Patient Monitor

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January 2024

Part-I

General principles

I. Monitor can not replace clinical observation of the patient and the vital findings ,e.g. :

- Skin perfusion (capillary refill &temperature)
- Skin color as (pallor or cyanosis).
- Skin turgor (elasticity or edema).
- Mucus membranes(state of hydration).
- Chest movement .
- Heart auscultation.
- Monitors provide information which should augment the above clinical findings .

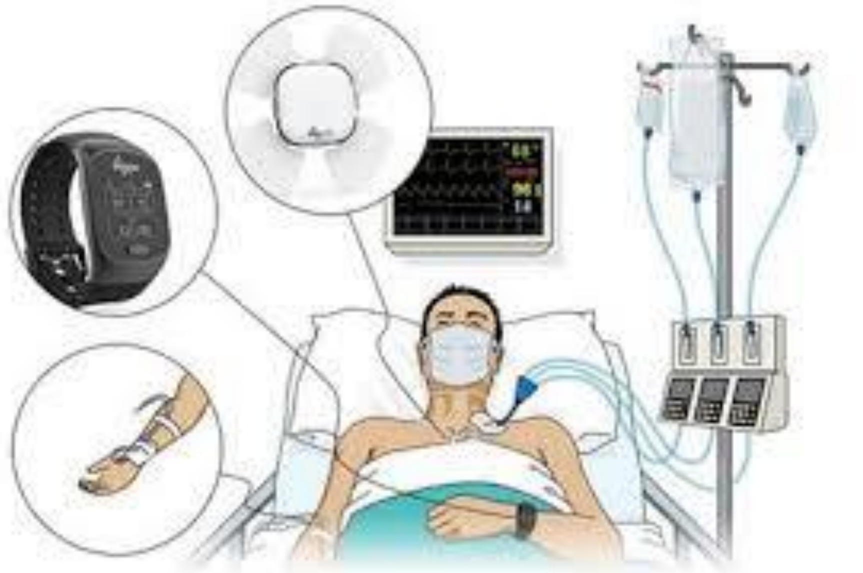
General principles

II. Patient Monitors are becoming more sophisticated . Therefore clinicians must be aware of there limitations and the potential causes of errors which can be due to one or more of the following factors:

1. *Patient factors.*
2. *Equipment factors.*
3. *Sampling factor.*

General principles

III. Monitoring equipment can be:



1. Invasive .

2. Non-invasive.

Notes

- *Nowadays monitors are compact ,integrated and durable after advances in information technology ; in contrast to old monitoring devices which were discrete and bulky.*
- *Recent introduction of plug-in monitoring modules.*
- *More recently wireless monitoring systems are available.*

Electrocardiogram(ECG)

This monitors the electrical activity of the heart with electrical potentials of 0.5-2 mV at the skin surface.

Benefits of ECG:- its useful in determining:

1. ***Heart rate(rate defects)***
2. ***Heart rhythm(arrhythmias).***
3. ***Myocardial ischemia(poor blood supply)***
4. ***Conduction defects***
5. ***Transthoracic cardiac output(recently)***

The bipolar leads (I, II, III, aVR, aVL and aVF) measure the voltage difference between 2 electrodes.

The unipolar leads (V1-6) measure voltage at different electrodes relative to a zero point.

Components

1. ***Electrodes which get into contact with the skin by foam pads which are soaked in conducting gel.***

2. ***Color coded cables transmit signals from the electrodes to the monitor, available as :***

- ***3 leads and 5 leads versions.***
- ***Grabber or snap designs.***

3. ***A variety of lengths (provided that all the cables in one set must have the same length to minimize the electromagnetic interference).***

Components

4. An amplifier to boost the signals and a filter (low-pass filters and high-pass filters) to remove the noise /artifact and produce a clean signal.

5. High resolution multicolor oscilloscope that displays the signals.

Electrocardiogram(ECG)

Mechanism of action

1. *Proper attachment of the electrodes to (clean, non-hairy and bony prominences) using conductive gel. Females have higher impedance.*
2. *Modern monitors have two modes:*

- *The monitoring mode (surgery mode) reduces the noise/artifacts or distortion from muscle movements like respiratory movements) , mains current and electromagnetic interferences from other equipment (electro-cautery).*
- *The diagnostic mode allows assessment of p-wave, QRS complex morphology ,T-wave and ST-segment analysis.*

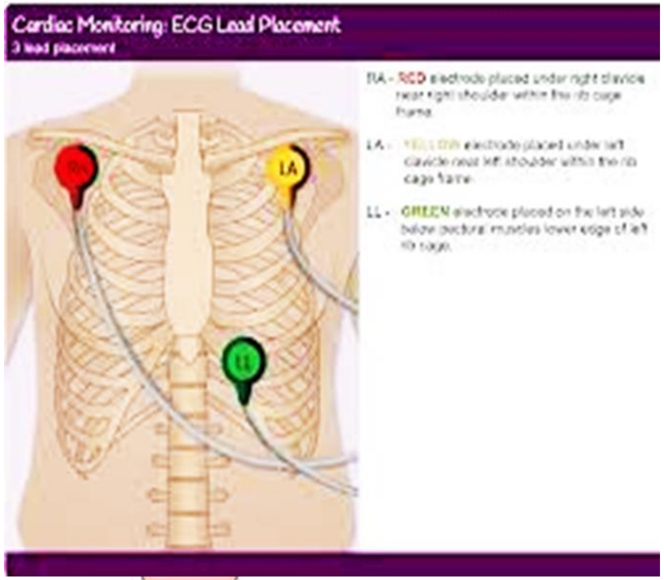
3. *A display speed of 25mm/s and sensitivity of 1mV/cm are standard in UK.*

Mechanism of action

4. ECG leads configurations:

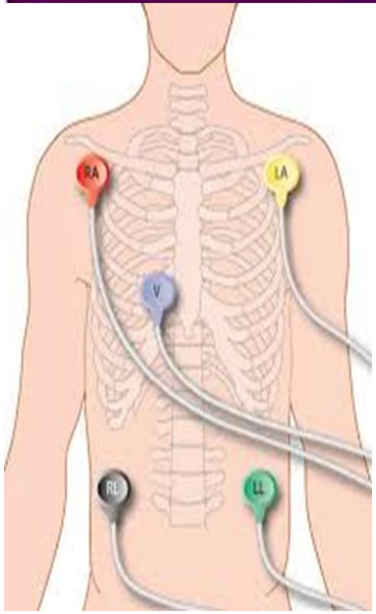
-The 3 leads configuration is commonly used during anesthesia is:

(Rt. Arm , Lt. arm and indifferent leads).

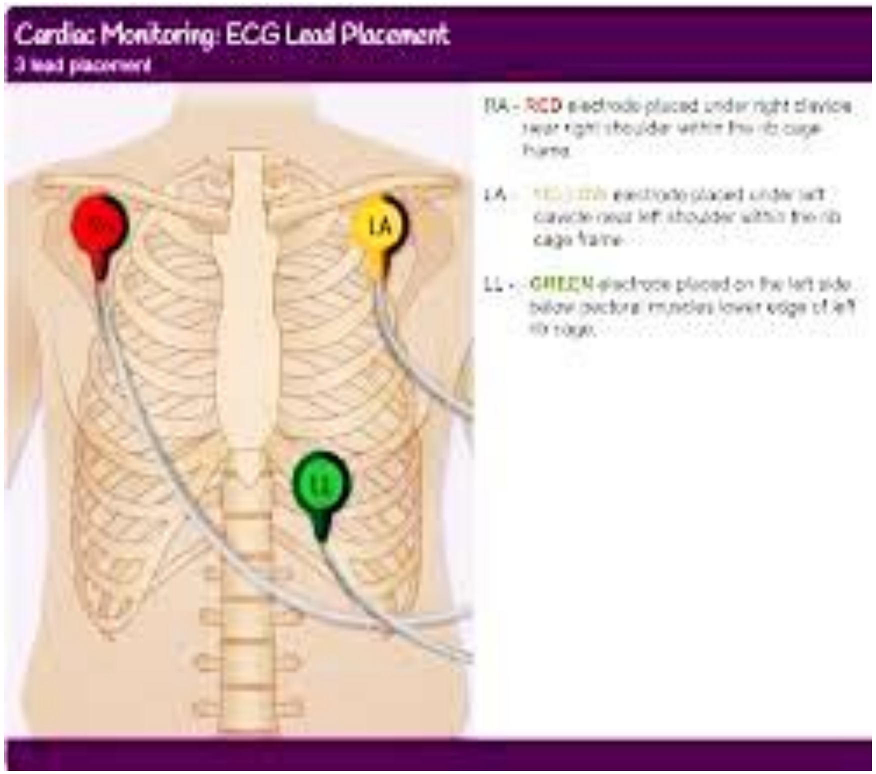


-The 5 leads configuration is sometimes used.

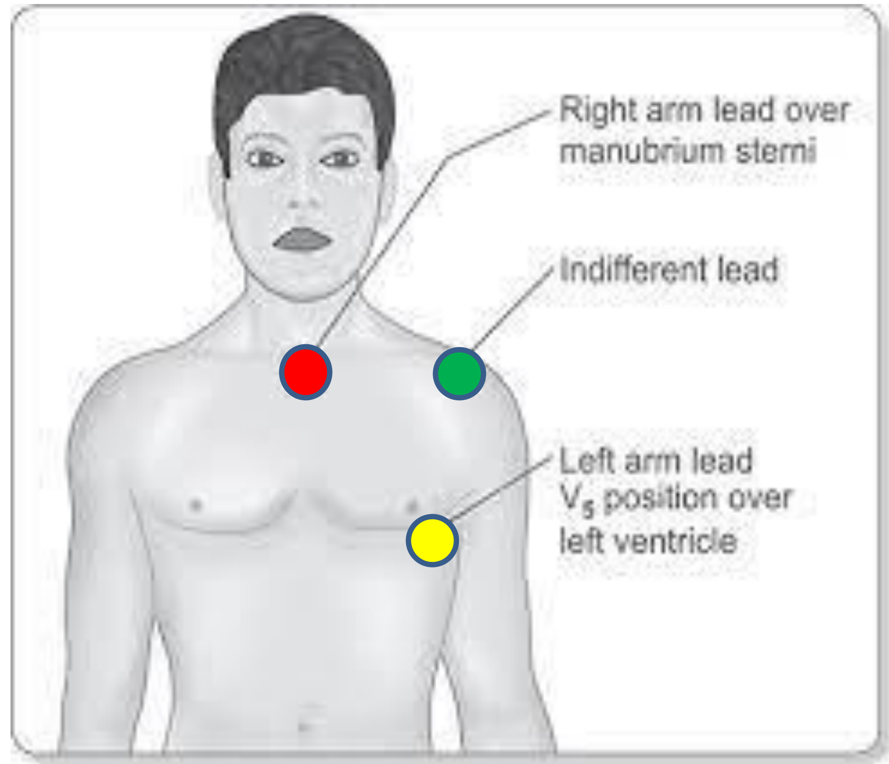
(RA ,LA ,LL, RL and Chest leads)



Modified ECG electrodes configurations



Ordinary Three leads positions



CM5 configuration

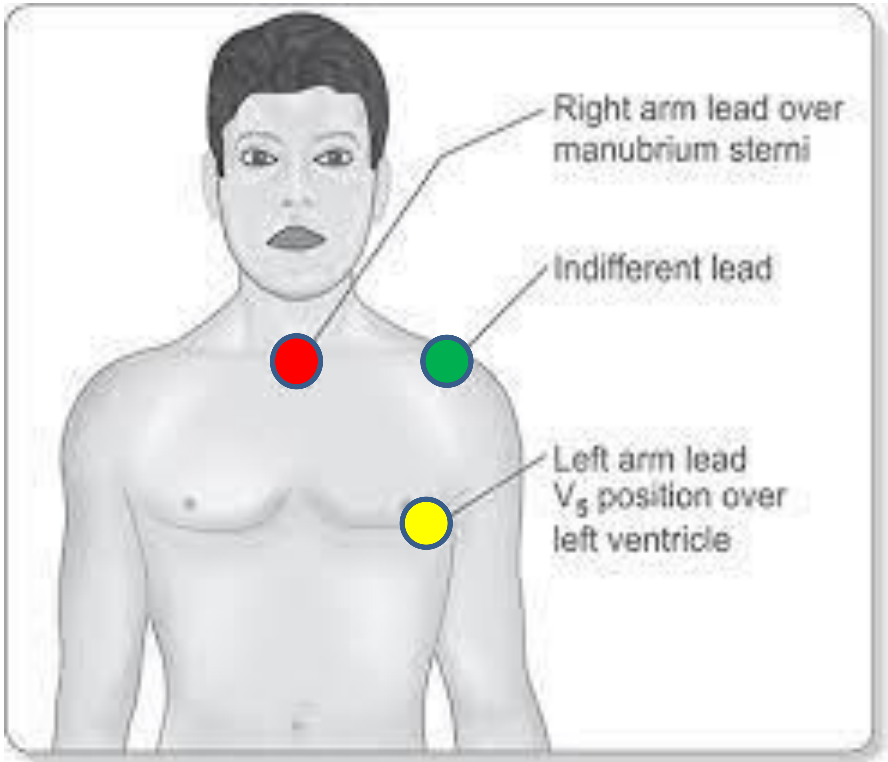
CM5 ECG electrode configurations

RA electrode is over manubrium.

LA electrode 5th interspace(V5 position) in the anterior axillary line.

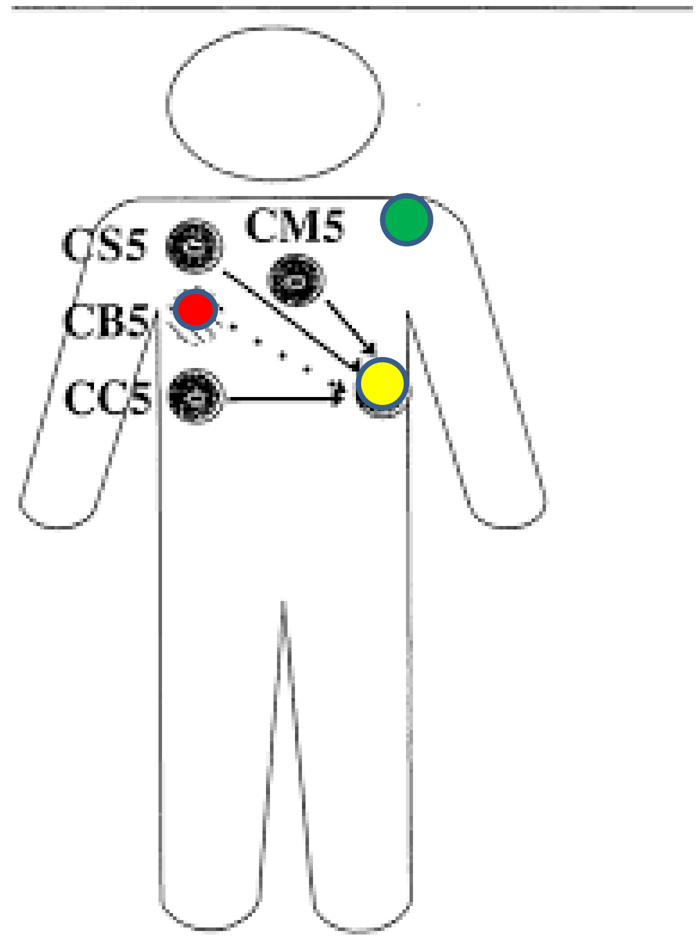
Indifferent lead on Lt. shoulder or any convenient position.

Its able to detect 89% of ST-segment Changes due to left ventricular ischemia.



The CB5 ECG electrodes configurations

- *Useful during thoracic anesthesia.*
- *RA electrode is over the center of the Rt. scapula .*
- *LA electrode is over V5.*
- *Indifferent electrode at the right shoulder tip.*



Problems in practice and safety features

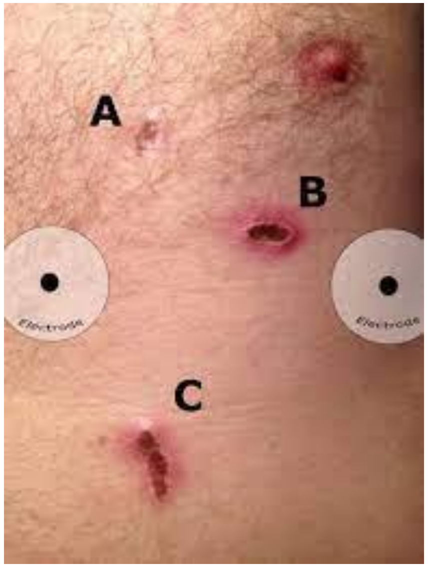
1. *Incorrect ECG electrodes is common and result in false information.*
2. *Electrical interference from mains line, other devices powered by AC or current interference from diathermy will distort ECG waves and information. This has been eliminated in modern monitors by shielding of cables, amplifiers and electronic filters.*

Problems in practice and safety features

3. ***Muscular activity like shivering can produce artifacts. This is reduced by positioning of the electrode over bony prominences and the use of filters.***
4. ***Visual and audible high and low ventricular rate alarms and continuous monitoring of ST- segment allow early diagnosis of ischemic changes.***

Problems in practice and safety features

5. Absence of or improperly positioned patient diathermy plate can cause burns at the sites of the ECG electrode.



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Part-II

Arterial blood pressure monitoring

Oscillometry is the commonest method of blood pressure monitoring non-invasively.The term Device for Indirect Non-invasive Automatic Mean Arterial Pressure(DINAMAP)is used for such devices.

- ***Non-Invasive Blood Pressure (Systolic , diastolic and mean arterial pressure)and pulse rate are measured, calculated and displayed.The term NIBP is used***
- ***NIBP is less reliable when sudden change in the BP is anticipated or when minimal changes in the BP is clinically relevant.***

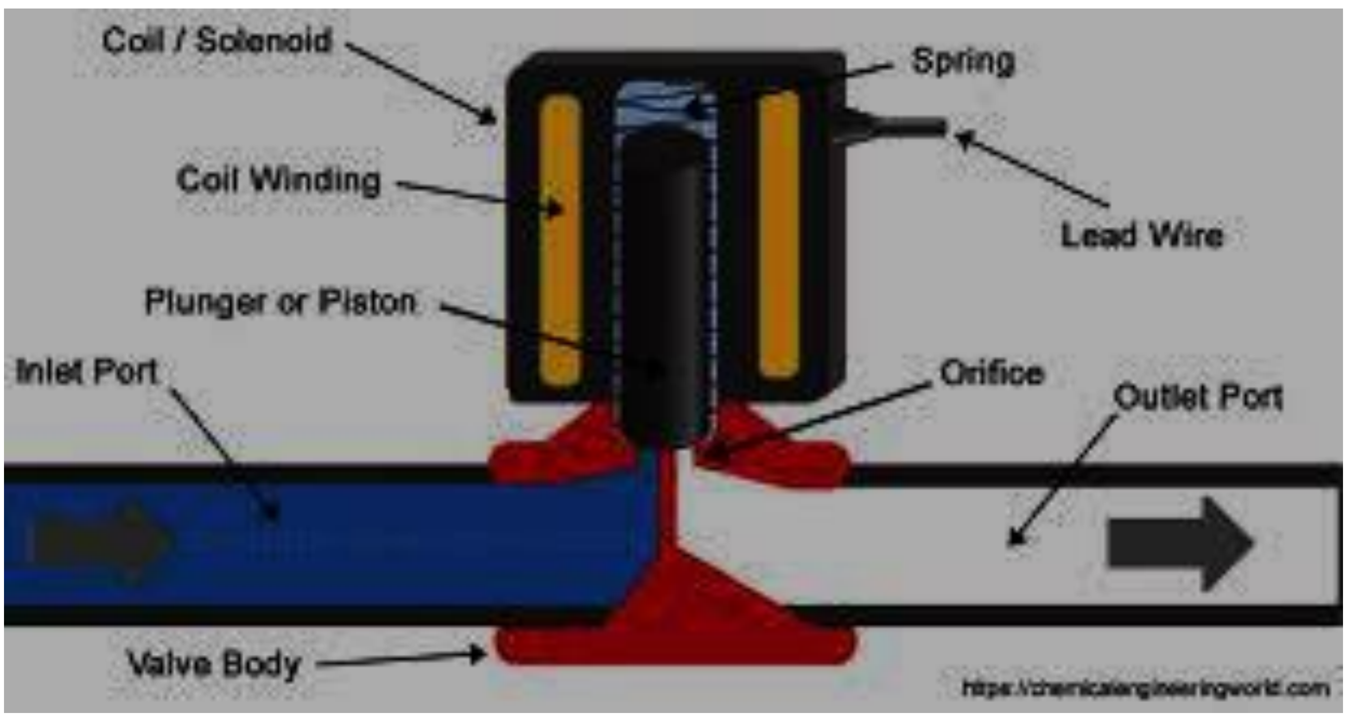
Components

1. ***A cuff with a tube used for inflation & deflation. Some designs have an extra tube to transmit pressure fluctuations to the pressure transducer.***
2. ***The case which houses:***

a) The microprocessor.
b) Pressure transducer .
c) A solenoid valve which controls the deflation of the arm cuff.
d) Display.
e) Timer to adjust the intervals between repeated readings.
f) Alarm limits for high and low values.

How does a solenoid work?

A solenoid works by producing an electromagnetic field around a movable core, called an armature. When compelled to move by the electromagnetic field, the motion of that armature opens and closes valves or switches and turns electrical energy into mechanical motion and force.



Mechanism of action

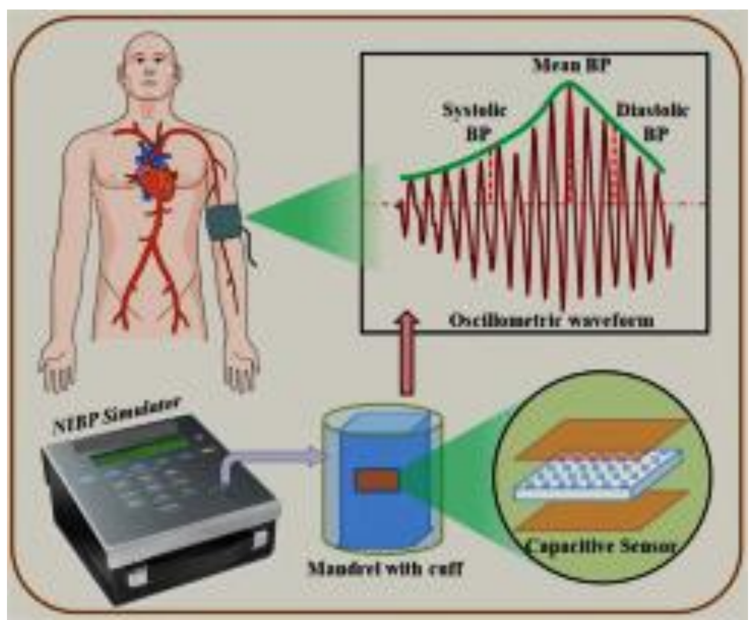
1. ***The microprocessor is set to control the sequence of inflation and deflation.***
2. ***The cuff is inflated to a pressure above the previous systolic pressure, then deflated incrementally. The return of blood flow causes oscillation in the cuff pressure.***
3. ***The pressure transducer senses the pressure changes which are interpreted by the microprocessor. This transducer has an accuracy of(+/_ 2%).***

Mechanism of action

4. The oscillations are changed to electrical signals by the transducer to pass through a filter then an amplifier to amplify the oscillations .The amplified signals then pass to the microprocessor which changes them to analogue digits.The microprocessor controls the pneumatic pump for inflation of the cuff and the solenoid valve for deflation of the cuff.

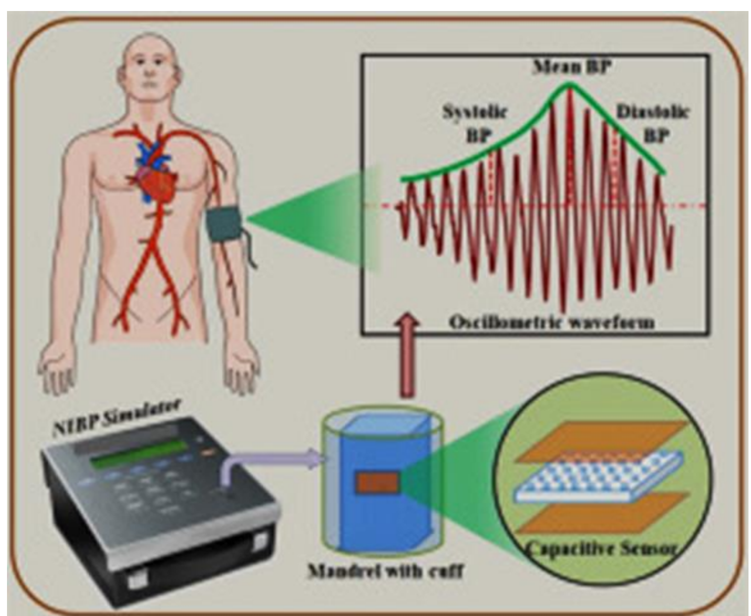
Mechanism of action

5. *The systolic pressure corresponds to the onset of rapidly increasing oscillations. The mean arterial pressure corresponds to the maximum oscillation at the lowest cuff pressure.*



Mechanism of action

6. The diastolic pressure corresponds to the onset of rapidly decreasing oscillations. In addition its computed mathematically from the systolic and mean arterial pressure values(MAP=DAP + 1/3 pulse pressure).



Mechanism of action

7. The cuff must be of correct size :

a) It should cover at least upper 2/3 of the arm.

b) The width of the cuff must be 40% of the mid-circumference of the limb.

c) The middle of the cuff bladder must be placed over the brachial artery (arrow or label).

8. Some designs has the ability to apply venous stasis to facilitate i.v. cannulation.

Mechanism of action

Problems in practice and safety features

1. ***Accurate BP measurement requires rapid inflation and slow deflation(at a rate of 3 mmHg/s or 2 mmHg/beat)of the cuff.***
2. ***Too small cuff causes over-read BP, while too large cuff causes under-read BP. Errors are greater with too small cuff.***
3. ***The systolic pressure is over-read at low pressures(<60mmHg) ,while under-read at high systolic pressure .***

Cuff sizes

6pcs Cuff (each size 1pc)

Leg (Thigh) :(46-66cm)

Adult Large: (33-47cm)

Adult :(25 - 35cm)

Pediatric: (18-26cm)

Infant: (12-19cm)

Neonate: (7-13cm)

Problems in practice and safety features

4. ***Atrial fibrillation and other arrhythmias affect performance.***
5. ***External pressure on the cuff or its tubes can cause inaccuracies.***
6. ***Frequently repeated cuff inflations can cause ulnar nerve palsy and petechial hemorrhage of the skin under the cuff.***

Finapres (finger arterial pressure) measures the arterial pressure via a small cuff around the finger.

Pulse oximetry

Pulse oximetry

- ***Non-invasive measurement of arteriolar O_2 saturation.***
- ***Continuous display of oxygenation by simple, accurate and rapid method.***
- ***Powerful monitoring tool in the O.T., recovery ward, ICU , general ward ,outpatient and during transport of critically ill patients (i.e. everywhere).***
- ***A great technical advance in monitoring of the last 2 decades .***
- ***Detects incipient and unsuspected arterial hypoxemia, allowing treatment before tissue damage.***

Componenets

1. ***A probe positioned on the finger, toe, ear lobe nose or forehead.***

- ***Two light-emitting diodes(LEDs) produce beams at red and infrared frequencies***

(660-940 nm) on one side and a sensitive photo-detector detects them on the other side.

Note: Center wave length is usually 805nm

- ***The LEDs operate in sequence at a rate of about 30 times per second.***

Componenets

2. The case houses the microprocessor.

- *There is a display of oxygen saturation, pulse rate and a plethysmographic waveform.*
- *Alarm limit for low O_2 saturation.*
- *Alarm for high and low pulse rates can be set.*

Mechanism of action

1. ***The of O_2 saturation is estimated by measuring the transmission of light through pulsatile vascular tissue bed (e.g. finger tip or ear lobe).***
2. ***The amount of light transmitted depend on many factors:***

- ***The light absorbed by non-pulsatile tissues (skin ,soft tissue , bone and venous blood is constant (DC).***
- ***The light absorbed by pulsatile tissue (arterial blood pulsations) is non-constant (AC) .***
- ***The photodetector generates a voltage proportional to the transmitted light. The (AC) component is about (1-5)% of total signal .***

Mechanism of action

3. ***The high frequency of the LEDs allows absorption to be sampled many times during each pulse beat. This allows average of saturation to be calculated many times per second thus decreasing the (noise e.g. movement) effect on signals.***
4. ***The microprocessor mathematically analyses the AC and DC components .the result is related to the arterial saturation***

Mechanism of action

5. More recent designs use multiple wave lengths to eradicate false readings from carboxyhemoglobin and Methemoglobin.

Advanced oximeter use more than 7 light wavelengths that enables hemoglobin values, O_2 content, carboxyhemoglobin and methemoglobin concentration.

6. A variable pitch beep provides an audible signal of changes in saturation.

Problems in practice and safety features

1. ***Its inaccurate (+/_2%) between 70-100%. Below 70% readings are extrapolated.***
2. ***The absolute measurement of O_2 saturation vary from probe to probe but with accurate trends. This is due to variability of the center wave length.***
3. ***Carbon monoxide poisoning (including smoking), colored nail varnish, intravenous injection of certain dyes(methylene blue or indocyanine green), drugs produce methemoglobinemia are all source of error.***

Problems in practice and safety features

4. ***Hypoperfusion and severe peripheral vasoconstriction affects the performance of the pulse oximeter.***
5. ***It monitors the O_2 saturation without direct information about O_2 deliver to the tissues.***
6. ***Pulse oximeters average their reading every (10-20 s). The response time to desaturation is longer with finger probe(more than 60 s) whereas (10-15 s) with ear probe.***

Problems in practice and safety features

7. Excessive motion or malposition of the probe is a source if error, although some manufacturers claim more stability despite motion. Ambient fluorescent light can be a source of interference.

8. Venous pulsation and impaired venous return as in Valsalva maneouvre can lead to false interpretation by the pulse oximeter.

Problems in practice and safety features

9. *Prolonged application to a single site can cause pressure sores thus its recommended to change application site every 2 hours, especially in patients with impaired microcirculation. Burns in infants has been reported .*
10. *It gives information about oxygenation but not about ability of CO_2 elimination.*

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Part-III

End-tidal carbon dioxide (CO_2) analyser (capnographs)

Measures both inspired and expired CO2 concentration directly and continuously throughout the respiratory cycle.

1. ***Capnograph* records and shows the graphical display of the waveform of CO_2 in (kPa or mmHg) at the end of expiration, which is known as end-tidal CO_2 ($EtCO_2$).**
2. ***Capnogram* is the graphical plot of CO_2 partial pressure (or percentage) versus time.**
3. ***Capnometer* only shows numerical concentration of CO_2 without a waveform.**

End-tidal carbon dioxide (CO_2) analyser (capnographs)

$EtCO_2$ < alveolar CO_2 < Arterial CO_2 ($PaCO_2$)

unventilated alveoli Vs unperfused alveoli

Ventilation /Perfusion mismatch.

Dead space: is the space where gas exchange will not take place as there is no perfusion

Arterio-venous shunting: blood crosses from pulmonary arterial side to pulmonary venous side without gas exchange as there is no ventilation.

Components

1. The sampling chamber which is available in two versions:

a) Main-stream version :the sampling chamber is positioned within the patients gas stream.

b) Side-stream version : connected to the distal end of the breathing system via a sampling tube.

2. A photodetector measures light reaching is from a light source after passing through the gases.

Components

Main-stream Analyzer

Side-stream Analyzer

Side-stream analyzer

1. ***A 1.2 mm internal diameter tube, samples the gas at a rate of (150-200 ml/min).***
2. ***Moisture trap with an exhaust port to vent the gases to the atmosphere or return it to the breathing system.***

Both the tube and the trap are single use and must be changed frequently.

3. ***The sampling tube must be as near as possible to the patient's trachea.***

Side-stream analyzer

4. *There is a variable time delay before the sample reaches the chamber(<3.8s is acceptable). This delay depends on*

a) *the length of the sampling tube (usually< 2m).*
b) *The diameter of the sampling tube.*
c) *Sampling rate.*
d) *Size of the sample chamber.*

5. *Other gases and vapors can be analyzed from the same sample.*
6. *Portable hand-held side-stream analyzers are available for patient transport.*

Portable hand-held Side-stream analyzer

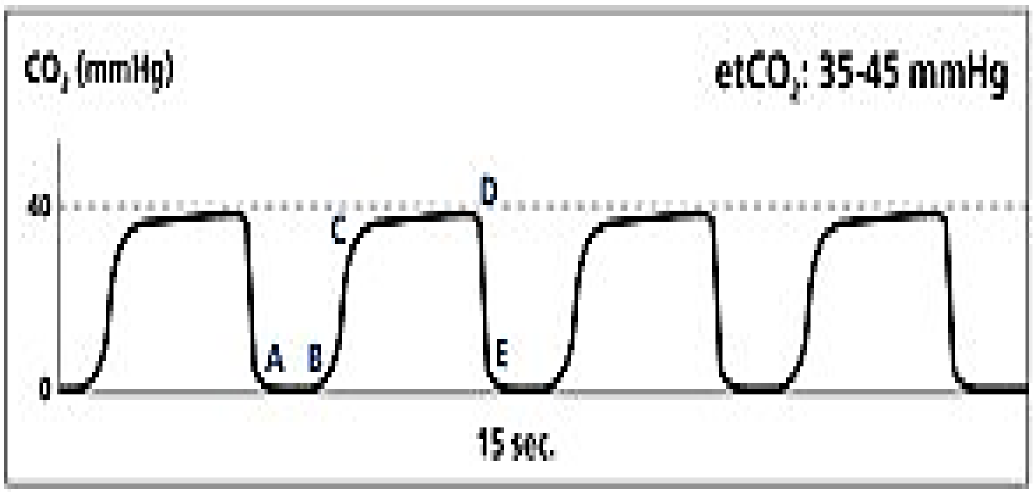
Main-stream analyzer

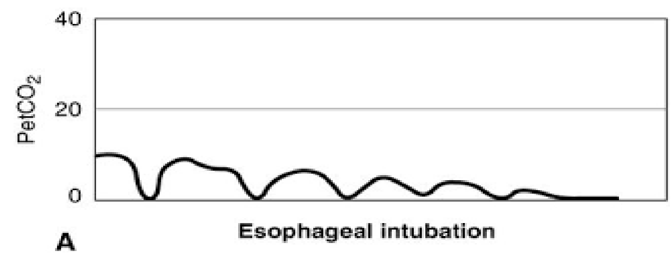
1. *The sample chamber is positioned within the patient's breathing system increasing the dead space.*
2. *It doesn't have moisture trap, instead its heated to about 41◦C to prevent water vapor condensation.*
3. *There is no transport time delay since it doesn't need sampling line.*
4. *Other gases and vapors can not be measured simultaneously.*

Uses and benefits of $EtCO_2$ measurement or capnography

1. ***To diagnose esophageal intubation(no or very little CO_2 is detected) specially following carbonated drinks ,some CO2 may be present in the stomach gas, characteristically 5-6 waveforms with an abnormal shape and decreasing amplitude.***

Uses and benefits of $EtCO_2$ measurement or capnography



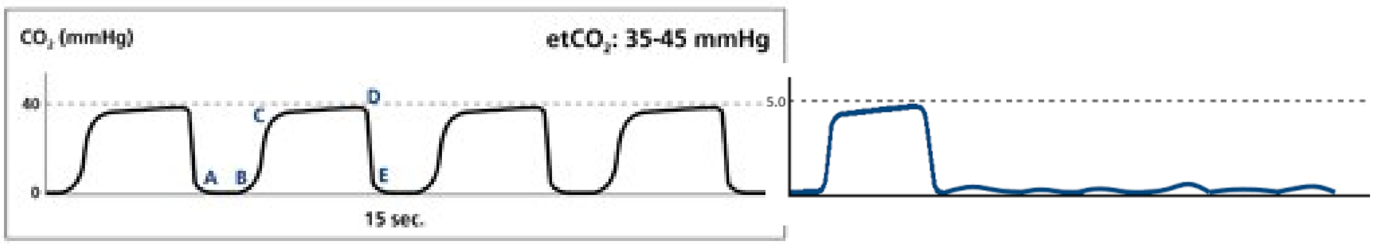


Normal capnography waveform

Esophgeal intubation capnography waveform

Uses and benefits of $EtCO_2$ measurement or capnography

2. ***Diagnosis of disconnection of the breathing system. There will be a sudden absence of $EtCO_2$.***



Disconnection capnography waveform in the breathing system

Uses and benefits of $EtCO_2$ measurement or capnography

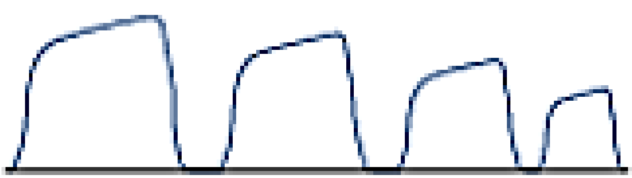
3. ***Diagnosis of tube cuff leaks . There will be a disappearance of plateau of $EtCO_2$ waveform.***

Tube cuff leaks capnography waveform

Uses and benefits of $EtCO_2$ measurement or capnography

4. To diagnose pulmonary embolism as a sudden *decrease* of the $EtCO_2$ waveform.

Exponential decrease in $ETCO_2$



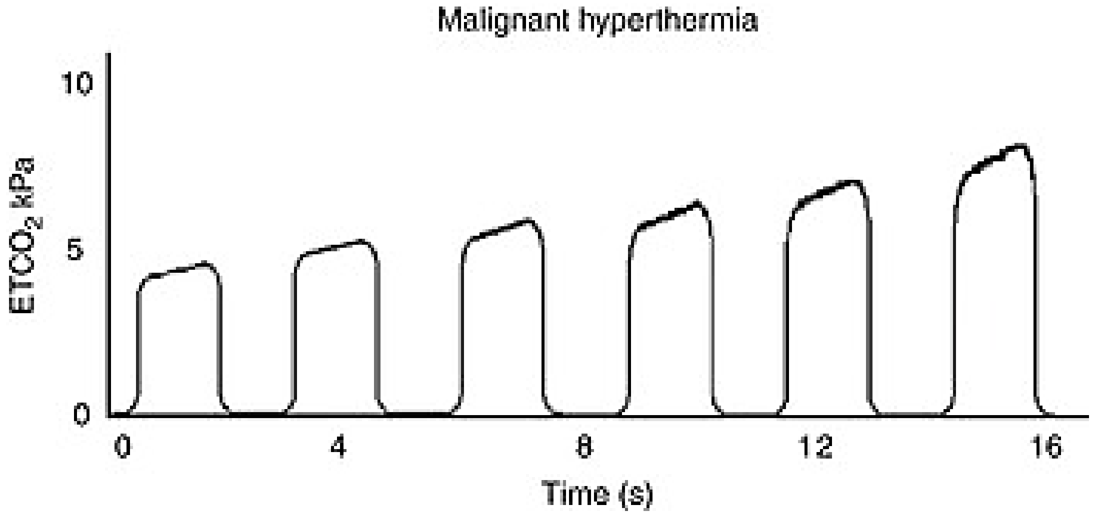
Possible causes:

- Cardiopulmonary arrest
- Pulmonary embolism
- Sudden hypotension; massive blood loss
- Cardiopulmonary bypass

Pulmonary embolism capnography wave form

Uses and benefits of $EtCO_2$ measurement or capnography

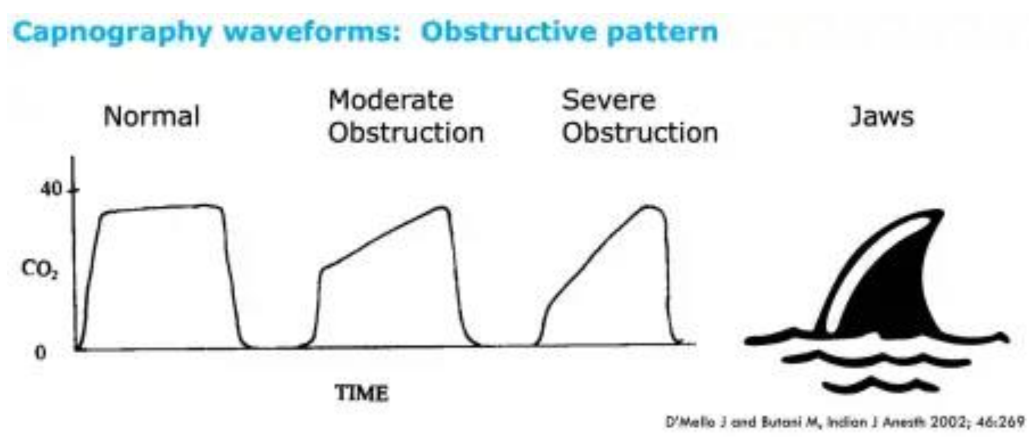
5. ***To diagnose malignant hyperpyrexia as a gradual increase in the $EtCO_2$.***



Malignant hyperpyrexia capnography wave form

Problems in practice and safety features

1. In patients with chronic obstructive airways disease (COAD) ,the waveform shows ascending plateau which indicates impaired ventilation perfusion ratio because of uneven emptying of the alveoli and doesn't reflect the $EtCO_2$ accurately.



Problems in practice and safety features

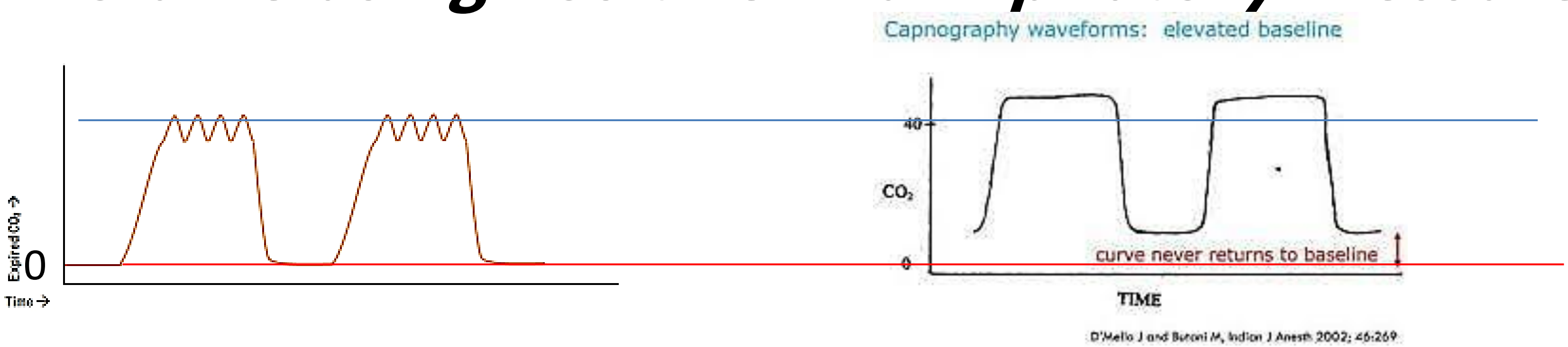
2. In pediatric anesthesia it can be difficult to produce and interpret $EtCO_2$ and the patients tidal ventilation can be diluted with FGF due to:

a) High respiratory rates.

b) Small tidal volumes.

Problems in practice and safety features

3. During prolonged expiration or End-expiratory pause, the gas flow reaches zero. The sampling line may aspirate gas from the trachea ,causing ripples on the $EtCO_2$ wave plateau resulting from cardiac oscillation (heart beat). It can be eliminated by increasing lung volume using Positive End Expiratory Pressure.



Problems in practice and safety features

4. ***Dilution of EtCO2 can occur whenever there are loose connections and system leaks.***

Oxygen concentration analyzer (O2 sensor or O2 Cell)

- ***Its fundamental to monitor oxygen concentration in the gas mixture delivered to the patient during general anesthesia.***
- ***The inspired O_2 concentration(FiO_2) is measured using:***

a) Galvanic method(slow response time)

b) Polarographic method(slow response time)

c) Paramagnetic method (rapid response time)

Oxygen concentration analyzer (O_2 sensor or O_2 Cell)

Problems in practice and safety features

1. ***Regular calibration of the analyzer is vital.***
2. ***Paramagnetic analyzers are affected by water vapor thus a water trap is incorporated in their design.***
3. ***The galvanic and polarographic cells have limited lifespan and need regular service.***
4. ***The galvainc and polarographic cells have slow response times of about 20-30 s with an accuracy of +/_3%.***

Nitrous oxide and inhalational agent analyzers

- *Modern vaporizers are capable of delivering accurate concentrations of the anesthetic agent(s) with different flows.*
- *Its important to monitor the inspired and end-tidal concentrations of the agents*
- *In the circle system the exhaled inhalational agent is re-circulated and added to the FGF.*
- *Modern analyzers measures the concentration of all agents(Halothane , Enflurane ,Isoflurane , Sevoflurane and Desflurane on a breath-by-breath basis.*

Nitrous oxide and inhalational agent analyzers

- ***In low-flow anesthesia ,the inhalational agent concentration the patient is receiving is different from the setting of the vaporizer concentration dial because Inhalational agent come from 2 sources:***

1-The Vapor that comes with FGF from the vaporizer. **+**

2- Re-circulated vapor from exhaled gases and the sampled gas from the patient.

Components

1. ***A sampling tube that transfers the gas and inhalational agent sample from the breathing system to the analyzer.***
2. ***A sample chamber to which the sample is delivered.***
3. ***An infrared light source.***
4. ***Optical filter.***
5. ***A photodetector.***

Problems in practice and safety features

1. ***Some designs are not agent-specific therefore they must be programmed by the user for each specific agent. Incorrect programming results in errors in measurement.***
2. ***Alarms can be set for inspired and expired inhalational agent concentration which allows meticulous administration of the desired level of anesthesia.***

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Part-IV

Temperature probes and Thermometry

- ***Monitoring a patient's temperature during surgery is one of the routine and vital monitoring parameters .it is important because:***

a) ***Most surgeries require keeping body temperature within the physiological range (36.6-37.2)∘C .Early detection of hypothermia or hyperthermia ,prevents related complications.***

Temperature probes and Thermometry

- ***Monitoring a patient's temperature during surgery is one of the routine and vital monitoring parameters .it is important because:***

a) ***b) Some special surgeries require lower than normal range body temperature.***
b) ***Difference between the peripheral and core temperatures give an idea about the cardiac output and volemic status specially in pediatric patients.***

Temperature probes and Thermometry

Skin (peripheral) temperature probe

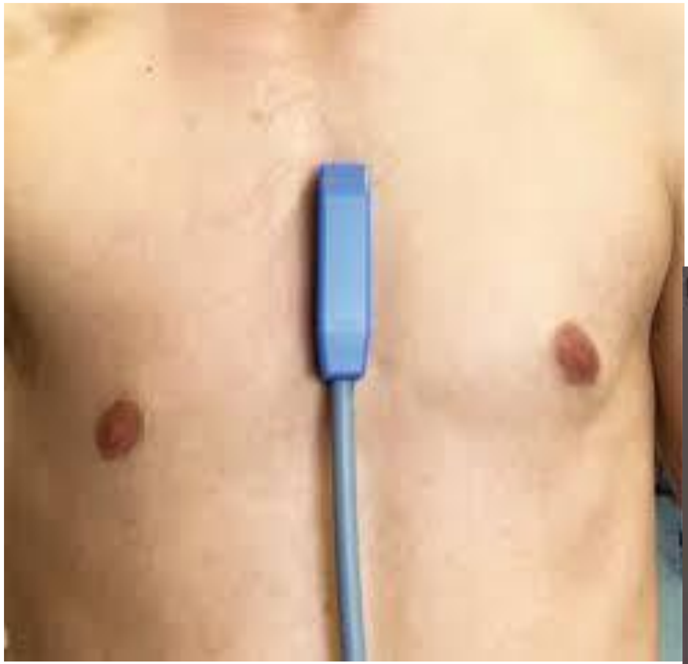
core temperature probe

Sites of body Temperature measurement

A. Skin (cutaneous) temp. the disc-like probe is applied to the skin:

1. *Of the forehead.*
2. *Over the sternum.*
3. *In the axilla which is the best location for monitoring muscle temp. making it most suitable for detecting malignant hyperthermia.*

Sites of body Temperature measurement

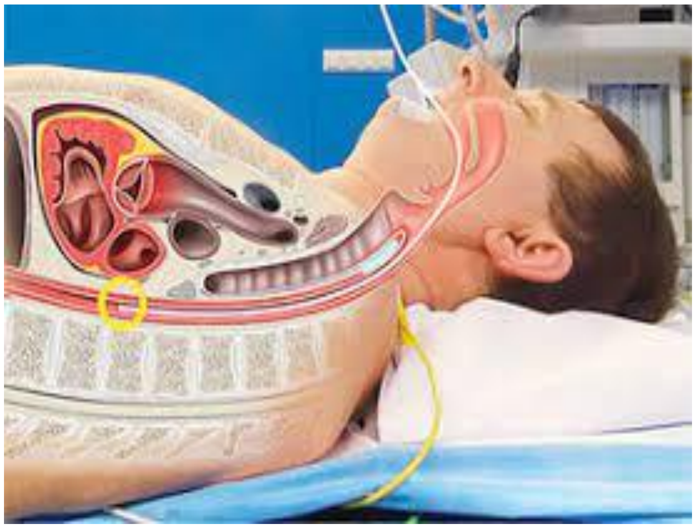


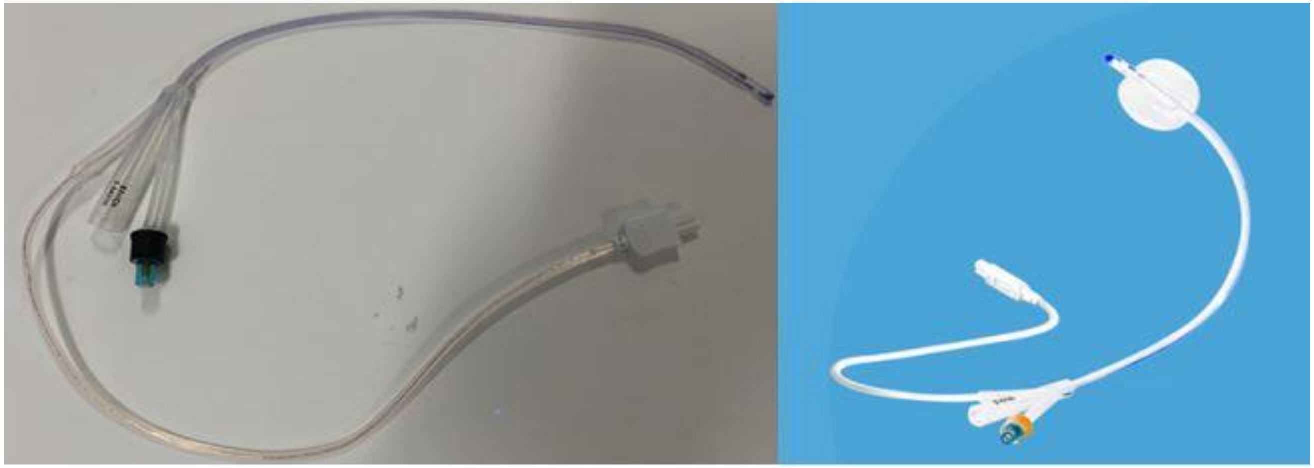
Sites of body Temperature measurement

B. Core temperature from :

1. *Rectal temp. which is not accurate and lags behind.*
2. *Esophageal temp. is accurate and the probe is placed in the lower esophagus.*
3. *Tympanic membrane temp. is more accurate than esophageal temp. and closely related to the brain temp.*
4. *Bladder temp. correlates well with the core temp. when there is normal urine output.*

Sites of body Temperature measurement





Invasive monitoring

1. ***Invasive arterial pressure monitoring (IBP monitoring).***
2. ***Central venous catheterization and pressure monitoring (CVP monitoring).***
3. ***Invasive cardiac output monitoring (CO monitoring).***
4. ***Balloon-tipped flow-guided pulmonary artery catheter.***
5. ***Esophageal Doppler hemodynamic measurement.***

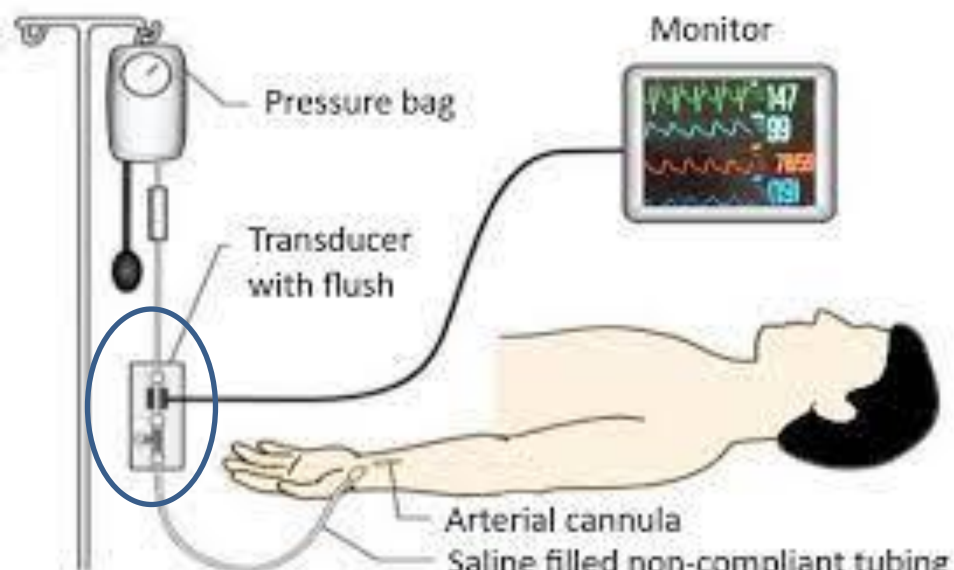
Invasive arterial pressure monitoring (IBP monitoring)

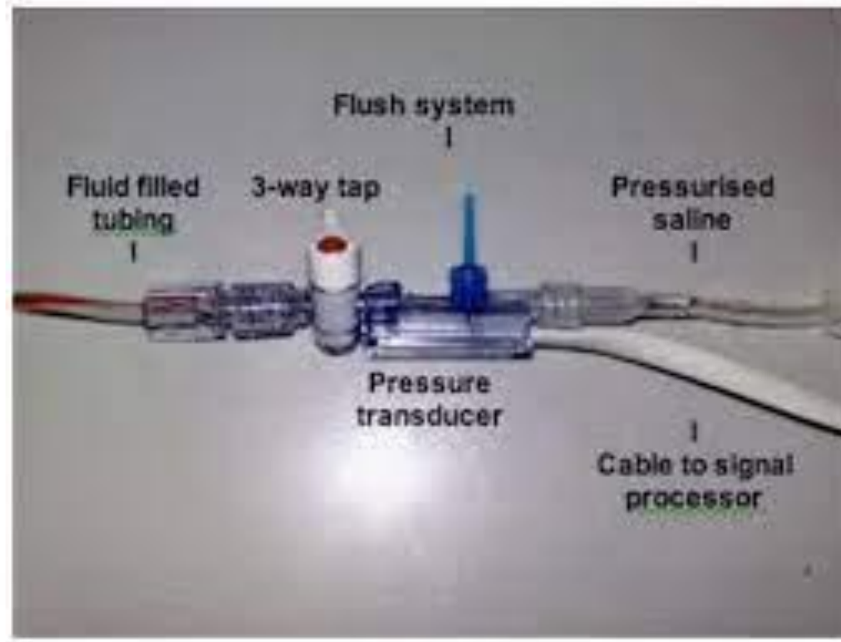
Provides beat-to-beat ,real-time accurate sustained blood pressure monitoring.

Components:

1. ***An arterial cannula.***
2. ***A heparinized saline column.***
3. ***A flushing device.***
4. ***A transducer ,changes mechanical signals to electrical signals.***
5. ***An amplifier.***
6. ***An oscilloscope.***

Invasive arterial pressure monitoring (IBP monitoring)



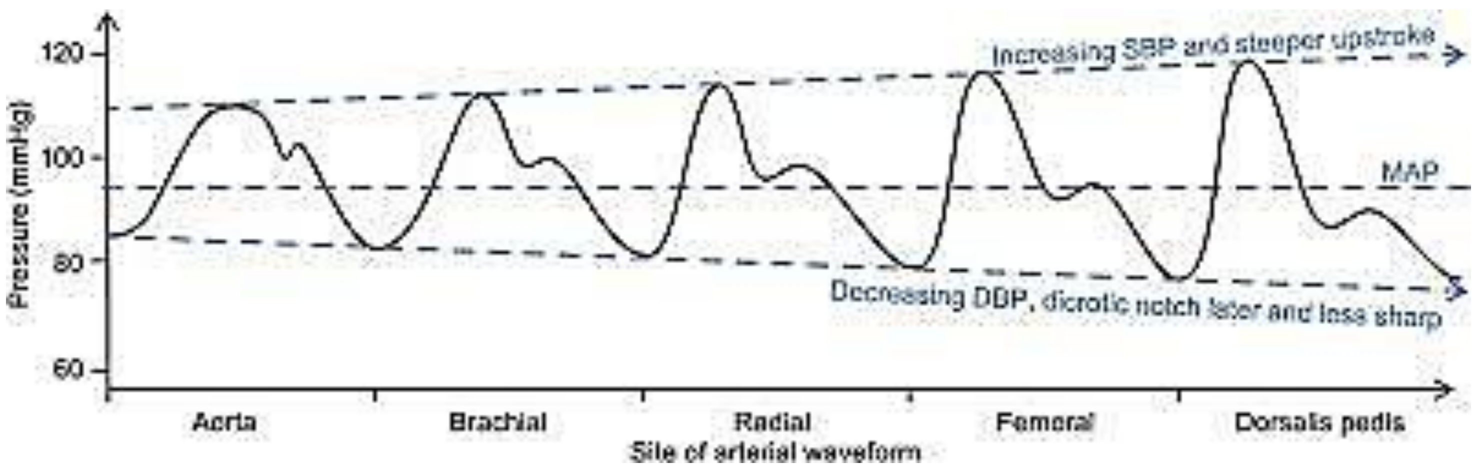


problems in practice and safety features

1. *The transducer should be positioned at the level of mid-axillary line, raising or lowering causes errors in reading.*
2. *Ischemia distal to the cannula is rare but catastrophic ,avoid repeated attempts for cannulation and cannulation for more than 24 h ,these minimizes ischemia.*
3. *Arterial pressure waves are wider in the peripheral arteries than in the central arteries like aorta ,Because of less elastic tissues in the wall of the peripheral arteries.*

Because of less elastic tissues in the wall of the peripheral arteries

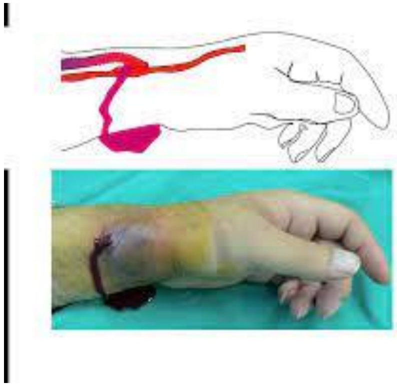
The systolic arterial pressure is higher and the diastolic arterial is lower in the more distal the artery is.



problems in practice and safety features

4. There is risk of bleeding due to disconnection.
5. Inadvertent drug injection causes distal vascular occlusion and gangrene. Thus arterial cannula must be clearly labelled.
6. Local infection<20%, systemic infection<5%.(common in cannulas for >4days with traumatic insertion).
7. Avoid infected ,traumatized sites for insertion.
8. Periodic checks and re-zeroing is necessary.

problems in practice and safety features

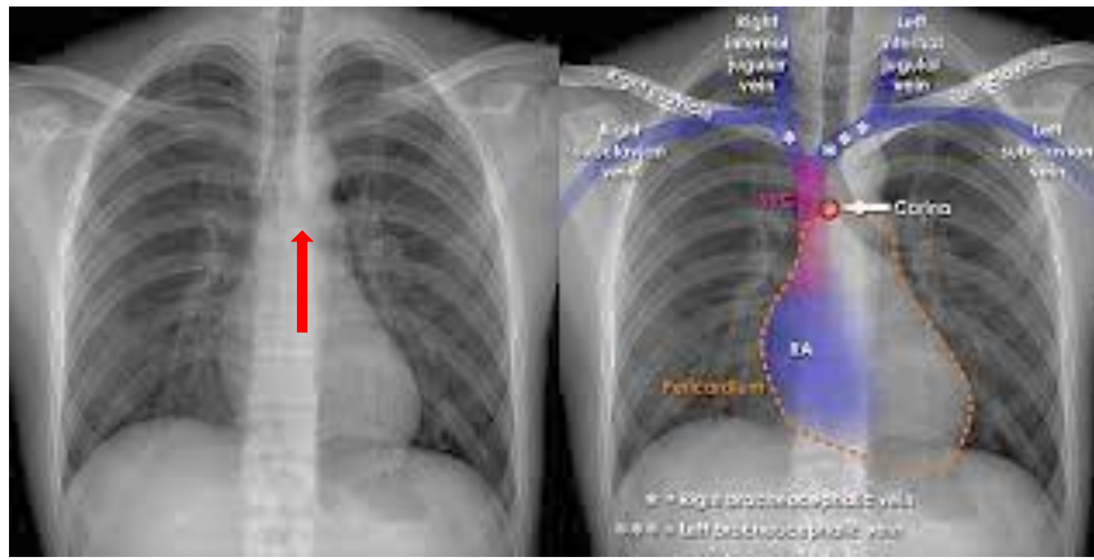




Central venous catheterization and central venous pressure monitoring (CVP monitoring).

1. *Is the Rt. atrial filling pressure.*
2. *It can be measured directly by using central venous catheter.*
3. *Manufactured in different sizes and lengths.*
4. *The tip of the catheter is radio-opaque and must be settled at the sternal angle(sterno-manubrial joint), T4 vertebra or carina level using ultrasound or fluoroscopy(X-ray).*

placement of the catheter tip

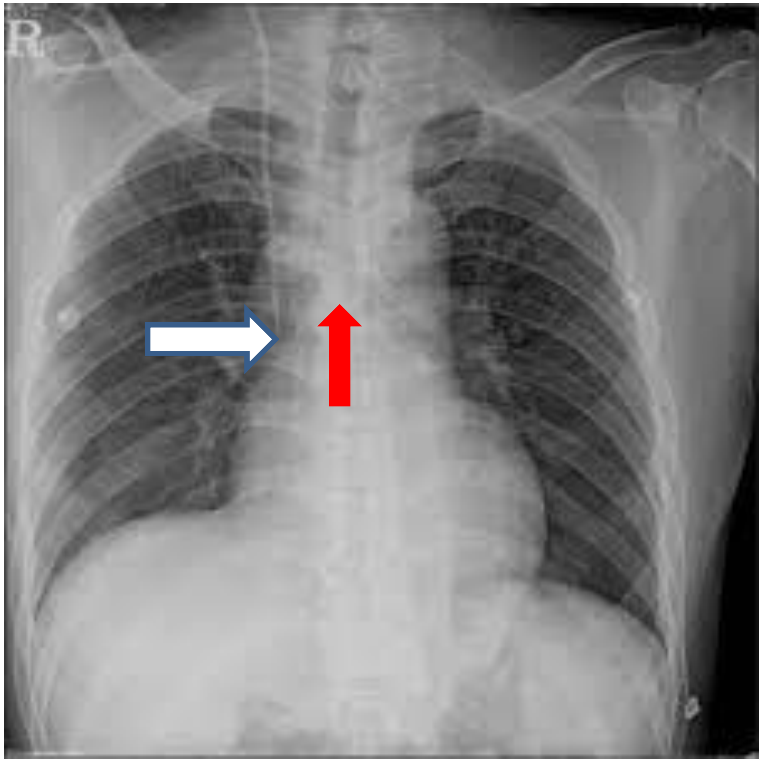
at the junction of SVC and Rt. Atrium which corresponds to the level of :



sternal angle=carina=T4 vertebra

placement of the catheter tip

at the junction of SVC and Rt. Atrium which corresponds to the level of :



sternal angle=carina=T4 vertebra

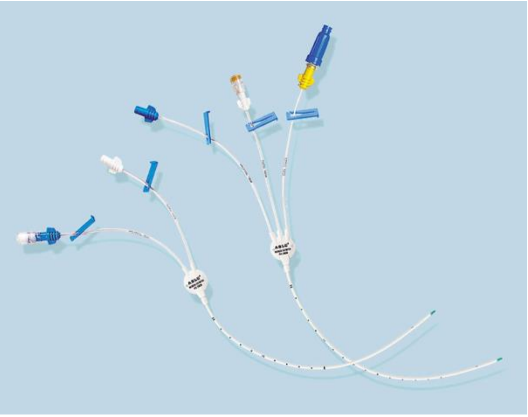
Main uses of central venous catheter

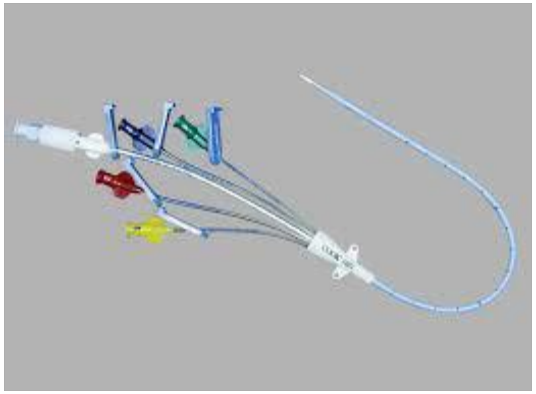
1. *CVP monitoring (used as a guide for fluid therapy).*
2. *Administration of (fluid , blood and parenteral nutrition).*
3. *Blood sampling.*

Special catheters are used for:

1. *Hemofiltration.*
2. *Hemodialysis.*
3. *Transvenous pacemaker placement*

Central venous catheters single ,double ,triple , Quadra and Penta lumen

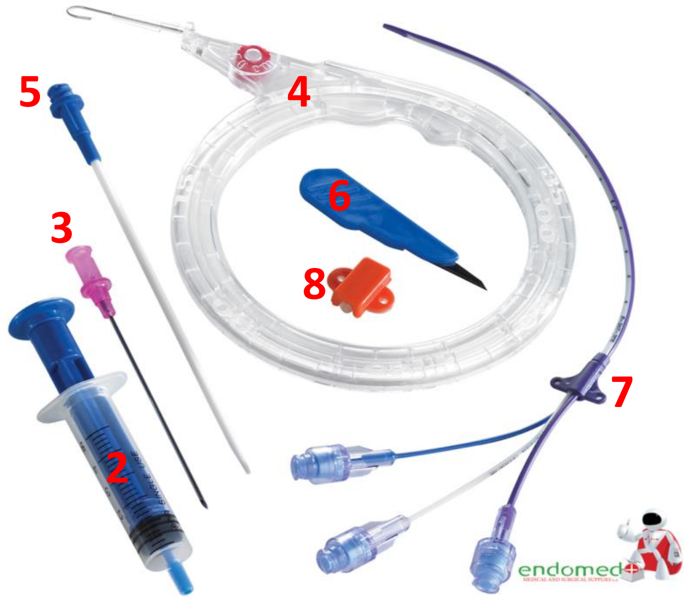




contents of Central venous catheter kit

Note: must be inserted using strict aseptic technique.

1. ***Open drape.***
2. ***Syringe.***
3. ***Trocar or introducer.***
4. ***Guide wire.***
5. ***Dilator.***
6. ***Scalpel.***
7. ***Central venous catheter.***
8. ***Cover for fixation to the skin.***



Routes of Central venous catheterization

Common sites:

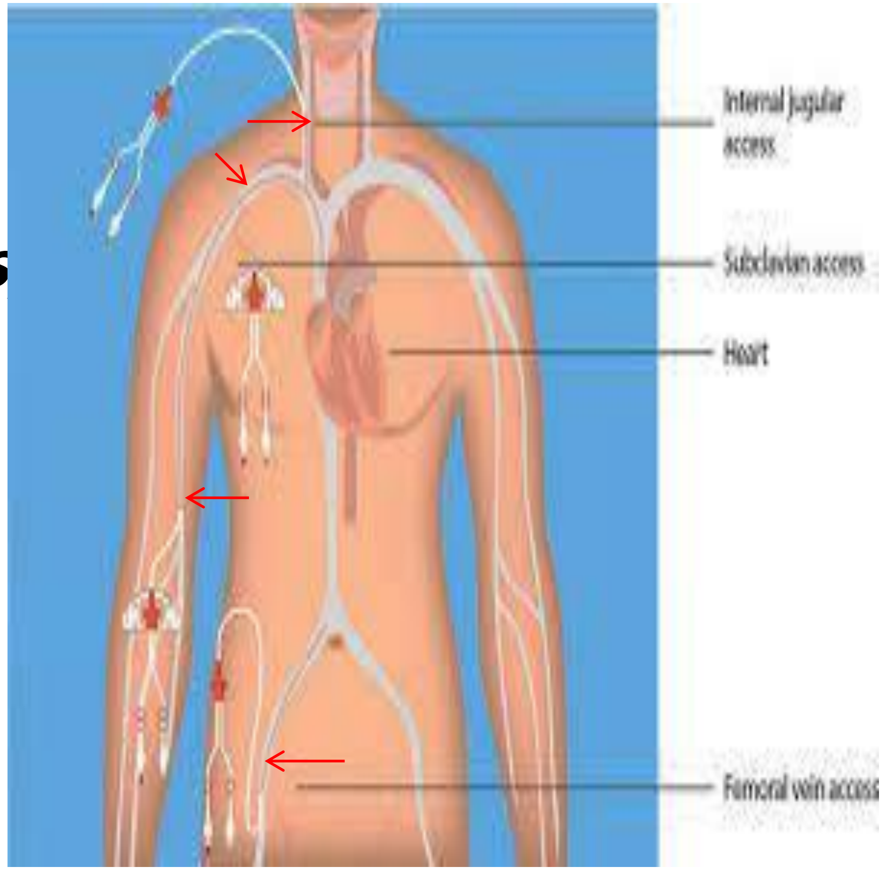
1. *Sub-clavian vein.*

(Highest rate of complications

1. *Internal jugular vein.*
2. *Basilic vein.*

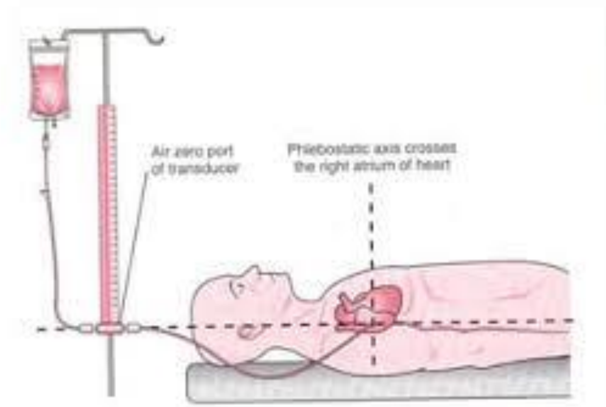
Less common sites:

1. *External Femoral vein.*
2. *External jugular vein.*

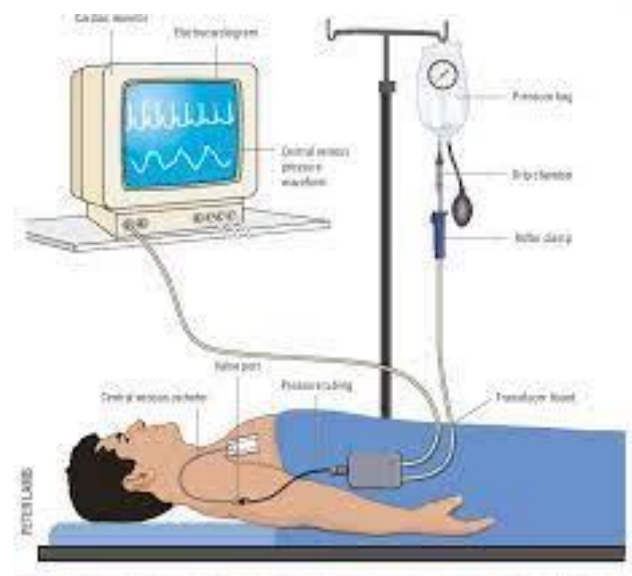


Measurement of Central venous pressure(CVP)

1. **By fluid manometer.**



2. **Pressure transducer.**



Note: zero reference point is at the mid-axillary line.

problems in practice and safety features

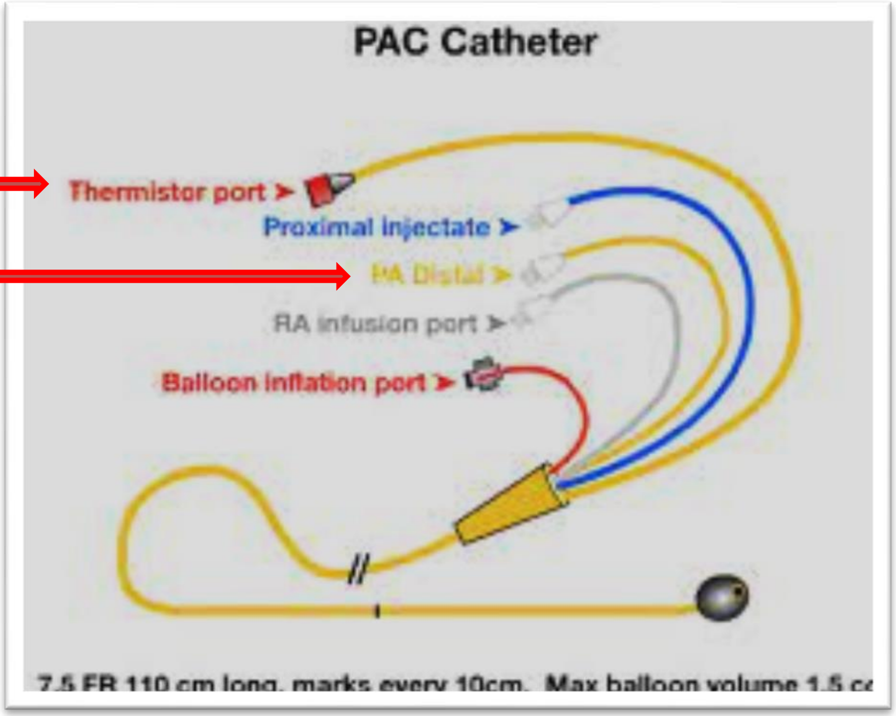
1. Inaccurate reading can be due to catheter blockade, improper positioning and incorrect zero level.
2. Pneumothorax injury to the nearby arteries and lymphatic duct ,Air embolism, hematoma formation, and tracheal injury.
3. Sepsis can be minimized with nowadays antibiotic+/- antiseptic covered catheters.
4. False passage.
5. Arrhythmias by catheter tip irritation of the atrium.
6. Venous thrombosis 40%
7. Microshock if the tip hits the myocardium using faulty electrical equipment which can produce ventricular fibrillation.

Balloon-tipped flow-guided pulmonary artery catheter.

1. *Pulmonary artery (PA) catheter are inserted via the internal jugular or subclavian veins.*
2. *They are floated through the Rt. Atrium to the Rt. Ventricle into the Pulmonary artery.*
3. *Available as sizes of 5-8 G and 110cm length.*
4. *Marked at 10cm intervals.*
5. *It's a more accurate guide for fluid therapy.*
6. *Have up to 5 lumens.*

PA catheter lumens

1. ***A themistor connected to a C.O. computer via 2 insulated wires, for cardiac output measurement.***



2. ***Distal lumen for PA and Pulmonary capillary wedge Pressure(PCWP) and to sample mixed venous blood.***

PA catheter lumens

3. Proximal lumen for :

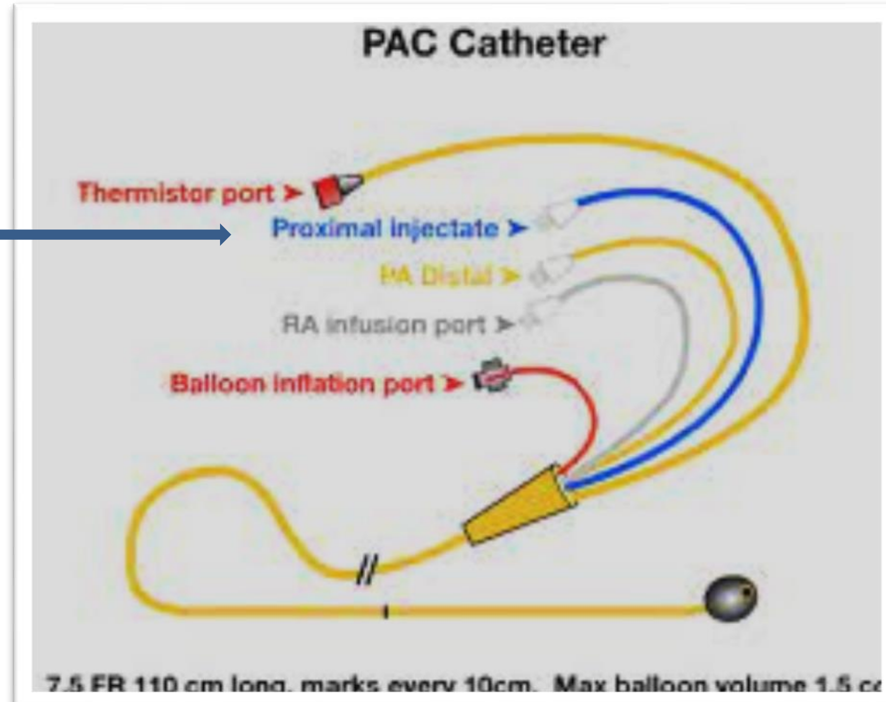
-CVP measurement.

-Administer injectate.

-To measure C.O. by thermodilution.

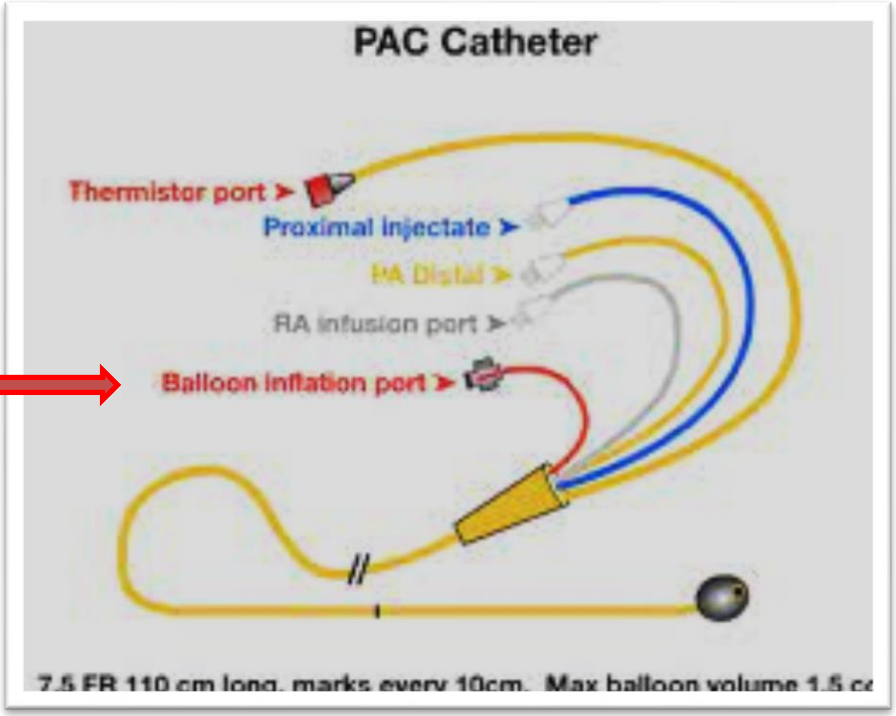
-fluid infusion.

-some designs make a more proximal lumen for drug infusions.

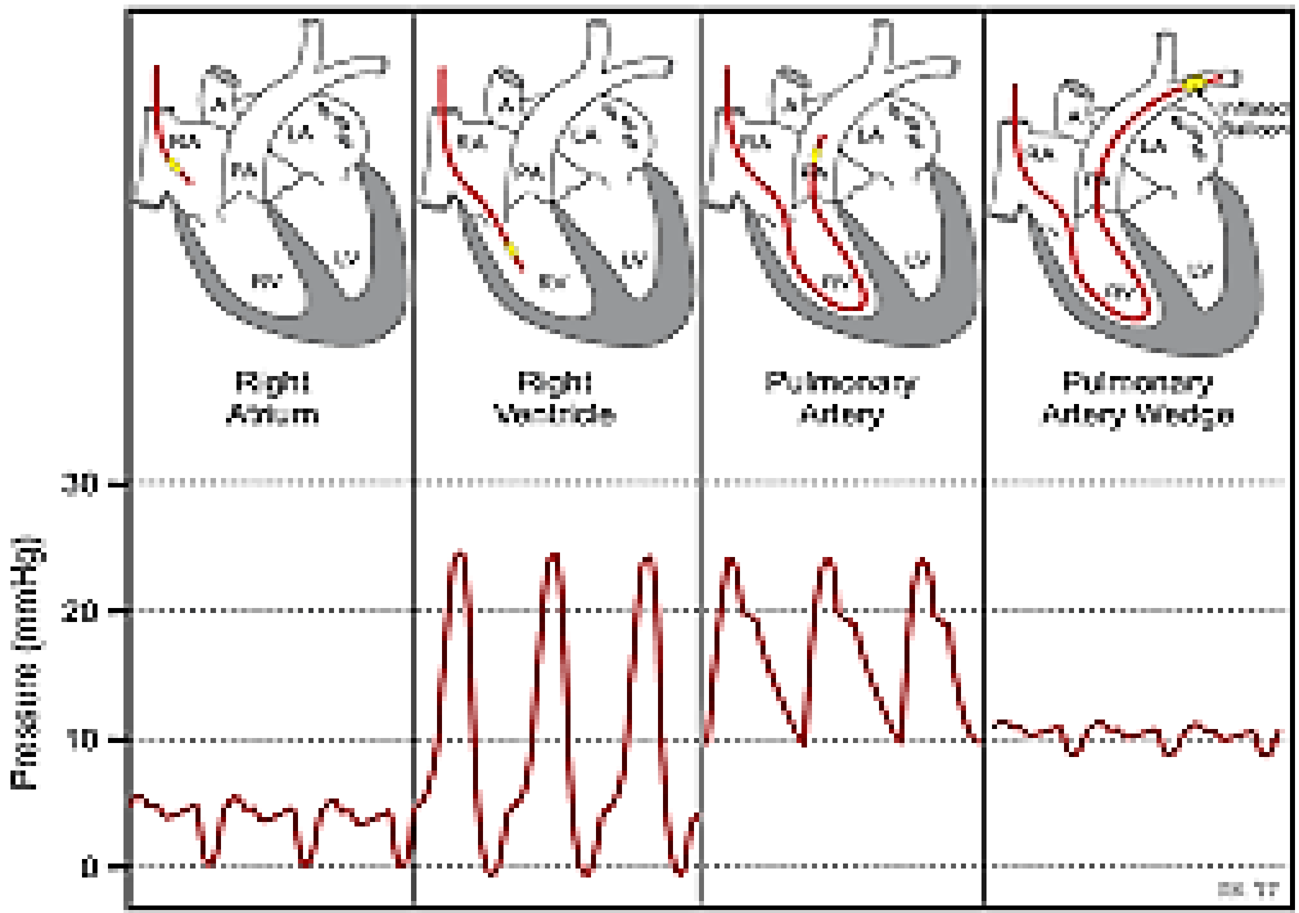


PA catheter lumens

4. Balloon inflation lumen to inflate it with 1.5 ml air to float.



PA floating catheter waveforms with advancement until it wedges in a branch of PA



Peripheral nerve stimulators

Assignment

Bispectral index

Assignment

Entropy

Assignment