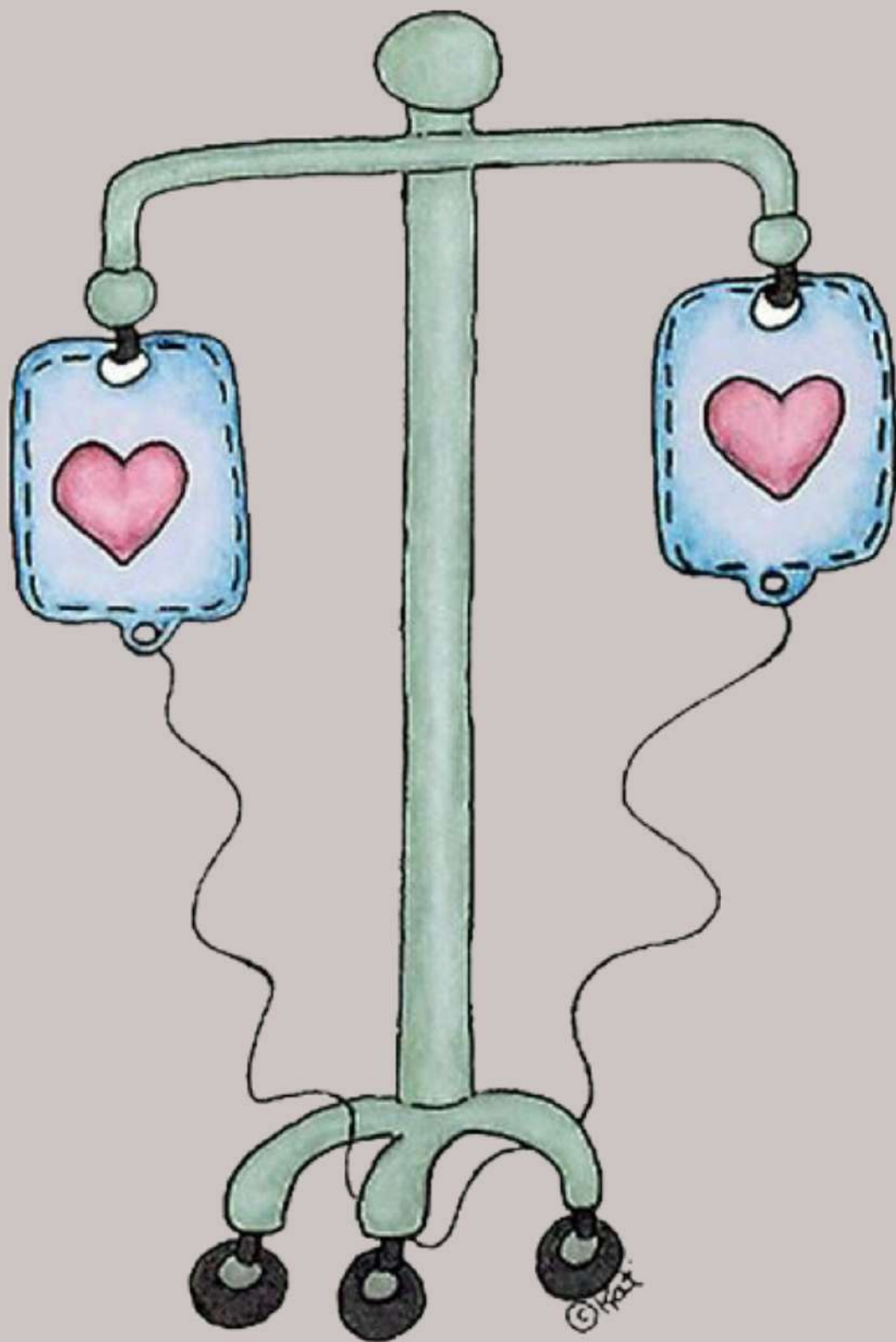
10- If surgery requires, a heart-lung machine or other specialized equipment may be brought into the room.

11- Advances in technology now support hybrid operating rooms, with a diagnostic imaging systems such as MRI and cardiac catheterization

Surgeon and assistants' equipment:

People in the operating room wear PPE (personal protective equipment) to help prevent bacteria from infecting the surgical incision. This PPE includes the following:

- 1- A protective cap covering their hair
- 2- Masks over their lower face, covering their mouths and noses
- 3- Shades or glasses over their eyes, including specialized colored glasses for use with different lasers.
- 4- Sterile gloves; usually latex-free due to latex sensitivity which affects some health care workers and patients.
- 5- Protective covers on their shoes
- 6- If x-rays are expected to be used, lead aprons/neck covers are used to prevent overexposure to radiation
- 7- The surgeon may also wear special glasses that help him/her to see more clearly. The circulating nurse and anesthesiologist will not wear a gown in the OR because they are not a part of the sterile team. They must keep a distance of 12-16 inches from any sterile object, person, or field



أجهزة نظري

محاظرة 3

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محاضرة اجهزة (3)

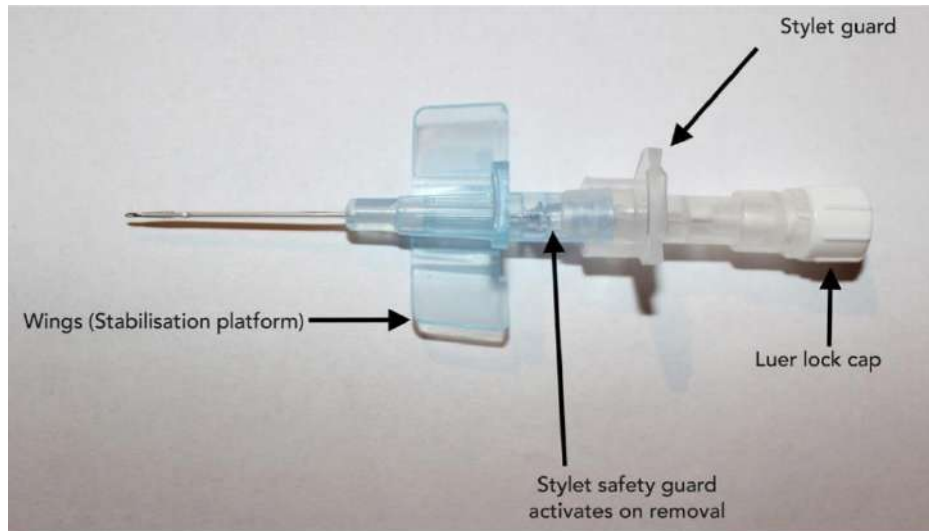
د. نزار الحياي

Peripheral intravenous cannula (PIC)

Cannula:

flexible plastic tubing which has been inserted into the vein using a needle; the tubing has been taped to the patient's arm to prevent it coming out when the patient moves, and a sterile dressing has been placed over the punctured place in the skin where the cannula has been

inserted to prevent bacteria that commonly exist on the skin's surface from getting into the bloodstream.



© Sally Shaw

. Indications:

- 1- Administration of anaesthesia.
- 2- Administration of fluids.
- 3- Administration of medications.
- 4- Administration of blood or blood products.
- 5- Allow sampling of the blood
- 6- Radiological imaging using IV contrast

Contraindication:

- 1- Sites close to infection
- 2- Veins of fractured limbs

3- Where there is an A-V fistula present

4- Oedema

5- Affected side of CVA and side of Mastectomy

Site Vein Selection:

1- Back of hand

2 – Forearm

3 - Antecubital fossa

Which vein is chosen?

Patent - Palpable - Distal - Straight - Avoid bifurcations

Areas to Be Avoided:

1- Areas of joint flexion

2- Hardened/sclerosed veins

3- Major veins near arteries

4- Veins in lower extremities

5- Areas of surgery

6- Previously cannulated veins

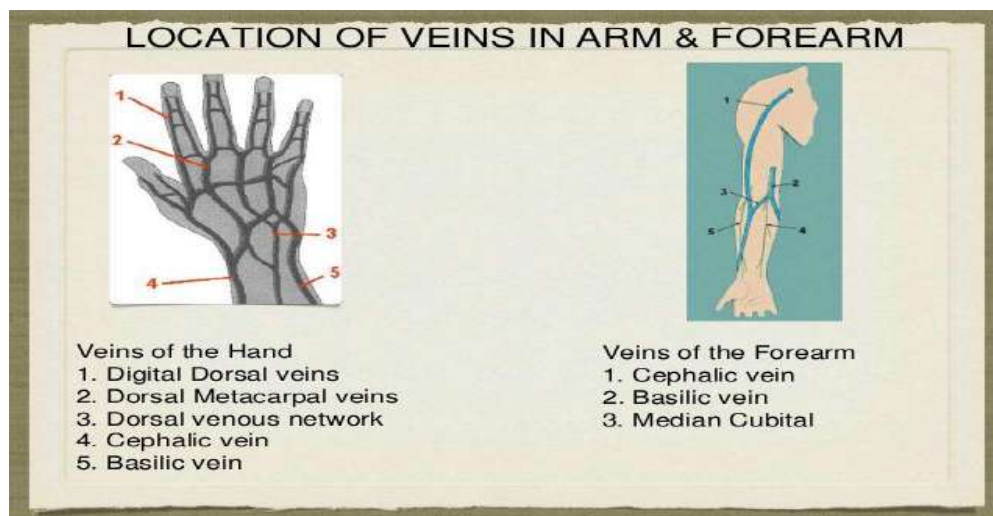
Location of Veins in Arm & Forearm

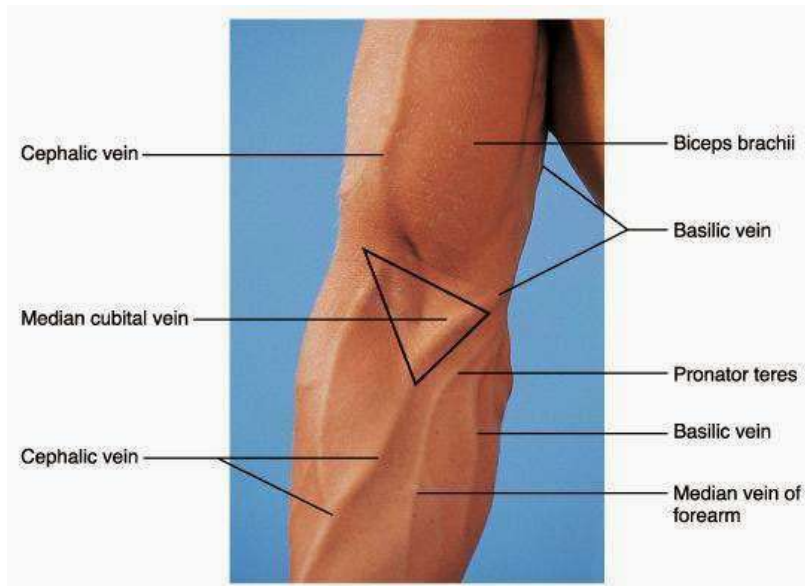
Veins of the Hand:

1. Digital Dorsal veins
2. Dorsal Metacarpal veins
3. Dorsal venous network
4. Cephalic vein
5. Basilic vein

Veins of the Forearm:

1. Cephalic vein
2. Basilic vein
3. Median Cubital





Types of cannula:

Size Color Coding, Flow Rate, Uses

- 1) 14G Orange: it is used in Trauma Patients. Rapid, Large-volume replacement
- 2) 16G Grey: Trauma Patients, used in Major Surgery, , GI bleeds, Multiple blood transfers, High volume of fluids
- 3) 17 G White
- 4) 18G Green: Blood products, delivery of irritant medications, major surgery,
- 5) 20G Pink: General use, IV maintenance, IV antibiotics, IV analgesia
- 6) 22G Blue: Small or Fragile veins, cytotoxic therapy

7) 24G: Yellow 20ml/min for pediatric usage

8) 26G Violet 13ml/min newly added



Butterfly Cannula:

A Butterfly cannula is a device specialized for venipuncture. It is used to access a superficial vein for IV injections. Used in children



Procedure of IV. Cannulation:

- 1- Explain procedure to the patient.
- 2- Wear personal protection equipment's, i.e. gloves
- 3-Select the location according to the procedure
- 4-Apply tourniquet
- 5- Make the selected vein prominent & clean the area with betadine solution. Clean the area with alcohol swab
- 6-Stretch the skin and fix the vein distally and tell the patient to expect a sharp scratch.
- 7- Insert the needle, bevel upwards at about 30 degrees. Advance the needle until you observe blood at the back of the cannula.
- 8- Once bloods appear, progress the entire cannula a further 2mm, and then fix the needle.
- 9- Release the tourniquet, apply pressure to the vein at the tip of the cannula and remove the needle fully. Remove the cap from the needle and put this on the end of the cannula.
- 10- Apply the dressing to the cannula to fix it in place.
- 11- Fill the syringe with saline and flush it through the cannula to check for patency.

Complications of IV cannula:

1- Hematoma

2- Hemorrhage

3- Infection

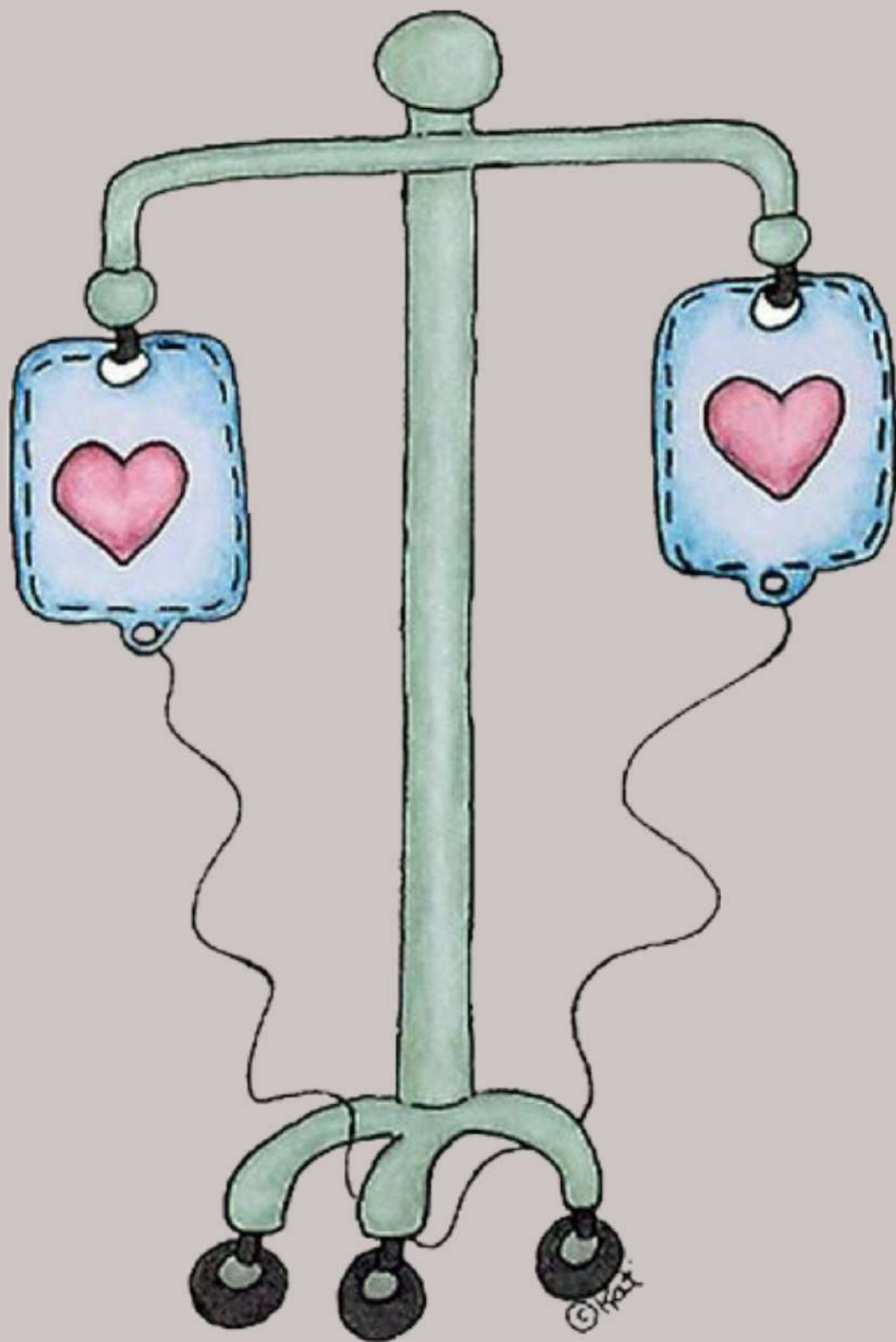
4- Extravasation

5- Infiltration

6- Thrombophlebitis

7- Puncturing an artery

8- Puncturing a nerve



أجهزة نظري

محاظرة 4

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محاضرة اجهزة (4)

د. نزار الحياي

IV Setup

It is used when we want to give a large amount of fluid, or when we need to dilute a medication in a lot of fluid to make less irritant. Also, because IV administration generally involves larger quantities of fluid, the medication given by IV is usually infused over a longer period of time.

Structure of IV Setup :

It consist of bag and tubing

The standard sizes of the bags can range from 50 mL to 1000 mL. and IV tubing is attached to the bottom of the bag.

The IV tubing contains several important parts:

a)The **drip chamber** is located just below the IV bag; inside this chamber we can see the fluid drip down from the bag into the IV tubing. **This is where we measure the speed of a manual IV setup; we look at this chamber and count the number of drops we see per minute.** So, for example, if we count 25 drops over the period of 60 seconds, we would say that the IV is infusing at a rate of 25 drops per minute, or 25 gtt/min. (In reality, we may not count the number of drops in a full minute; we can, for example, count the number of drops we see over a period of 15 seconds, and then multiply that number by 4 to get the number of drops in a full minute.)

The drip chamber must always be half full. If the drip chamber is too full, we will not be able to see the drops to count them and If the drip chamber is not full enough, then this will allow air to get into the IV tubing, which means that air would get into the patient's circulatory system, which could be very dangerous, blocking a blood vessel or stopping the heart.

b)The **roller clamp** used to control the rate at which the IV fluid infuses. If we roll it one way, it squeezes the IV tubing more tightly, making it more narrow and therefore making the fluid flow through the tubing more slowly; if we roll it the other way, it loosens its pinching of the IV tubing, making the tubing less narrow, and allowing the IV fluid to flow through at a faster rate. All roller clamps on a set of IV tubing should be closed before we attach a bag of IV fluid to the top of the tubing; this ensures that no air gets into the tubing.

Every IV medication will be ordered to infuse at a specific rate, and one of the major tasks of hospital nurses is to set up the IV so that it infuses at this rate and to adjust the IV periodically if the rate has changed so that it remains at the ordered rate. The rate at which an IV fluid infuses is referred to as the IV **infusion rate** or **flow rate**.

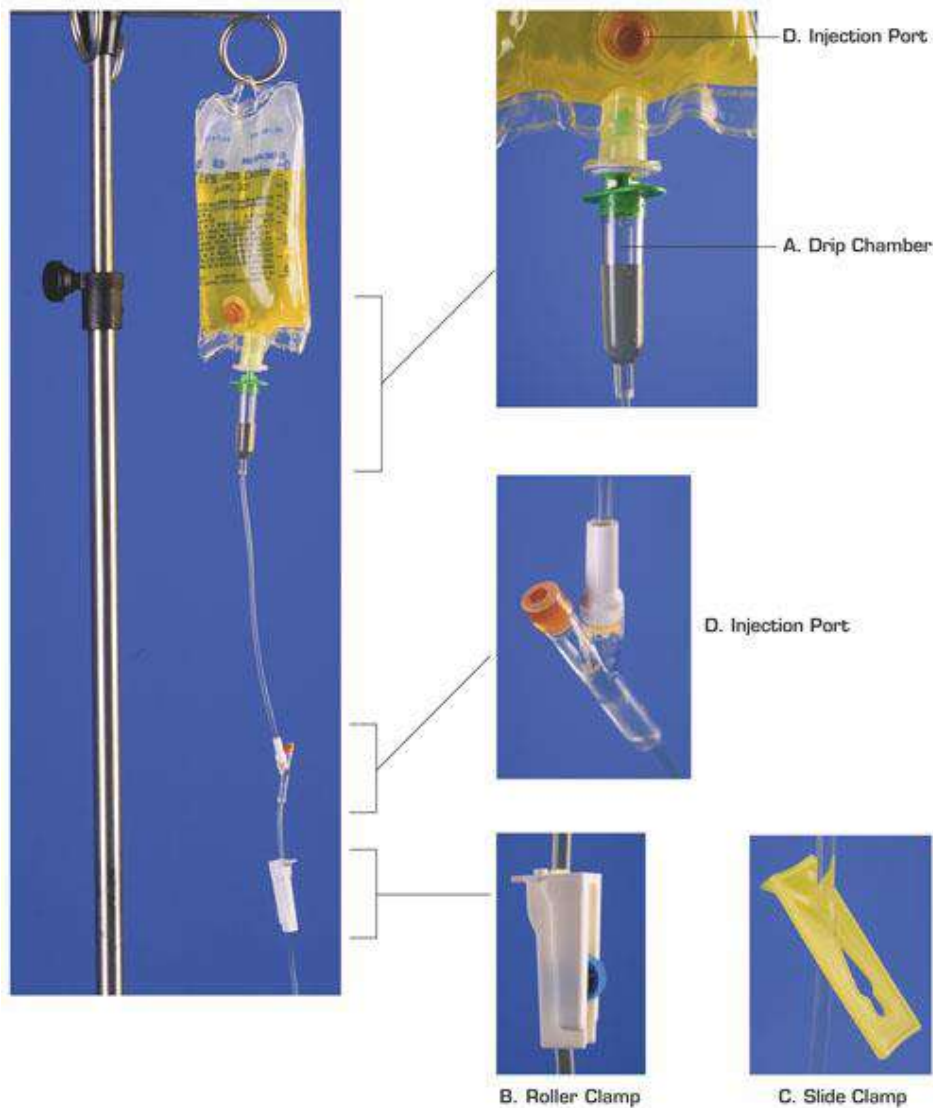
c)The **slide clamp** is used **when we want to completely stop the IV from flowing**, without having to adjust the roller clamp. This is handy if we want to stop the IV for a moment, but we don't want to have to reset the flow rate by readjusting the roller clamp all over again once we start the IV up again. This works by pinching the tubing completely shut when we slide the tubing into the narrowest part of the clamp.

d)The **injection port** is a place **where medicine or fluids other than those in the current IV bag can be injected so that they will infuse into the patient's vein through the IV tubing**. On the photo below we

can see two ports: one on the IV bag itself and one below the drip chamber. There is also usually an injection port close to where the needle goes into the patient's vein;

The injection port on the actual IV bag is used if we want to mix some kind of medication with the fluid that is in the IV bag; if we inject the medication into this port and then roll the bag a little to mix the medication into the fluid in the bag, then the patient will receive both the medication and the IV fluid at the same time

:



How the Height of the IV Bag Affects the Infusion Rate

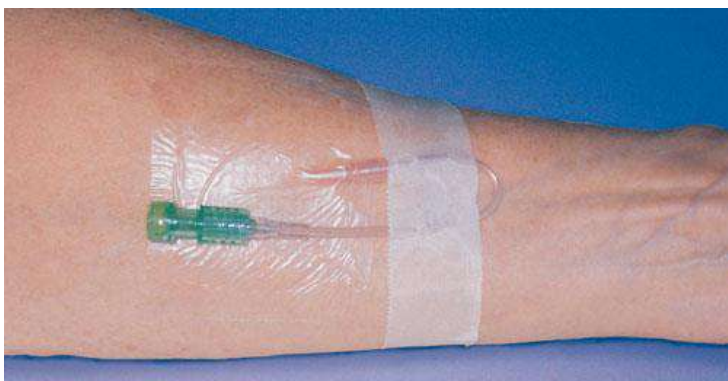
IV infusion works because gravity pushes the fluid down through the IV tubing into the patient's vein. **The higher the bag is hung, the greater the gravitational pressure on the IV fluid to go downward through the tubing. So, all IV bags must be hung above the patient's heart**

and it is standard procedure to **hang the IV bag at least 3 feet above an adult patient's heart**

Continuous IV infusion : when an IV medication or fluid is given continuously, or all the time.

Intermittent IV Infusion : when we want to administer an IV fluid and/or medication to a patient only at specific times; this is called an intermittent IV infusion.

A patient who is to receive a continuous IV infusion , the IV setup connected to them all the time, but for a patient who should receive only intermittent IVs, we can't leave them permanently attached to an IV setup. What we do instead is insert a cannula like the one in the picture below to the patient, which allows us to connect an IV only when the patient is actually receiving an infusion and to disconnect it in between doses:



This is a length of IV tubing with an injection port attached to one end; this special injection port is called an **infusion port adapter**,

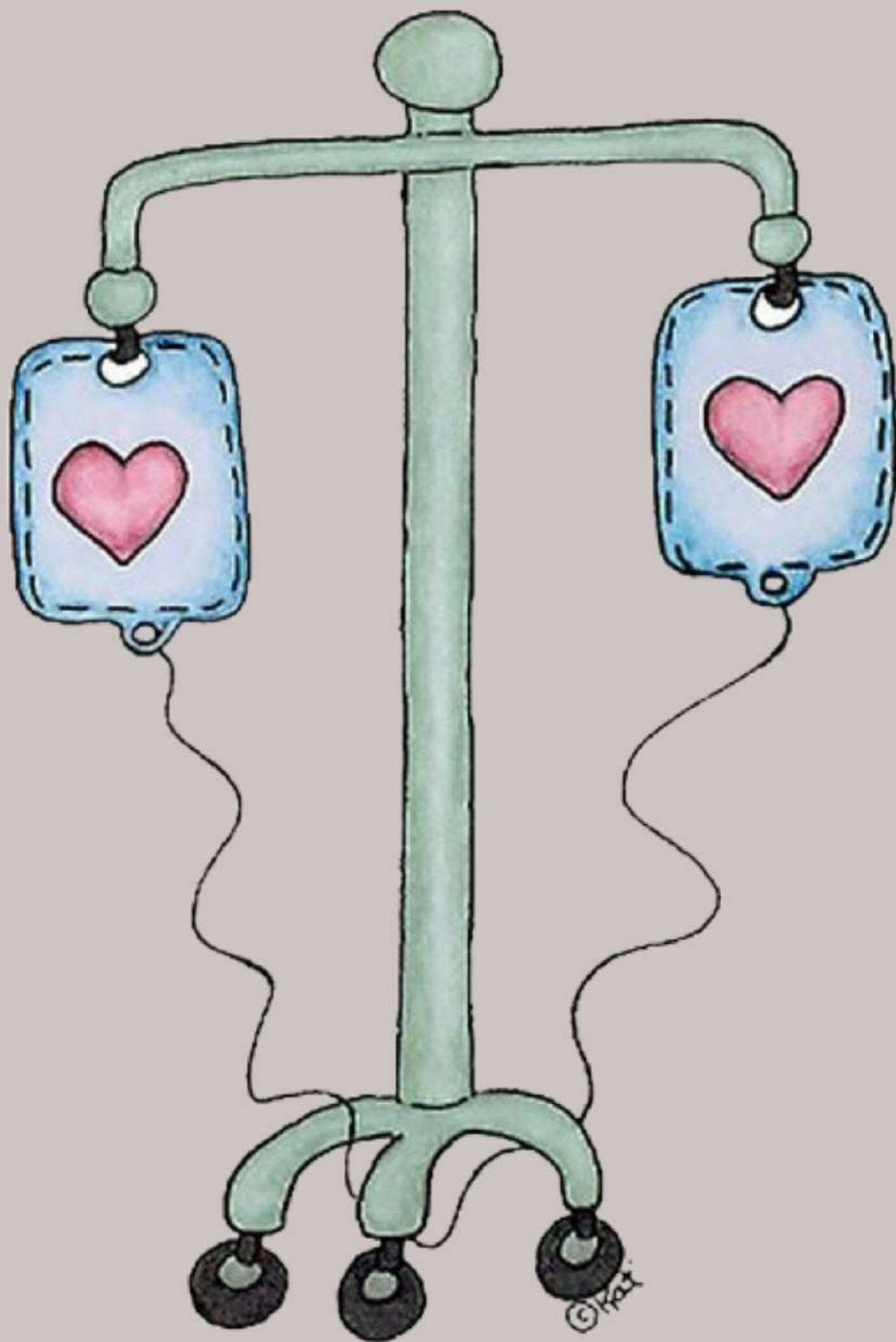
Secondary IV or IV Piggyback

If a patient is receiving continuous IV fluids and in addition must receive a second kind of intermittent infusion, or if a patient's current IV infusion must be interrupted in order to administer a second IV medication or fluid that is more pressing, then we will need to hang a **secondary IV** for the patient. A **secondary IV**, also known as **IV Piggyback**, and abbreviated **IVPB**, is a second IV medication or fluid that is hung alongside the first and which is attached to the first set of IV tubing through one of the injection ports that is below the drip chamber of the primary IV (if we were to connect it through the injection port inside the primary IV bag, the contents of the primary and secondary IVs would mix and infuse at the same time, which is not what we want).

The picture below shows a secondary IV set up to the left and the primary IV hung to the right:



Notice that in this picture, the secondary IV bag is above the primary IV bag; this means that the pressure on the secondary IV bag will be greater than the pressure on the primary IV bag, and so this pressure will push it down into the tubing and prevent any of the fluid from the primary IV from entering the tubing until the secondary IV has emptied. Then, once the secondary IV has finished infusing, the primary IV will be able to go down into the tubing again, and the infusion of the primary IV will resume.



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محاظرة 5

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محاضرة اجهزة (5)

د. نزار الحياي

Physical property

All matter is made from atoms. Every substance (oxygen, lead, silver) has a unique number of protons, neutrons, and electrons. Oxygen, for example, has 8 protons, 8 neutrons, and 8 electrons. Hydrogen has 1 proton and 1 electron. Individual atoms can combine with other atoms to

form molecules. Water molecules contain two atoms of hydrogen **H** and one atom of oxygen **O** and is chemically called **H₂O**.

Phases of matter :

matter normally exists as either a **solid, a liquid, or a gas**. We call this property of matter the **phase** of the matter..

1- Solid

In the **solid phase** the molecules are closely bound to one another by molecular forces. A solid holds its shape and the volume of a solid is fixed by the shape of the solid.

2-Liquid :

In the **liquid phase** the molecular forces are weaker than in a solid. A liquid will take the shape of its container and the liquid has a fixed volume.

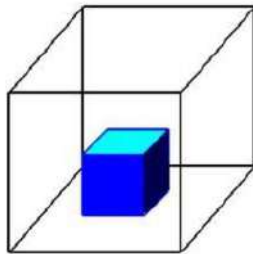
3- Gas

In the **gas phase** the molecular forces are very weak. A gas fills its container, taking both the shape and the volume of the container.



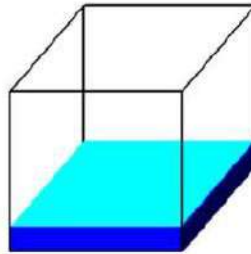
Phases of Matter

Glenn
Research
Center



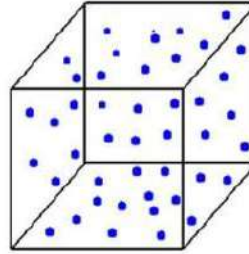
Solid

Holds Shape
Fixed Volume



Liquid

Shape of Container
Free Surface
Fixed Volume



Gas

Shape of Container
Volume of Container

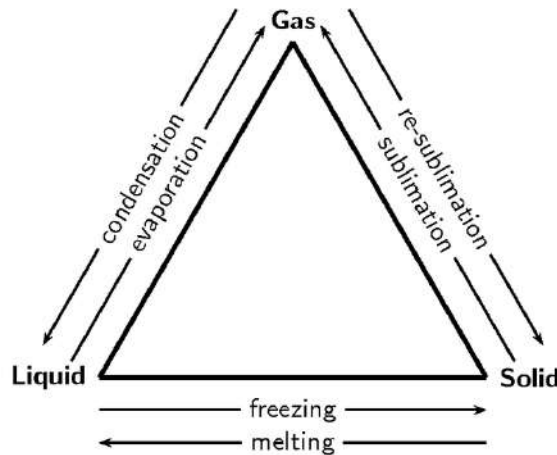
Fluids (Liquids and Gases)

Liquids and gases are called **fluids** because they can be made to flow, or move. In any fluid, the molecules themselves are in constant, random motion, colliding with each other and with the walls of any container..

Physical change of matter :

Any substance can occur in any phase. Under standard atmospheric conditions ‘ water exists as a liquid. But if we lower the temperature below 0 degrees Celsius, or 32 degrees Fahrenheit, water changes its phase into a solid called ice. Similarly, if we heat a volume of water above 100 degrees Celsius, or 212 degrees Fahrenheit, water changes its phase into a gas called water vapor. Changes in the phase of matter

are physical changes, not chemical changes. A molecule of water vapor has the same chemical composition, **H₂O**, as a molecule of liquid water or a molecule of ice.



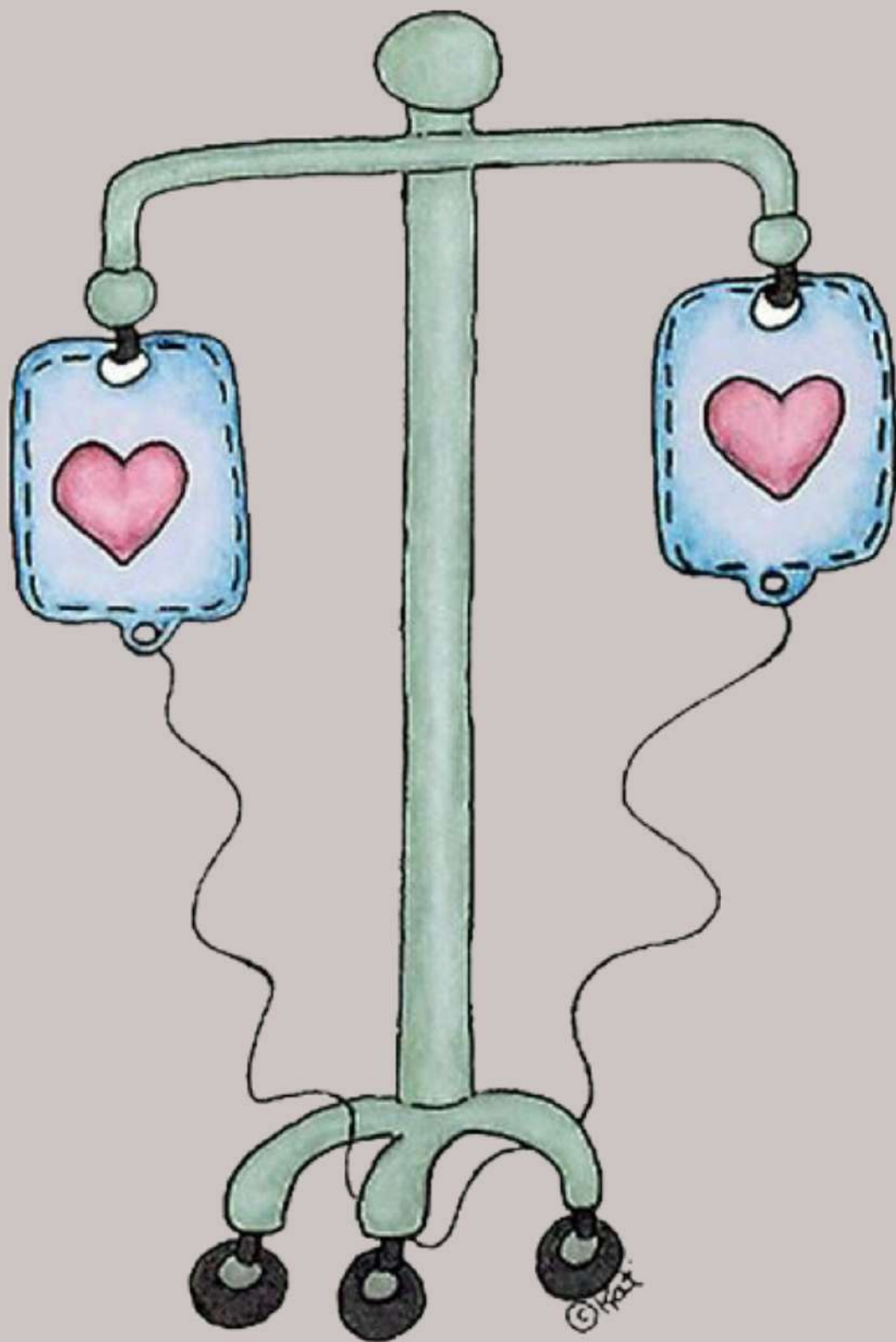
Plasma - the "fourth phase"

The three normal phases of matter (solid, gas, liquid)have been known for many years. In recent times, we have begun to study matter at the very high temperatures and pressures which typically occur on the Sun, or during re-entry from space. Under these conditions, the atoms themselves begin to break down; electrons are stripped from their orbit around the nucleus leaving a positively charged **ion** behind. The resulting mixture of neutral atoms, free electrons, and charged ions is called a **plasma**. ("fourth phase" of matter).

kinetic molecular theory :

The kinetic molecular theory of matter states that:

- 1- Matter is made up of particles that are constantly moving.
- 2- All particles have energy, but the energy varies depending on the temperature. This in turn determines whether the substance exists in the solid, liquid, or gaseous state. Molecules in the solid phase have the least amount of energy, while gas particles have the greatest amount of energy.
- 3- The temperature of a substance is a measure of the average kinetic energy of the particles.
- 4- A change in phase may occur when the energy of the particles is changed.
- 5- There are spaces between particles of matter. The average amount of empty space between molecules gets progressively larger as a sample of matter moves from the solid to the liquid and gas phases.
- 6- There are attractive forces between atoms/molecules, and these become stronger as the particles move closer together. These attractive forces are called intermolecular forces.



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محاضرة اجهزة (5)

د. نزار الحياي

Liquid State :

a solid begins to liquefy at the melting point as the particles gain enough energy to overcome their ordered arrangement

Energy required to reach the melting point is called the heat of fusion .
Liquid particles have more space between them allowing them to flow and take the shape of their container

Gaseous State :

particles have enough energy to escape the attractive forces of the other particles in liquid

Heat Of Vaporization :

is the energy required for a liquid to change to a gas At the Boiling Point the pressure of the liquid's vapor is equal to the pressure of the atmosphere and that liquid becomes a gas

Thermal Expansion:

increase in the Size of a substance when the temperature increases The size of the substance will then decrease when the temperature decreases
Expansion and contraction occur in most solids liquids and gases

WATER is an exception because it expands as it becomes a solid

Behavior of Gases

PRESSURE- is measured in units called Pascal (Pa) P

A collisions of particles in air result in **atmospheric pressure**

Moving particles colliding with the inside walls of a container result in **gas pressure**

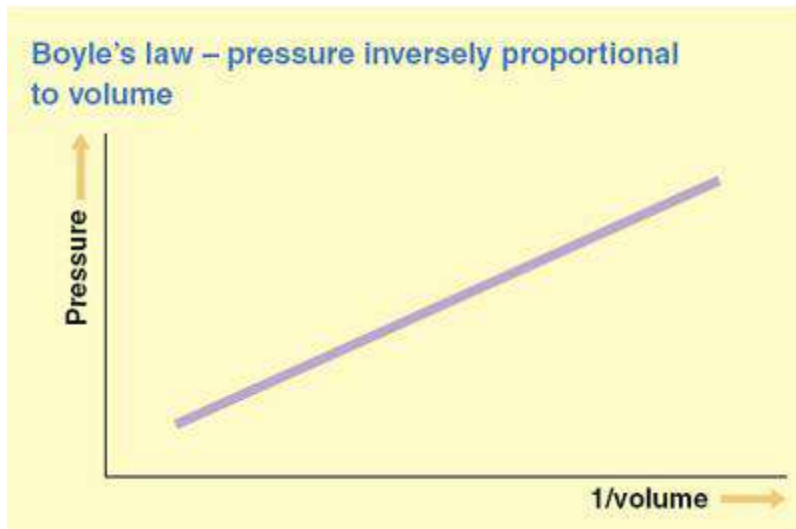
gas laws

1- Boyle's Law :

at a constant temperature, the volume of a mass of gas is inversely proportional to the pressure ($PV = \text{Constant}$).

Volume decreases as pressure increases Pressure decreases as volume increases

Pressure multiplied by volume is always equal to a constant if the temperature is constant Weather Balloons



Example of the application of Boyles law :

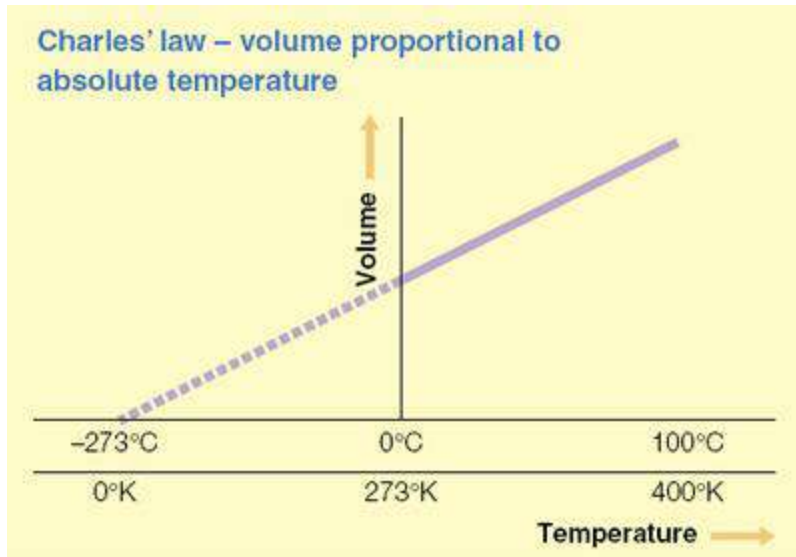
A typical large oxygen cylinder such as used in oxygen therapy, How much oxygen will be available at atmospheric pressure ?

The internal capacity of the cylinder is about 10 liters and when full it has a gauge pressure of 137 bar or 13700 kPa. If the atmospheric pressure is 100 kPa , the total or absolute pressure of the oxygen will be 13800 kPa , since absolute pressure is gauge pressure plus atmospheric pressure .

The total volume of oxygen = 1380 liters , as 10 liters is retained in the empty oxygen cylinder , 1300 liters is available for delivery at atmospheric pressure

Charles's Law :

at a constant pressure the volume of a gas is directly proportional to its absolute temperature ($V/T = \text{Constant}$). Volume is proportional to temperature. Gases expand when they are heated and become less dense, thus hot air rises.

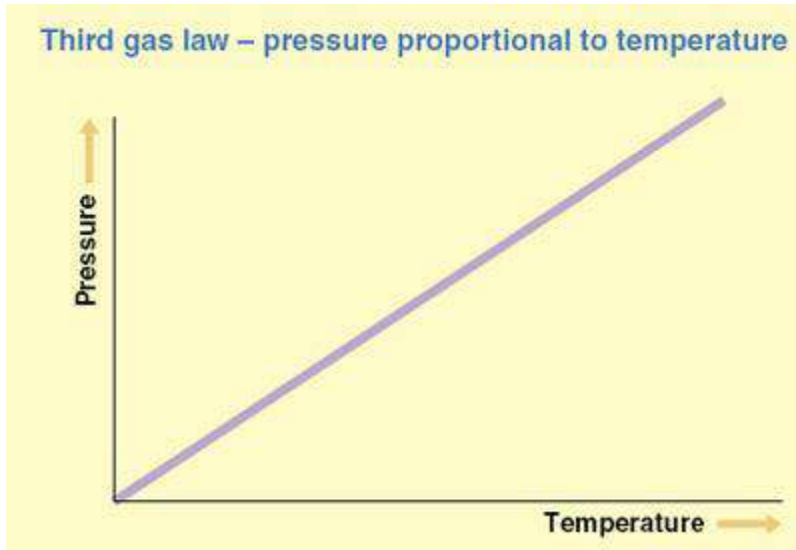


example of this law :

this law shows that gas expand when they are heated and so become less dense . it means that warm air tends to rise and this cause convection currents

Gay Lussac's Law :

at constant volume the absolute pressure varies directly with absolute temperature ($P/T = \text{Constant}$). Pressure is proportional to temperature. An example is the hydrogen thermometer. A constant volume of hydrogen when heated produces a change in pressure.



an example of this law :

consider an oxygen cylinder full to an absolute pressure of 138 bar at an ambient temperature of 290K (17C). cylinders are tested to withstand pressure of up to 210 bar . if the cylinder is dropped accidentally into an incinerator at 580 K (307C), there is a danger of explosion of the cylinder from the pressure increase . a doubling of the absolute temperature doubles the pressure , thus the pressure in the cylinder increase to over 210 bar . The cylinder is likely to explode

Standard temperature and pressure (STP) – it is important to specify the temperature and pressure at which the measurement of a volume is made. increased temperature reduces the density of fluids

- increased temperature reduces the viscosity of liquids
- increased temperature increases the viscosity of gases (increased molecular activity).

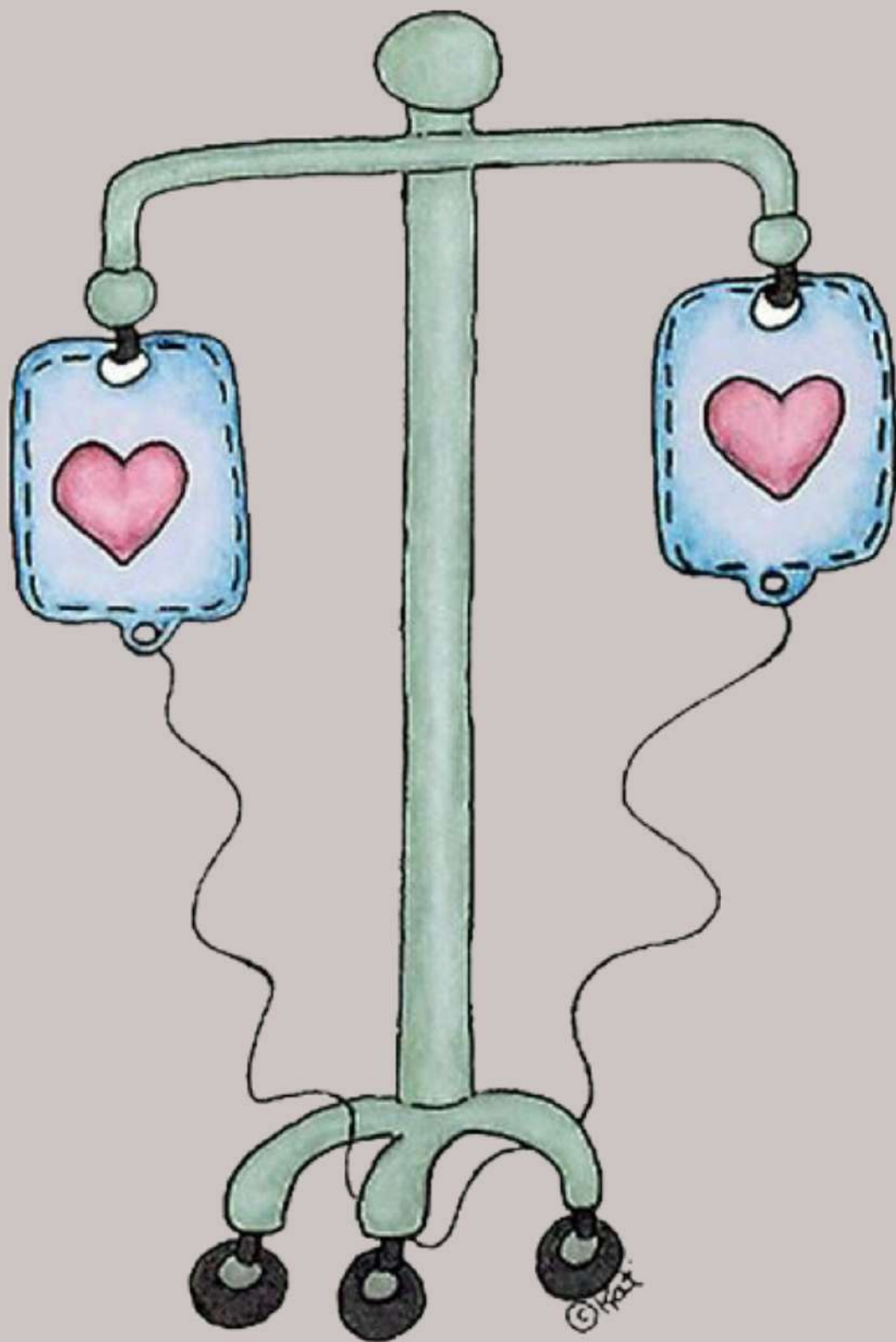
The standard temperature used is 273.15K (0c)

The standard pressure used is 101.325KPa (760mmHg)

This standard temperature and pressure is known as s.t.p.

Temperature, however, requires a scale that starts at absolute zero, therefore Kelvin must be used.

T Molybdenum steel can withstand pressure till 210 bars. Weakening of metal in damaged cylinders are at a greater risk of explosion due to rise in temperature.



أجهزة نظري

محاظرة 7

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محاضرة اجهزة (7)

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Gas laws in anesthesia and its Applications

What is gas?

A gas is a substance that is in its gaseous phase, but is above its critical temperature

What is pressure?

It is defined as the force per unit area acting at right angles to the surface under consideration

What is temperature?

This is a measure of the average kinetic energy in a system and translates to the degree of hotness or coldness of that system

Convert pressure values from kPa units to psi pressure units using the following method:

1. $1 \text{ psi} = 6894.76 \text{ Pascals (Pa)}$
2. $1 \text{ kPa} = 1000 \text{ Pascals (Pa)}$
3. $\text{psi value} \times 6894.76 \text{ Pa} = \text{kPa value} \times 1000 \text{ Pa.}$
4. $\text{psi value} = \text{kPa value} \times 0.145038$

$1 \text{ kPa to PSI} = 0.145 \text{ PSI}$

$10 \text{ kPa to PSI} = 1.450 \text{ PSI}$

$1 \text{ psi} = 6.89 \text{ kPa}$

Boyle's Law :

At a constant temperature, the volume of a given mass of gas is inversely proportional to the absolute pressure.

The volume of an E type cylinder is approximately 5 Litres. The service pressure at which the cylinder is filled is 2000psig (when it is full)

What is the gas law applied to know the volume of oxygen in a full “E” type of cylinder available for use at 15 psig (pressure at common gas outlet)?

$$P_1V_1 = P_2V_2$$

$$2000 \times 5 = 15 \times V_2$$

$V_2 = 2000 \times 5 / 15 = 665$ litres So if we use 3 litres of oxygen, the E type full cylinder will last for about 220 mins.

$$665 / 3 = 220$$

Charles's Law:

At constant pressure, volume of a gas is directly proportional to the temperature.

Application:

- i. Respiratory gas measurements of tidal volume & vital capacity etc. are done at ambient temperature while these exchanges actually take place in the body at 37 OC.
- ii. One way of heat loss from the body is that air next to the body surface gets warmer and moves up and thus our patient loses heat this way (esp. important in Paediatric anaesthesia) .

Gay Lussac's Law:

At constant volume, the absolute pressure of the given mass of gas is directly proportional to the temperature.

Application:

- i. Medical gases are stored in cylinders having a constant volume and high pressures (138 Barr in a full oxygen / air cylinder). If these are stored at high temperatures, pressures will rise causing explosions.
- ii. Molybdenum steel can withstand pressures till 210 bars. Weakening of metal in damaged cylinders are at a greater risk of explosion due to rise in temperature.

Gas contents in a cylinder From ideal gas equation,

the pressure exerted by any gas is dependent on the number of moles present. Therefore in a fixed volume such as cylinder, the pressure is a measure of amount of gas contained. This is only applies to gas (e.g. O₂ or CO₂ cylinder) but not to vapour like full nitrous, where liquid and gas phases are present..

Avogadro's hypothesis

Equal volumes of gases at the same temperature and pressure contain equal numbers of molecules. the number of molecules present is expressed as a mole. A mole is the quantity of a substance containing the

same number of particles One mole of gas at standard temperature and pressure is contained in a volume of 22.4 litres.

A clinical application would be to calculate the volume of nitrous oxide in a cylinder. A nitrous oxide cylinder contains 2.2 kg of nitrous oxide. The molecular weight of nitrous oxide is 44. One mole is 44 g. At STP we know that 44 g occupies 22.4 litres, therefore 2200 g occupies $22.4 \times 2200/44 = 1120$ litres.

From known cylinder wt. and measured wt. the amount of N₂O is found out using Avogadro's hypothesis

The universal gas equation (the ideal gas law)

If the perfect gas laws and Avogadro's hypothesis are combined:

$PV/T = \text{Constant}$. For one mole of gas, PV/T equals the universal gas constant R . The equation can be rearranged to $PV = nRT$ (the universal gas equation) where n equals the number of moles present. The practical application of this law is the use of pressure gauges to assess the contents of a cylinder. The volume, temperature and gas constant remain the same and pressure is therefore proportional to n , the number of moles.

Adiabatic changes in a gas

Applying the three gas laws, for a change to occur in the state of a gas, heat energy is either added or taken away from the gas. If the state of a gas is altered without a change in heat energy it is said to undergo adiabatic change. If a compressed gas expands adiabatically, cooling occurs as seen in the cryoprobe. (when a gas is allowed to escape through a narrow opening, there is a sudden temperature drop). Energy is required as the gas expands to overcome van der Waal's forces. No heat exchange occurs between the gas and its surroundings because the source of energy is from the molecule's own kinetic energy, thus the gas cools as it expands. Conversely, if a gas is rapidly compressed its temperature rises (the Joule–Kelvin principle). When a cylinder connected to an anaesthetic machine is turned on too quickly the temperature rises in gauges and pipelines and in the presence of oil or grease may lead to a fire or explosion.

Dalton's law of partial pressures :

states that if a mixture of gases is placed in a container then the pressure exerted by each gas (partial pressure) is equal to that which it would exert if it alone occupied the container.- Thus in any mixture of gases

(alveolar, fresh inspired gases, air) the partial pressure exerted by each gas is proportional to its fractional concentration . $P = P_1 + P_2 + P_3$

If a pressure exerted by a gas is 50 % of the total pressure exerted by all gases in that container, then it will occupy exactly 50 % of its volume.

Critical temperature:

gases can be liquefied by increasing the pressure or cooling. However , there is a temperature above which any gas cannot be liquefied by increasing pressure. This is critical temperature.

The pressure of the gas at the critical temperature is called the critical pressure and the volume occupied by the gas is called the critical volume

O₂ – -118 c, 50bar

N₂O – 36.5 c, 72bar

CO₂ –31 c, 73bar

Therefore one can define a gas as a substance in the gaseous phase above its critical temperature.

Vapour is the term applied to a substance in the gaseous phase below its critical temperature. Thus, simply increasing the pressure can liquefy a vapour, but not a gas.