University of Al- Mustaqbal
College Of Nursing

Critical Care Nursing

4th stage

semester 1

lecture 3+4

(Hemodynamic Monitoring)

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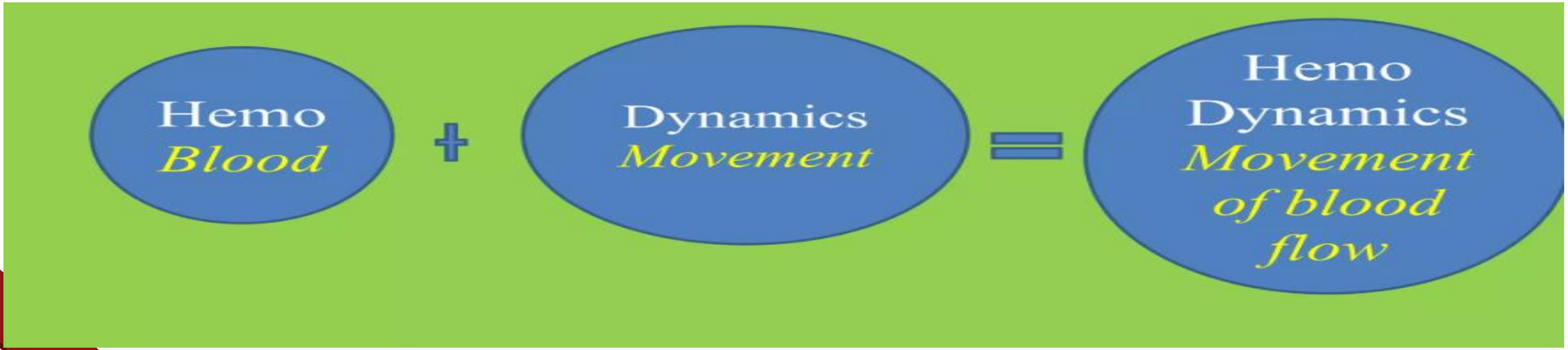
Cardiodynamics and Hemodynamics Regulation

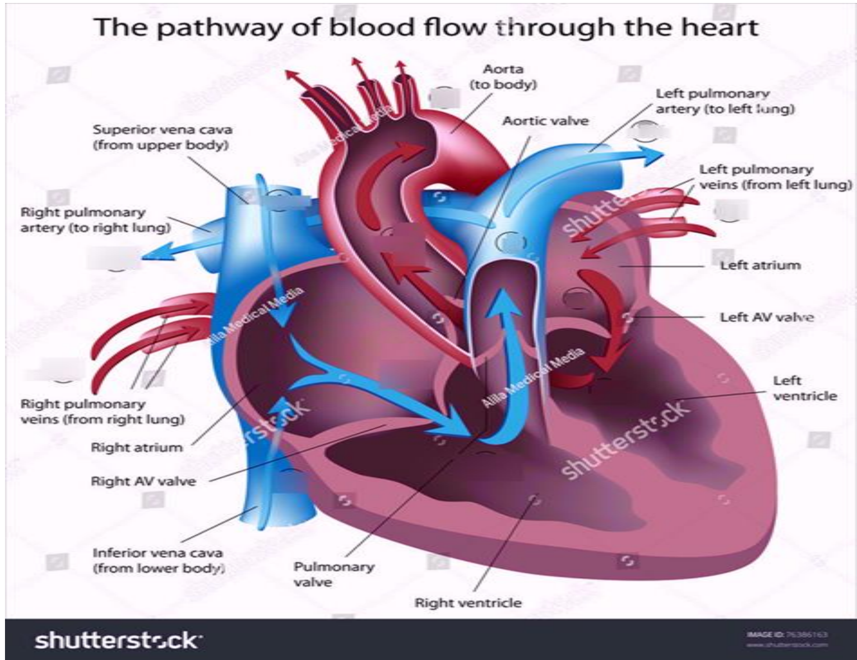
Hemodynamic is concerned with the forces generated by the heart and the resulting motion of blood through the cardiovascular system. These hemodynamic forces demonstrate themselves as blood pressure and blood flow.

Hemodynamic monitoring is the intermittent or continuous observation of physiological parameters pertaining to the circulatory system with a view to early detection of need for therapeutic interventions



Heart Anatomy and the Cardiac Cycle

- The heart located in the mediastinum between the lungs. Slightly left of the sternum.
- The heart consists of four chambers: the right and left atrium and the right and left ventricles.
- Major vessels lead into and out of the chambers, moving blood within the systemic and pulmonary systems.



Heart Anatomy and the Cardiac Cycle

The heart pumps blood through two main circuits:

•**Pulmonary circulation** (right heart):

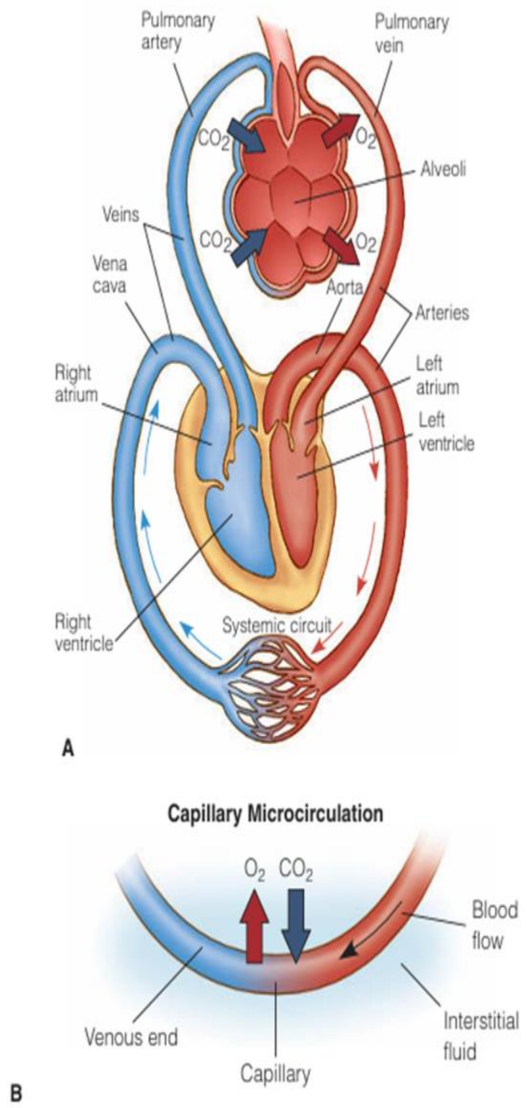
- Deoxygenated blood flows from the body
- → right atrium → tricuspid valve → right ventricle →
- pulmonary valve → pulmonary artery → lungs for oxygenation.

•**Systemic circulation** (left heart):

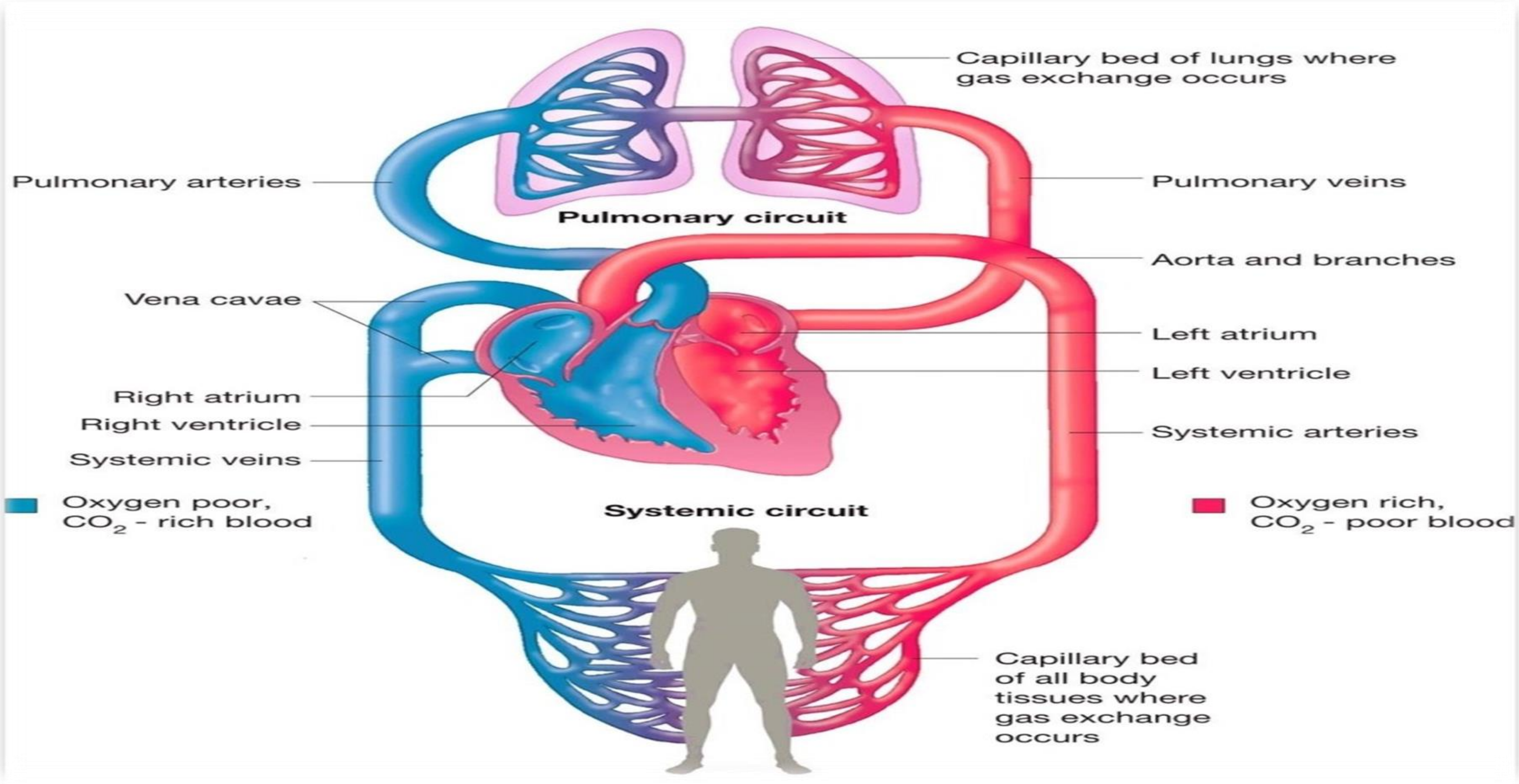
- Oxygenated blood from the lungs → through PA to

left atrium →MV → left ventricle → aorta

→ distributed to the body.



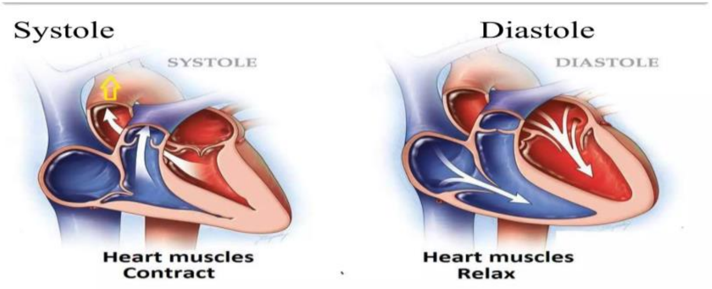
Heart Anatomy and the Cardiac Cycle

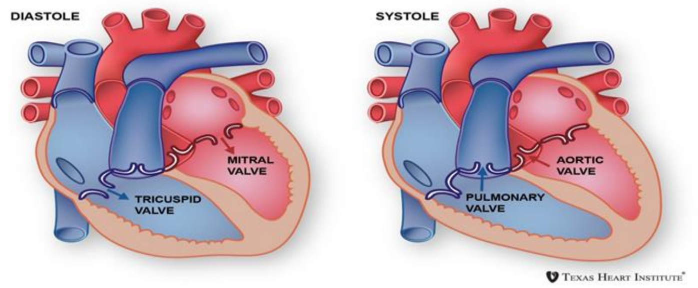


The Cardiac Cycle: Diastole and Systole

- The cardiac cycle is the sequence of events related to the flow of blood from the beginning of one heartbeat to the beginning of the next. It is divided into two phases: diastole and systole.
- The **diastolic phase(Relaxation Phase): during which the heart fills with blood. It** is further divided into the passive phase and the active phase.
- During the **passive phase**, when the heart is at rest, blood returning to the right and left atria creates a pressure exceeding that in the ventricles. At this point the tricuspid and mitral valves open, allowing blood to passively fill the right and left ventricles.
- The active phase immediately follows this passive filling. During this phase the atria contract and empty, fully filling the ventricles.
- This atrial contraction makes up 20% to 30% of the cardiac output and is an important contribution to the filling of the ventricles.
- **Systole (Contraction Phase): a period of contraction.**

- 70% of blood flows into the ventricles passively
- Other 30% from atrial contraction





PURPOSE OF HEMODYNAMIC

Hemodynamic monitoring is the assessment of the **cardiovascular system's ability to perfuse tissues and deliver oxygen** to the body.

- Evaluate cardiovascular system . Pressure, flow, resistance
- Establish baseline values and evaluate trends.
- Determine presence and degree of dysfunction
- Implement and guide interventions early to prevent problems

Concepts in Basic Hemodynamics

1. **Blood Pressure:** is determined by the flow through the vessels and the vessel resistance. The peak pressure is known as the systolic pressure and the lowest point of the pressure is known as the diastolic pressure. The difference between the systolic and diastolic pressure is known as the **pulse pressure(30-50).**

- **The mean arterial pressure (MAP):** is the average pressure over one cardiac cycle. The MAP is thought to be a very good estimate of the perfusion seen by the organs. A MAP 70–105 mmHg
- **MAP is the driving force for organ perfusion. A MAP of ≥ 65 mmHg is a critical target in shock.**
- **MAP = [Systolic +(2 x Diastolic)] / 3**
- MAP =[110+(2*80)] /3=270/3=90

2.Cardiac Output

- **The cardiac output (CO)** is the volume of blood ejected by the left ventricle every minute. The normal value is **4 to 8 L**/min.
- CO is determined by the heart rate (HR) * stroke volume (SV).
- **Stroke volume : (60–100** mL/beat) is the volume of blood ejected from each ventricle with each heartbeat. **SV = CO / HR**
- SV (mL/beat) = [CO (L/min)] / HR (beats/min) * 1000
- The primary factors that determine stroke volume are preload, afterload, and contractility.
- Preload : Amount of Blood coming into the heart.

Preload is the stretch on the ventricular myocardium at end diastole.

- **Example 1: Calculating Cardiac Output (CO)**
- **Scenario:** A patient has a heart rate of **72 beats per minute (bpm)** and a stroke volume of **70 mL per beat**. What is their cardiac output?
- **Formula:** CO = HR × SV
- **Calculation:**

1. CO = 72 beats/min × 70 mL/beat
2. CO = 5040 mL/min
3. To convert to the standard unit (L/min), divide by 1000: 5040 / 1000 = **5.04 L/min**

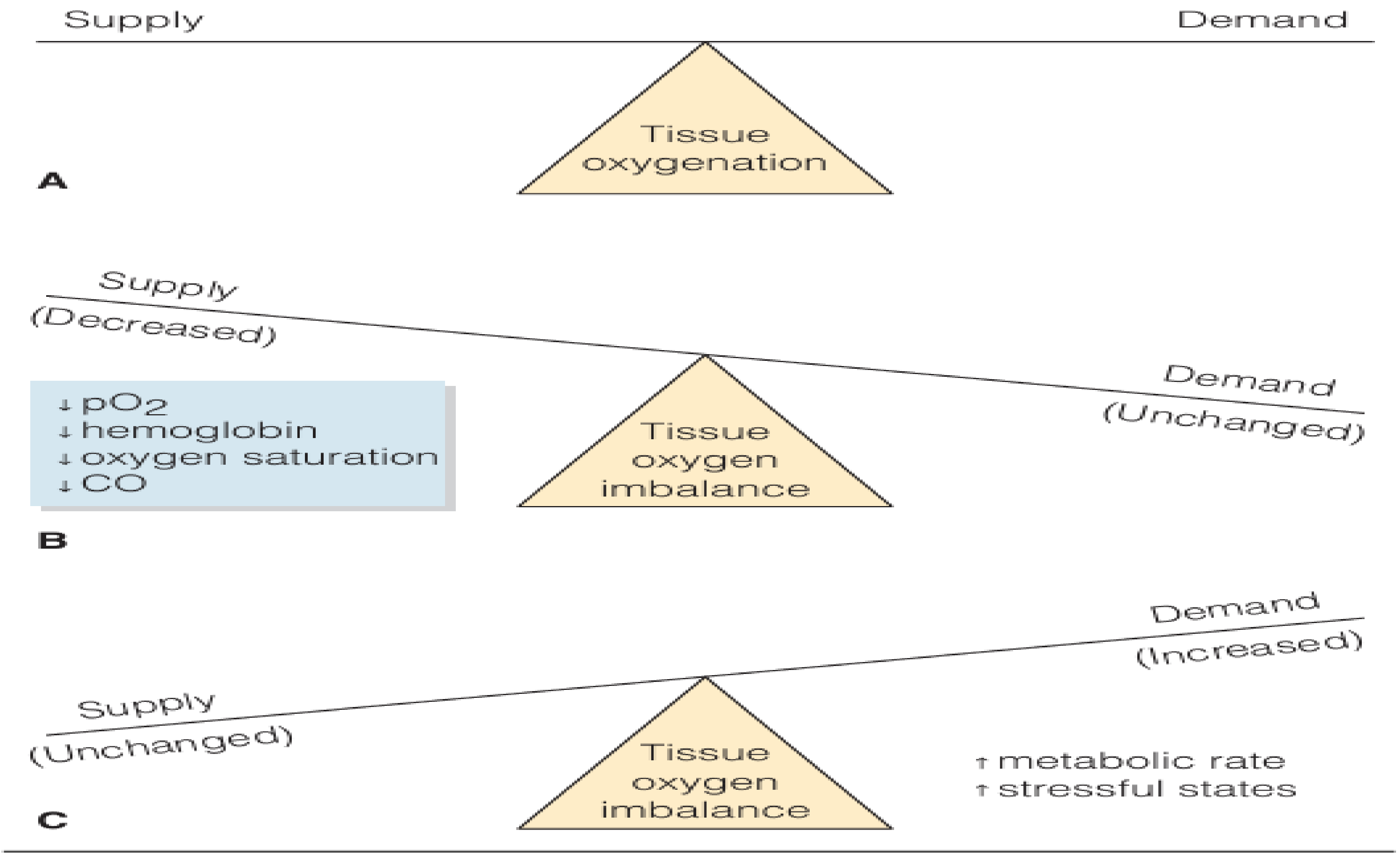
2.Cardiac Output

- **Afterload** is the pressure (resistance) against which the right or left ventricle has to pump to eject the blood.
- How much pressure or resistance the heart has to work against **Afterload**
- **Contractilit**y is the ability of the myocardium to shorten the muscle fibers. Contractility of the heart is influenced by electrolytes (particularly potassium and calcium), acid base abnormalities, and myocardial oxygen supply/ demand abnormalities.
- **How well the heart works – Contractility**

3. Tissue Oxygen Supply and Demand

- The primary goal of the cardiovascular system is to maintain a balance between oxygen supply to the tissues and oxygen demand of the tissues at any given time. An imbalance of oxygen supply and demand can lead to tissue hypoxia, cellular death, and eventual organ failure.
- Oxygen supply to the tissues is dependent on how much oxygen is in the arterial bloodstream (oxygen content) and how effectively that oxygen content is being delivered to the tissues.
- Oxygen demand is the tissue’s need for oxygen.

Tissue Oxygen Supply and Demand



Factors affecting the hemodynamic conditions

These factors can be categorized based on which part of the cardiovascular system they primarily impact: the **Pump (Heart)**, the **Pipes (Vessels)**, or the **Volume (Blood)**.

I. Factors Affecting the PUMP (Heart: Cardiac Contractility & Rate)

- These factors influence the heart's ability to generate sufficient **Cardiac Output Myocardial Oxygen Supply & Demand Balance:**
- **Myocardial Oxygen Supply & Demand Balance:**
  - **Ischemia/Infarction (Heart Attack):** reducing stroke volume and cardiac output.
  - **Coronary Artery Disease:** Narrowed arteries limit oxygen delivery to the myocardium, impairing contractility, especially during stress.
- **Cardiac Rhythm and Conduction:**
  - **Tachyarrhythmias** :The heart beats so fast that ventricular filling time is reduced, drastically lowering stroke volume and CO.
  - **Bradyarrhythmias** (e.g., Heart Block, Sinus Bradycardia): The heart rate is too low to generate adequate CO.
- **Structural Heart Problems:** (**Cardiomyopathy,Valvular Disorders**

Factors affecting the hemodynamic conditions

2. Factors Affecting the PIPES (Vasculature: Preload & Afterload)

A. Systemic Vascular Resistance (SVR - Afterload):

- **Increased SVR (Vasoconstriction):**
  - **Physiological Compensation:** Sympathetic nervous system activation in hypovolemia or heart failure.
  - **Pathological:** Hypertension, vasopressor drugs (Norepinephrine), hypothermia.
- **Decreased SVR (Vasodilation):**
  - **Sepsis/SIRS:** Inflammatory mediators cause profound vasodilation.
  - **Vasodilator Drugs:** Nitroglycerin, Nitroprusside, ACE inhibitors.

B. Venous Tone and Capacitance (Preload):

- **Venoconstriction:** Shifts blood from the periphery to the central circulation, *increasing* preload. (Caused by sympathetic stimulation).
- **Venodilation:** Pools blood in the periphery, *decreasing* preload. (Caused by nitrates, anesthesia, sepsis).

C. Blood Vessel Integrity:

- **Increased Permeability ("Leaky Capillaries"):** Seen in sepsis, burns, and anaphylaxis. Fluid leaks out of the vasculature into the tissues, reducing effective circulating volume and preload.

Factors affecting the hemodynamic conditions

2. Factors Affecting the VOLUME (Blood: Preload)

These factors determine the actual volume of fluid available to fill the heart and vessels.

- **Absolute Volume Changes:**

Volume Loss (Hypovolemia): Hemorrhage, Fluid Losses, Inadequate Intake

Volume Excess (Hypervolemia): Fluid Overload: Excessive IV fluid administration, renal failure (low urine output), heart failure (causing secondary renal retention).

- **Relative Volume Changes (Distribution):**
- Third-Spacing: Fluid is sequestered in a non-functional extracellular space, making it unavailable for circulation.

Examples: Ascites (liver failure), pleural effusions, intestinal edema (from sepsis/burns), capillary leak syndrome.

IV. Integrated and External Factors

These factors impact multiple components of the system simultaneously.

- **Autonomic Nervous System:**

Sympathetic Nervous System ("Fight or Flight"): Increases HR, contractility, and SVR. This is the primary short-term compensatory mechanism for hypotension.

Parasympathetic Nervous System ("Rest and Digest"): Decreases HR via the Vagus nerve.

- **Respiratory Interactions:**

Mechanical Ventilation: Positive pressure ventilation decreases preload by increasing intrathoracic pressure, which can reduce venous return.

- **Metabolic Demand:**

Fever: Increases metabolic rate and demand for oxygen, leading to increased CO and HR.

- **Pharmacological Sedation & Anesthesia:**

Most anesthetic and sedative agents (e.g., Propofol, Midazolam) cause vasodilation and myocardial depression, leading to decreased preload, and contractility.

Types of Hemodynamic Monitoring

A. <u>**Noninvasive Hemodynamic Monitoring**</u>

- Vital signs (Noninvasive BP monitoring, HR, RR, Temp.)
- Clinical assessment
- ECG

B- <u>**Invasive Hemodynamic Monitoring**</u>

Central Line , Arterial Line , **Central venous pressure** CVP, Pulmonary artery catheter (PAC).

Types of Hemodynamic Monitoring

A. Non-Invasive & Basic Monitoring :

1. Vital Signs:

- **Noninvasive BP Monitoring**
- Blood Pressure (BP): Differentiate between systolic (contractile force), diastolic (vascular tone), and Mean Arterial Pressure (MAP).
- **Heart Rate (HR) & Rhythm:** Tachycardia is an early compensatory mechanism for low stroke volume. Bradycardia can indicate hypoxia, ischemia, or elevated ICP. Arrhythmias (e.g., Atrial Fibrillation) can devastate cardiac output.
- **Respiratory Rate (RR) & Effort:** Tachypnea can signal hypoxia, acidosis, or pulmonary edema. Accessory muscle use indicates significant work of breathing.
- **Oxygen Saturation (SpO_2):** A non-invasive estimate of hemoglobin saturation. **Remember its limitations** (e.g., poor perfusion, carbon monoxide poisoning).

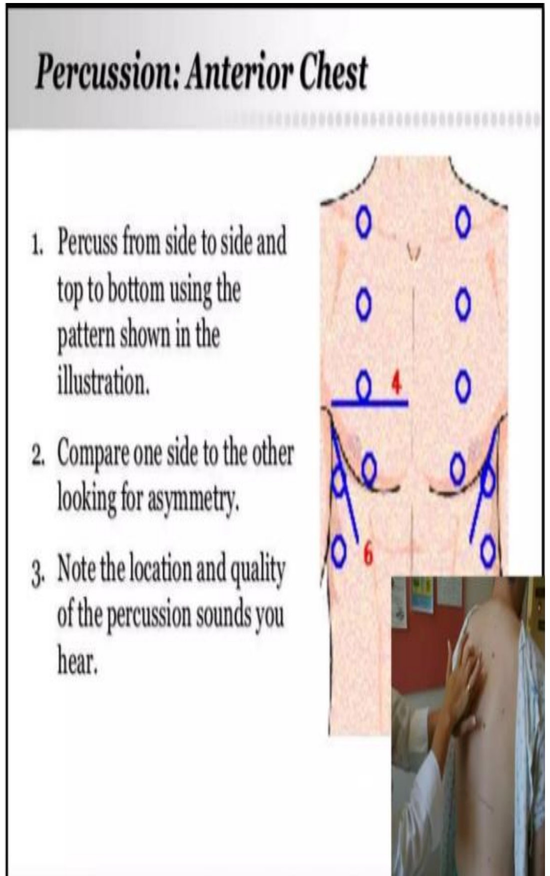
Types of Hemodynamic Monitoring

Clinical Assessment

- Physical examination
- inspection:
- Palpitation:
- Percussion:
- Auscultation:

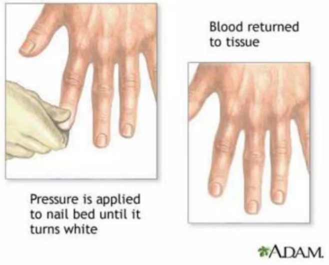
- Precordium

  Inspect anterior chest for heaves and an increase in visible pulsations

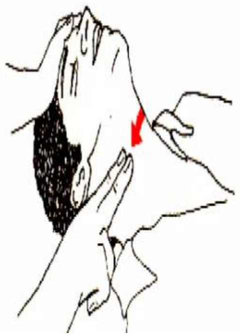


Inspect the neck for jugular venous distension

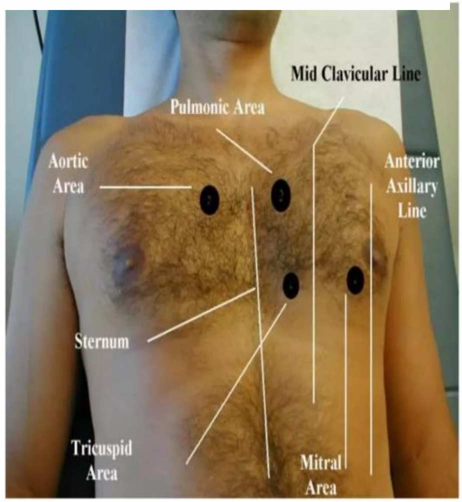
- Palpate the peripheral pulses and check nail bed capillary refill



Auscultate and palpate the carotid arteries



- Ausultate the aortic, pulmonic, second pulmonic, mitral and tricuspid areas of the precordium



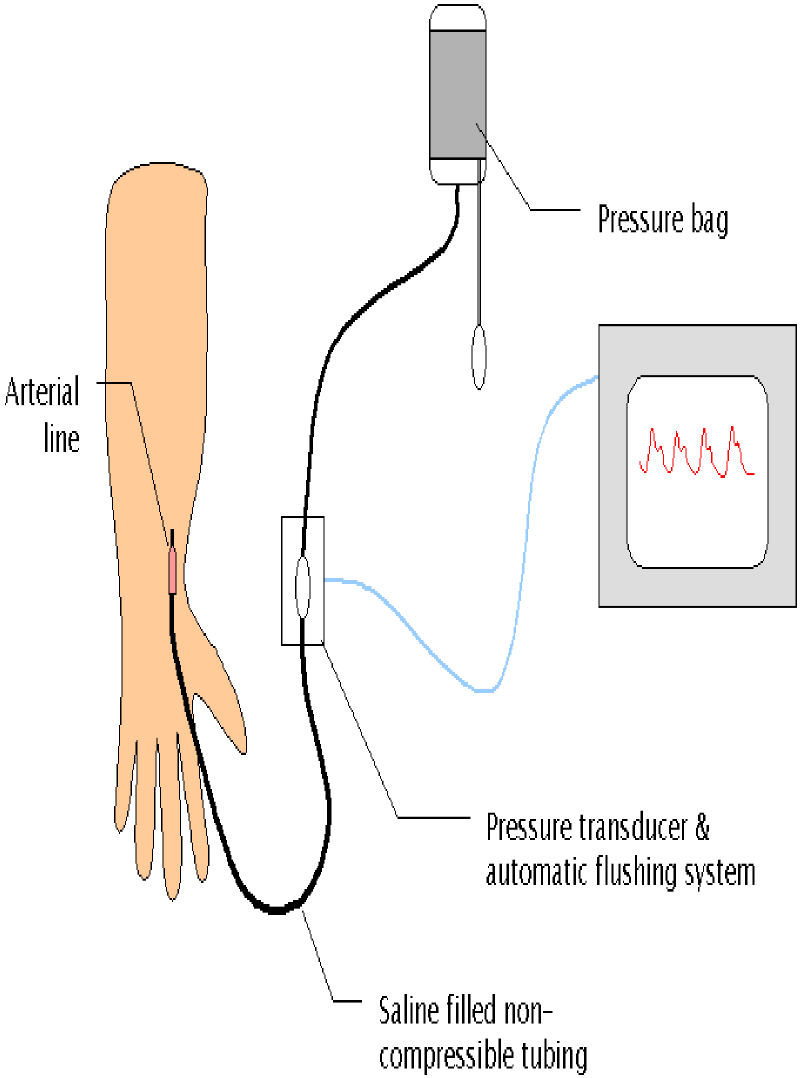
Types of Hemodynamic Monitoring

Clinical Assessment

- **Mental Status:** Agitation, confusion. The brain is exquisitely sensitive to hypoperfusion.
- **Skin:** Cool, clammy, cyanotic = poor perfusion (e.g., cardiogenic, hypovolemic shock). Warm, flushed, dry = vasodilation (e.g., septic, neurogenic shock).
- **Capillary Refill:** Normal Capillary Refill: ≤ 2 seconds. **> 2** seconds is a clear sign of poor peripheral perfusion and shock.
- **Urine Output (UOP):** The gold standard for end-organ perfusion. Measured via Foley catheter.
- **Target: > 0.5 mL/kg/hr.** A drop in UOP is often the first sign of **worsening hemodynamics.**
- **normal 24-hour urine output is 800 mL to 2 L. Output less than 400-500 mL/24hr (approximately 20 mL/hr) is severely low and is often classified as anuria**

Hemodynamic Monitoring

- **Blood Pressure**
  - Can be measured intermittently with a cuff or continuously with an arterial line
  - BP does not reflect CO – BP can be high with a low CO if vasoconstriction occurs and vice versa
- **Cardiac Output (CO)**
  - Usually measured by thermodilution PA catheter
  - Can also be measured by dye dilution, transesophageal Doppler, echo.
- **EKG**
  - Monitors rate and rhythm of heart



Respiratory Monitoring

- ABGs
  - Monitors acid-base balance, PaO_2, and $PaCO_2$
- Oxygen Saturation
  - SpO_2, measures the proportion of saturated to desaturated hemoglobin
  - Requires adequate perfusion for accuracy
  - Oxygenation is OK if SpO_2 >90%

Organ and Tissue Oxygenation

- Global measures
  - **Reflect the adequacy of total tissue perfusion** but could be normal with local perfusion abnormalities
  - **Increased lactate concentration** and metabolic acidosis suggests anaerobic metabolism and **inadequate tissue oxygenation**…lactate also increases with liver failure and sepsis, though
  - SvO2 <55% indicates global tissue hypoxia

Organ and Tissue oxygenation

- **Organ-specific Measures**
  - **Urine flow**
    - A sensitive indicator of renal perfusion provided the kidneys aren’t damaged
    - Normal is 1ml/kg
  - **Core-peripheral temperature**
    - The gradient between peripheral (skin) temp and core (rectal) is often used as an index of peripheral perfusion
    - The less perfusion, the colder the periphery
  - **Neurological monitoring**
    - Utilizes GCS, ICP measurement

Invasive Hemodynamic Monitoring

Arterial Pressure Monitoring

- An arterial line is a cannula usually positioned in a peripheral artery
- **Purpose :**
- facilitate monitoring of hemodynamic status by providing information about ABP readings.
- obtain hemodynamic data necessary for regulating vasoactive medication & fluid administration.
- Arterial blood gas sampling.

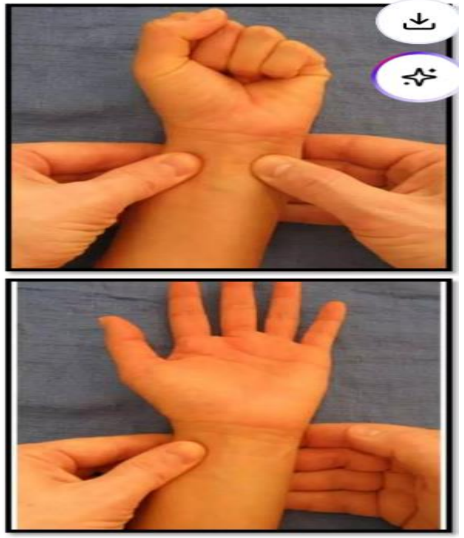
Insertion and Management

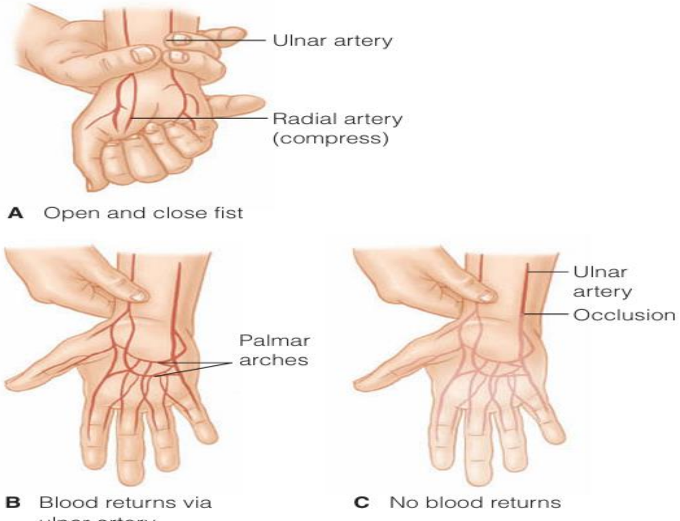
- Radial
- femoral
- Brachial
- axillary
- or dorsalis pedis arteries.
- Radial and femoral arteries are most commonly used, and radial arteries are preferred due to decreased risk of infection and complications.
- The dorsalis pedis artery is used infrequently due to its distance from central circulation.

Prior to inserting a catheter in the radial artery, an **Allen's test** should be performed to test the patency of the radial and ulnar arteries in the event that the radial artery becomes occluded.

Allen test

- To assess collateral perfusion
- The test is performed by asking the patient to clench their hand. The ulnar and radial arteries are occluded with digital pressure.
- The hand is unclenched and pressure over the ulnar artery is released. If there is good collateral perfusion, the palm should flush in less than 6 seconds.



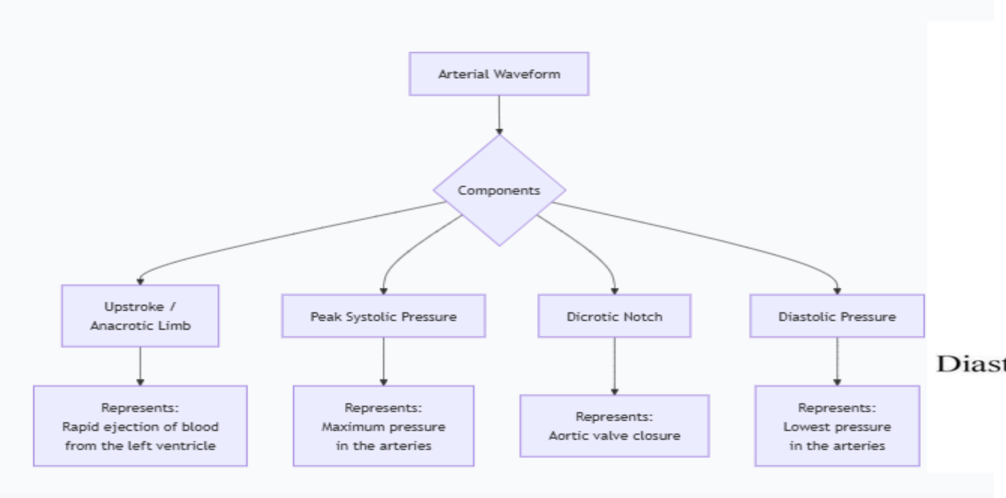


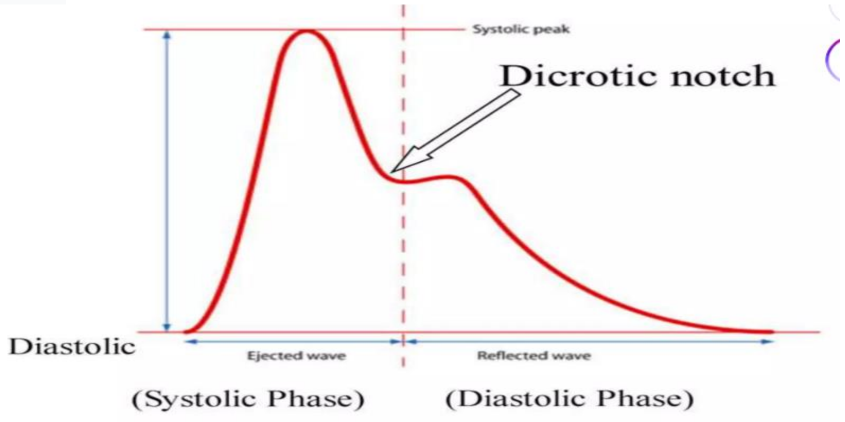
Nursing Responsibilities

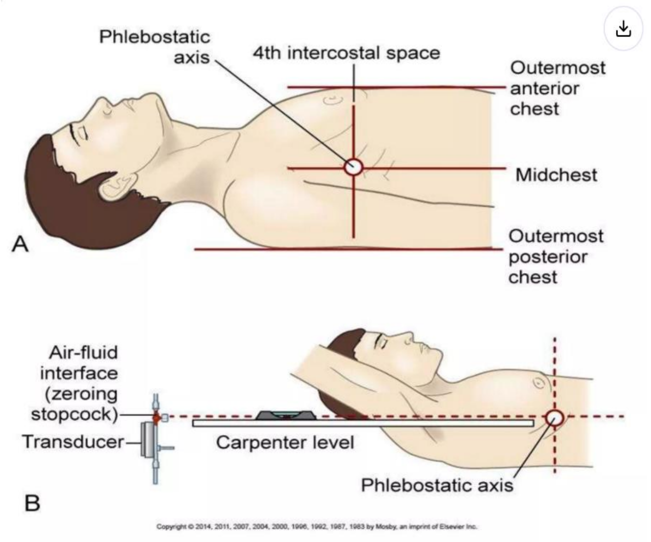
- **Transducer Setup & Leveling:**
  - **Phlebostatic Axis:** The reference point for leveling. Found at the 4th intercostal space, mid-axillary line. This approximates the level of the right atrium.
  - **Incorrect leveling is a major source of error:** Leveling too low gives a falsely high reading; leveling too high gives a falsely low reading.
  - **Zeroing:** The transducer is opened to atmospheric pressure and the monitor is "zeroed." This negates the effect of atmospheric pressure on the reading.

Waveform Analysis:

- **Normal:** Crisp, sharp upstroke (systole), dicrotic notch (aortic valve closure), and gradual downslope (diastole).







Complication Vigilance:

- **Distal Ischemia:** Check pulses (radial, ulnar), color, temperature, capillary refill, and sensation (CSM checks) every 1-2 hours.
- **Hemorrhage:** The line is under arterial pressure; a disconnection can lead to rapid exsanguination. All connections must be -locked.
- **Infection:** Maintain aseptic technique with dressing changes and cap changes.
- **Nerve Damage:** From improper insertion or hematoma formation.
- accidental intra-arterial injection of drugs
- local damage to artery

Central line

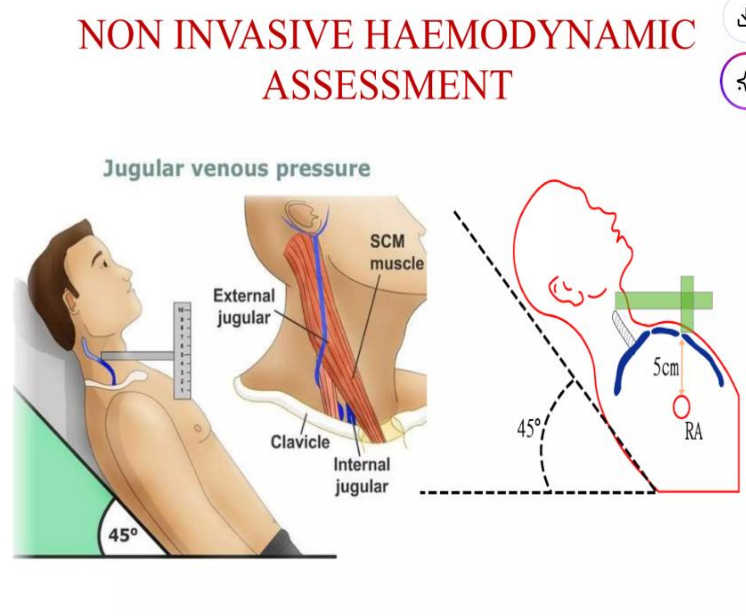
- It is a catheter that provides venous access via the superior vena cava or right atrium.

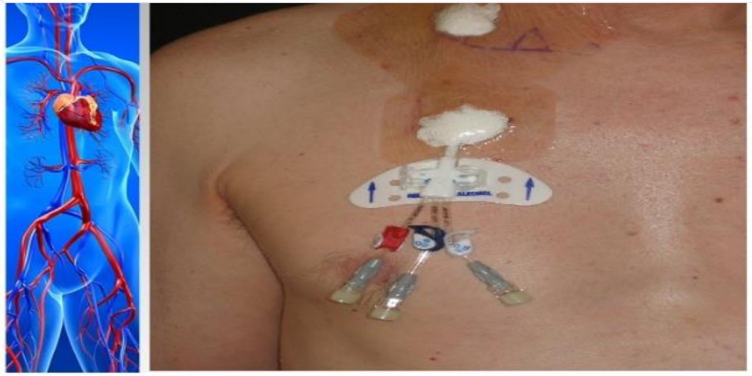
Purpose :

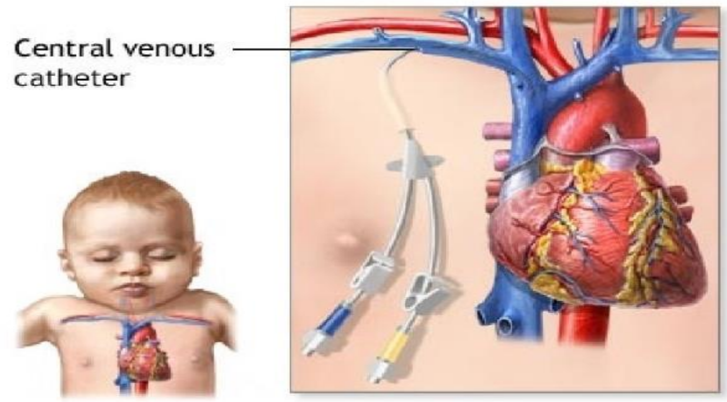
- Permits administration of medication & nutritional support that should not be given via a peripheral route or when standard peripheral route cannot be used .

Central Venous Pressure (CVP) Monitoring

- is the pressure within the superior vena cava or the right atrium to provide information about the body volume status & right ventricular function**.**
- **Normal CVP= 0 - 8 mmHg or 3-8 cm H2O**
- **- If less than 0 mean Hypovolemia**
- **- If more than 8 mean Hypervolemi**a.
- CVP reflects the amount of blood returning to the heart and the ability of the heart to pump the blood into the arterial system.







common central line insertion sites:

1- Right internal jugular

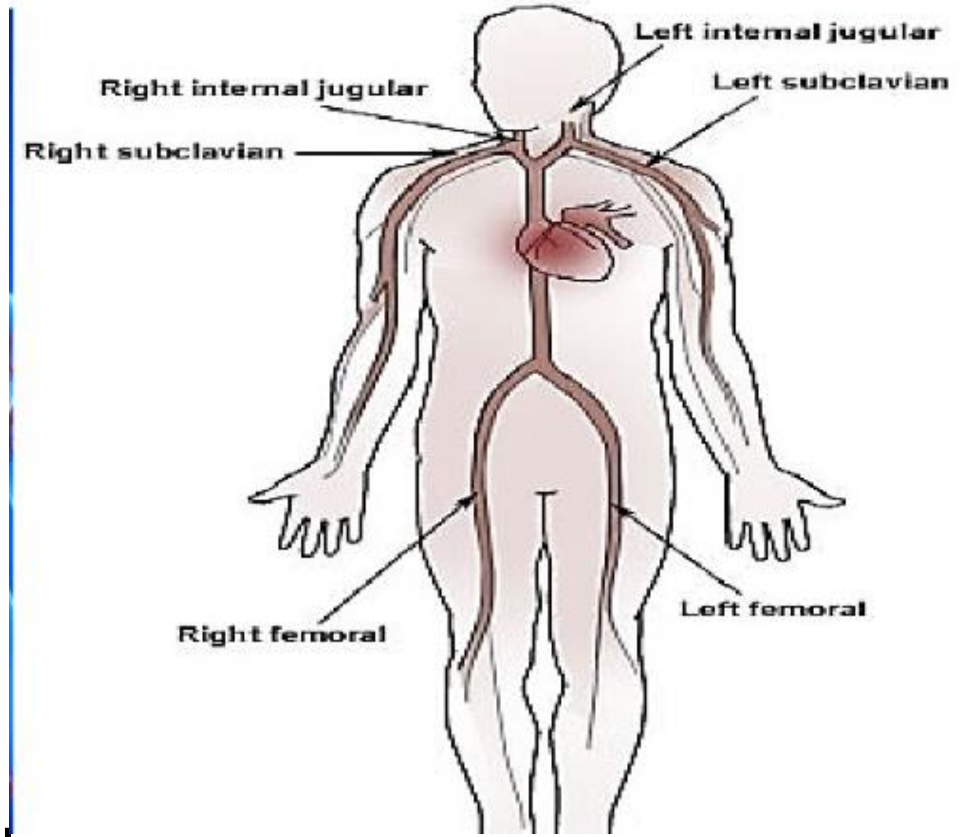
2- Left internal jugular

3- Right subclavian

4- Left subclavian

5- Femoral

6- Or peripherally inserted central catheters (PICC) which are inserted via the antecubital veins in the arm and is advanced into the central veins



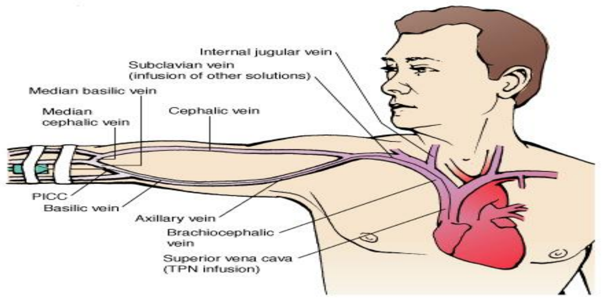
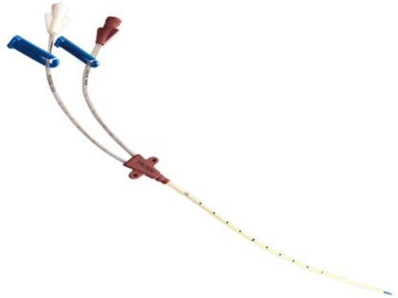


Figure 46-9 Placement of peripherally inserted central catheter (PICC).

TYPES OF CENTRAL LINE:

1- **SINGLE LUMEN**

2- **DOUBLE-LUMEN**



3- **TRIPLE LUMEN**

Methods to measure CVP

Indirect assessment:

- Inspection of jugular venous pulsations in the neck.

Direct assessment:

- Fluid filled manometer connected to central venous catheter.
- Calibrated transducer.

Causes of increase CVP;

- Hypervolemia
- Right ventricular failure
- Pericarditis
- Cardiac tamponade

Causes of decrease CVP;

- Hypovolemia
- Shock
- Vasodilation

Nursing management :

Before the insertion;

1- Prepare for equipment

During the insertion;

1- Explain procedure to the pt

2- Prepare the site of insertion (cleaning & shaving)

3- Assist the doctor during insertion

4-Perform continuous assessment of the pt cardiac & respiratory status

After the insertion;

1- Begin the IV infusion

2- Assess integrity of the skin at the site of insertion

3- Cover site of insertion with sterile gauze

4- Prepare pt for x-ray

5- Measurement CVP

Complications of CVP :

1- Hemorrhage

2- Catheter occlusion

3- Infection

4- Air embolism

5- Catheter displacement

6- Cardiac arrhythmias

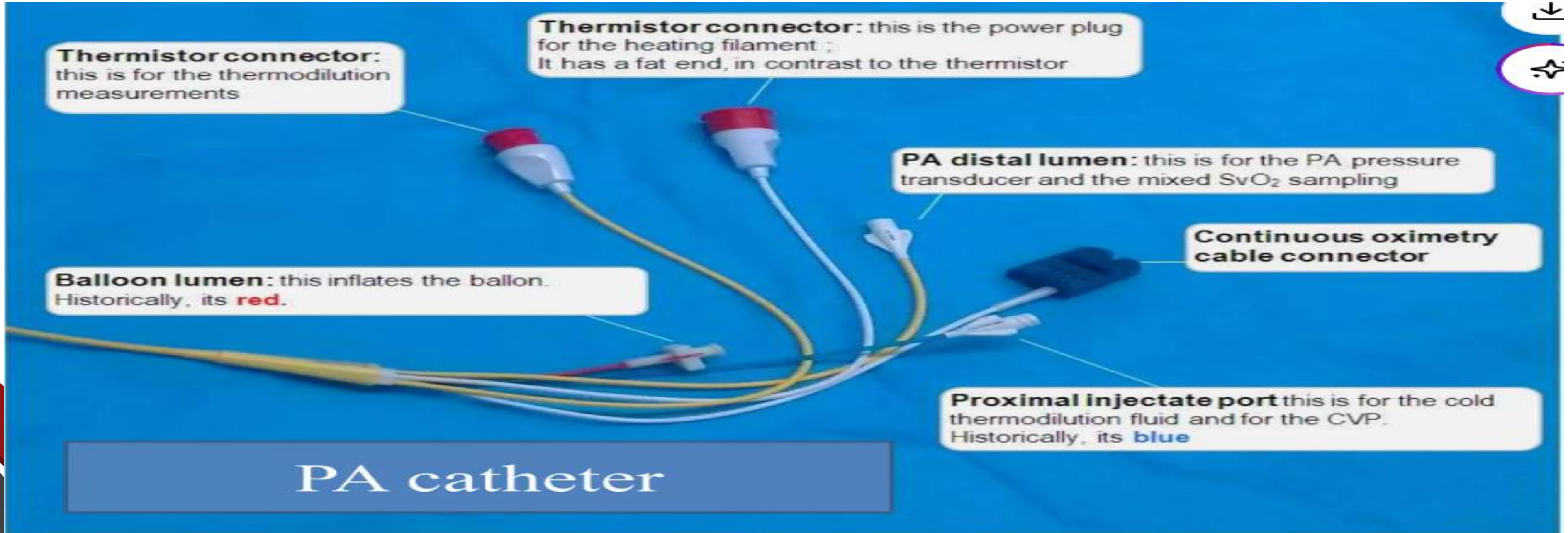
7- Pneumothorax

8- Hemothorax

9- Hemo-pneumothorax

Pulmonary artery catheter (PAC)

- Pulmonary artery catheter (PAC) is also know as Swan Ganz catheterization .
- - A light flexible balloon-tipped tube that is introduced into the pulmonary artery (the artery from the right ventricle of the heart to the lungs



Pulmonary Artery Pressure Monitoring

The PA catheter is used to:

- Provide support for a diagnosis, such as heart failure in a hemodynamically unstable patient
- Guide therapy such as volume repletion, or monitor for medication effects of vasopressors, inotropes and vasodilators
- Monitor cardiac function in patients undergoing high risk procedures, such as cardiac surgery or repair of aortic aneurysm.
- Assess cardiac output and the balance of oxygen sup ply and demand, such as with SvO2

Indications for Pulmonary Artery Catheterization

- Identification of the type of shock
  - Cardiogenic (acute MI)
  - Hypovolemic (hemorrhagic)
  - Obstructive (PE, cardiac tamponade)
  - Distributive (septic)
- Monitoring the effectiveness of therapy

Contraindication :

1- Uncontrolled ventricular or atrial dysrhythmias.

2- Right ventricular mural thrombus.

3- Cardiac arrest .

4- Respiratory arrest.

5- Cyanotic congenital heart disease.

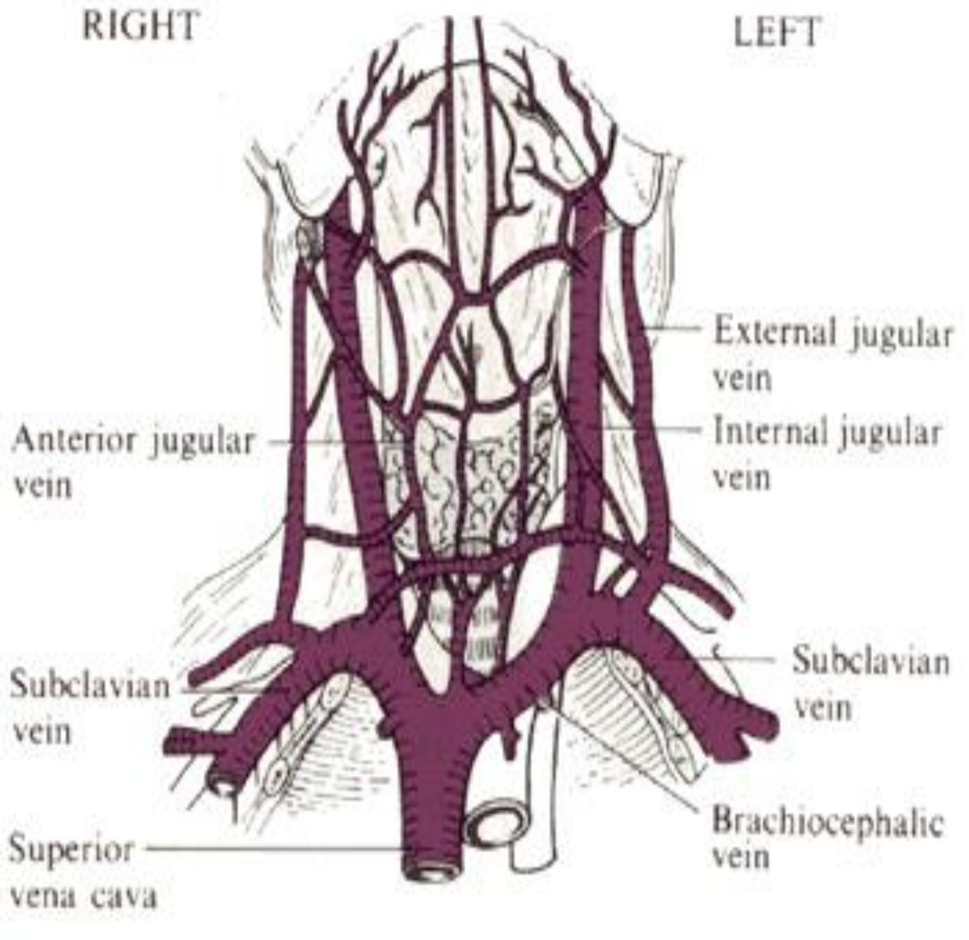
6- Ventricular masses or other structural abnormalities

Insertion site :

Catheterization of the right side of the heart and pulmonary artery via;

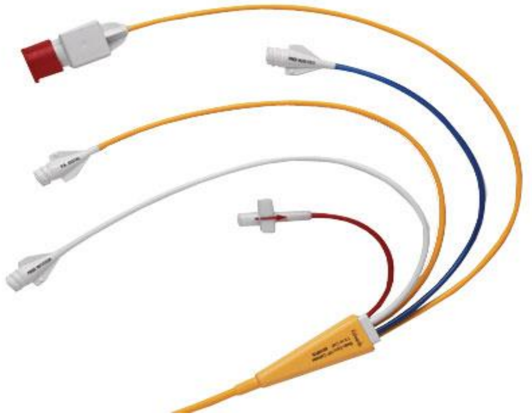
1- Right internal jugular vein

2- Subclavian vein



The chief veins of the neck.

Type of lumen :



PAC has 4-5 lumens:

1- Temperature thermistor located proximal to balloon to measure pulmonary artery blood temperature

2- Proximal port located 30 cm from tip for CVP monitoring, fluid and drug administration

3- Distal port at catheter tip for PAP monitoring

4- +/- Variable infusion port (VIP) for fluid and drug administration

5- Balloon at catheter tip

Complication :

1- Accidental puncture of adjacent arteries

2- Bleeding

3- Neuropathy

4- Air embolism

5- Pneumothorax

6- Dysrhythmias

a- Premature ventricular and atrial contractions

b- Ventricular tachycardia or fibrillation

7- Thromboembolism

8- Mechanical, catheter knots

9- Pulmonary Infarction

10- Infection, Endocarditis

11- Endocardial damage, cardiac valve injury

12- Pulmonary Artery Rupture

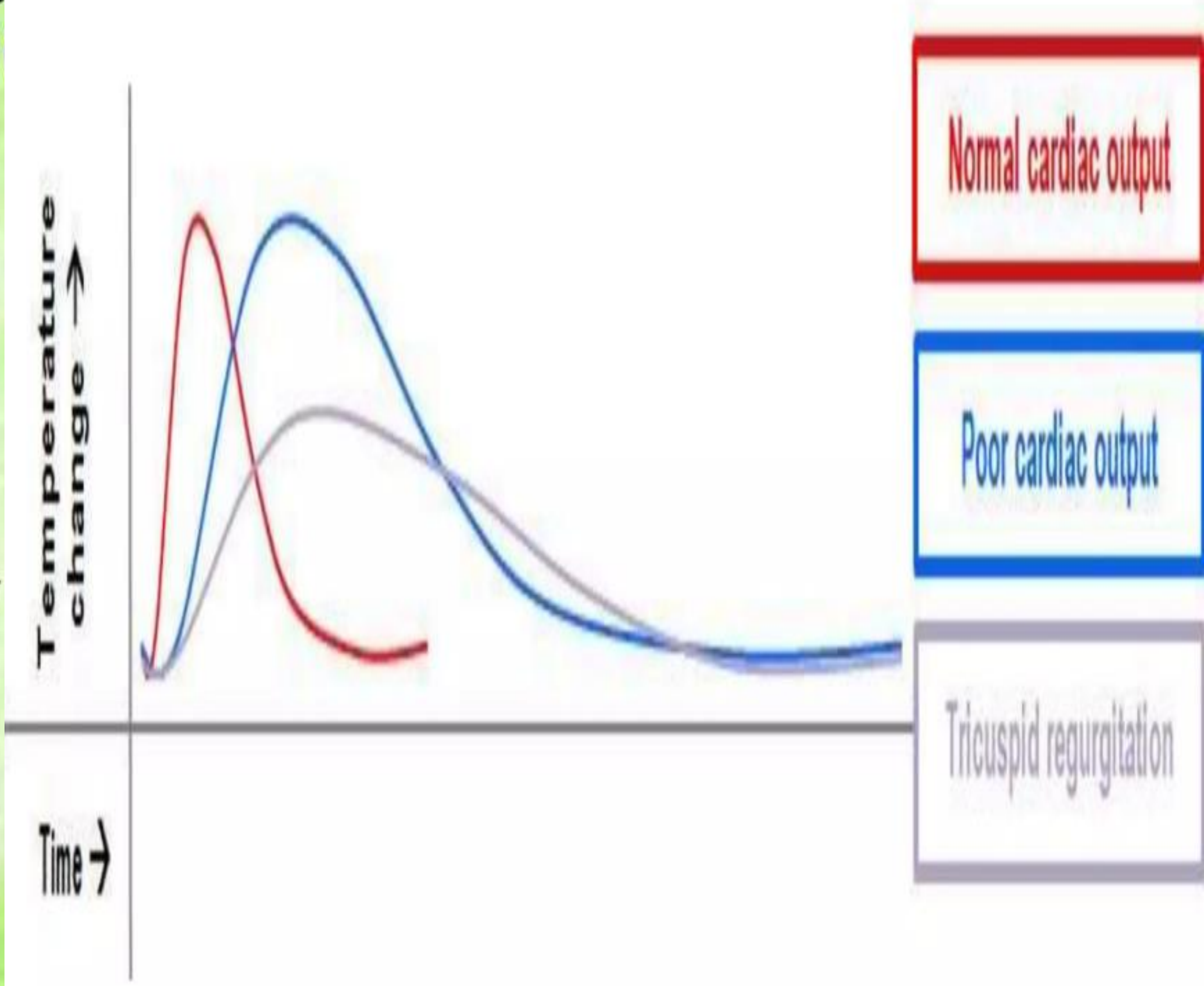
Normal values of commonly measured parameters are as follows:

- Pulmonary artery systolic pressure: 20-30mmHg
- Pulmonary artery mean pressure: 9-17mmHg
- Pulmonary artery diastolic pressure: 5-15mmHg
- Pulmonary capillary wedge pressure: 8-12mmHg
- Right atrial pressure: 2-6mmHg
- Cardiac index: 2.5-4 L/min/m2
- Cardiac output (CO) L/min

CARDIAC OUTPUT MONITORING

Thermodilution (pulmonary artery catheter)

- Boluses of ice-cold fluid are injected into the pulmonary artery and the change in temperature detected in the blood of the pulmonary artery



Thank you