CVS MODULE
PHYSIOLOGY (LECTURE 6)
HEMODYNAMICS OF BLOOD FLOW

Presented by

DR. FATMA FARRAG ALI

ASSOCIATE Professor of Physiology

2023-2024

THE VASCULAR SYSTEM

The blood vessels include:

- Elastic vessels: aorta and large arteries.
- Low resistance vessels: medium-sized and small arteries.
- High resistance vessels: arterioles.
- Exchange vessels: capillaries.
- Capacitance vessels: veins (60- 70% of blood).

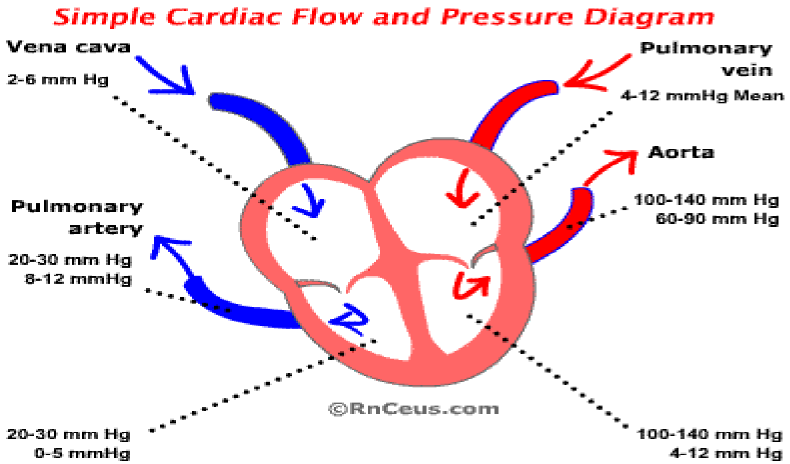
Hemodynamics

The study of the physical variables related to the containment and movement of blood in the cardiovascular system is called hemodynamics.

Biophysics of blood flow

The blood flow rate (F) is the volume of blood that crosses a certain point/unit time.

It is directly proportionate to the pressure gradient (difference between the mean arterial B.P. and the atrial pressure)and inversely proportionate to the peripheral resistance.



Biophysics of blood flow

Therefore,

$$F = \frac{\text{Pressure gradient}}{\text{peripheral resistance}}$$

In the systemic circulation, since (F) = cardiac output (CO), and the pressure gradient= mean systemic arterial B.P. (because the right atrial pressure is almost zero),

$$\text{So, CO} = \frac{\text{mean systemic arterial B.P.}}{\text{peripheral resistance}}$$

And

the mean systemic arterial B.P. = CO X peripheral resistance

Most of the resistance to blood flow occurs in the arterioles, so it is called peripheral.

The factors that affect **(R)** can be deducted from the following formula=

Poiseuille-Hagen formula

$$R = \frac{8 L \eta}{\pi r^4}$$

R = resistance of the vessel to the flow

L = length of the vessel

η (eta) = viscosity of the fluid

$\pi (pi)$ = circle constant (3.14)

r = radius of the vessel

The resistance to the flow of a fluid through a vessel (R) is directly proportionate to the length of the vessel and the viscosity of the fluid but inversely proportionate to the fourth power of the radius of the vessel.

FACTORS AFFECTING THE PERIPHERAL RESISTANCE (R):

The main factors that affect R include the following:

1-Diameter of blood vessels (r) (especially the arterioles). R is inversely proportional to the arteriolar diameter (r). Any factor that may cause vasoconstriction or vasodilation will affect the blood pressure by increasing or decreasing it respectively.

2-Viscosity of blood: It is about 3-4 times more than the viscosity of water. It is due to plasma proteins, and the blood cells (RBCs). Viscosity is increased by dehydration and polycythemia, and decreased by anemia and hypoproteinemia.

3-length of blood vessels: It is constant in the human organism, so it would not involved in the determinants.

Because the lengths of blood vessels are constant and the changes in viscosity are normally relatively small, these factors only share in producing peripheral resistance but play no role in its regulation. Consequently, the **diameters of blood vessels remains the most important factor** that regulates **R**.

Determinants of peripheral resistance (R)

R can't be directly measured but can be calculated from F and the pressure gradient as follows:

Since F= $\frac{\text{pressure gradient}}{(R)}$, then pressure gradient= (F) X (R) and R= $\frac{\text{pressure gradient}}{(F)}$

Accordingly, R can be obtained by dividing the pressure gradient (in mmHg) by the flow (in ml/second) and the result is expressed in R units (one R unit refers to the resistance that allows the flow of 1 ml blood/second at a pressure gradient of 1 mmHg),

e.g. in the systemic circulation, if F (the left ventricular CO) is 90 ml/second and the pressure gradient is 90 mmHg, then R= 90/90= 1 R unit.

Measurement of Blood Flow Rate (F)

- <u>F can be measured by:</u>

1. Using the electromagnetic and ultrasonic Doppler flowmeter.
2. Applying the Fick's principle.
3. Plethysmography.
4. Special method: RBF can be determined using the clearance of PAHA or Diodrast. PBF can be measured by Fick's principle .

VELOCITY OF BLOOD FLOW

It is calculated by dividing the blood flow rate (ml/second) / cross sectional area (cm^2).

In the aorta : the blood flow rate (COP) is about 90 ml/sec and its cross sectional area is 2.5 cm^2. So, Velocity of blood flow = 90/2.5 = 36 cm/sec.

In capillaries: Velocity of blood flow is slow (0.2-0.3 mm/sec) as the cross sectional area of capillaries is wide (3 0 0 0 - 4500 cm^2)

Estimation of blood velocity

The blood velocity can be clinically estimated by measuring the circulation time (C.T) between two points (the time taken by blood to move from one point to the other) using certain substances, dyes or isotopes.

1. **Arm to Lung CT:**

By Injection of few drops of ether into an antecubital vein. The time between ether injection and smell of ether in expired air gives rough measurement of pulmonary C. T = 5 seconds. It indicates the pumping power of RV (prolonged in right-sided heart failure).

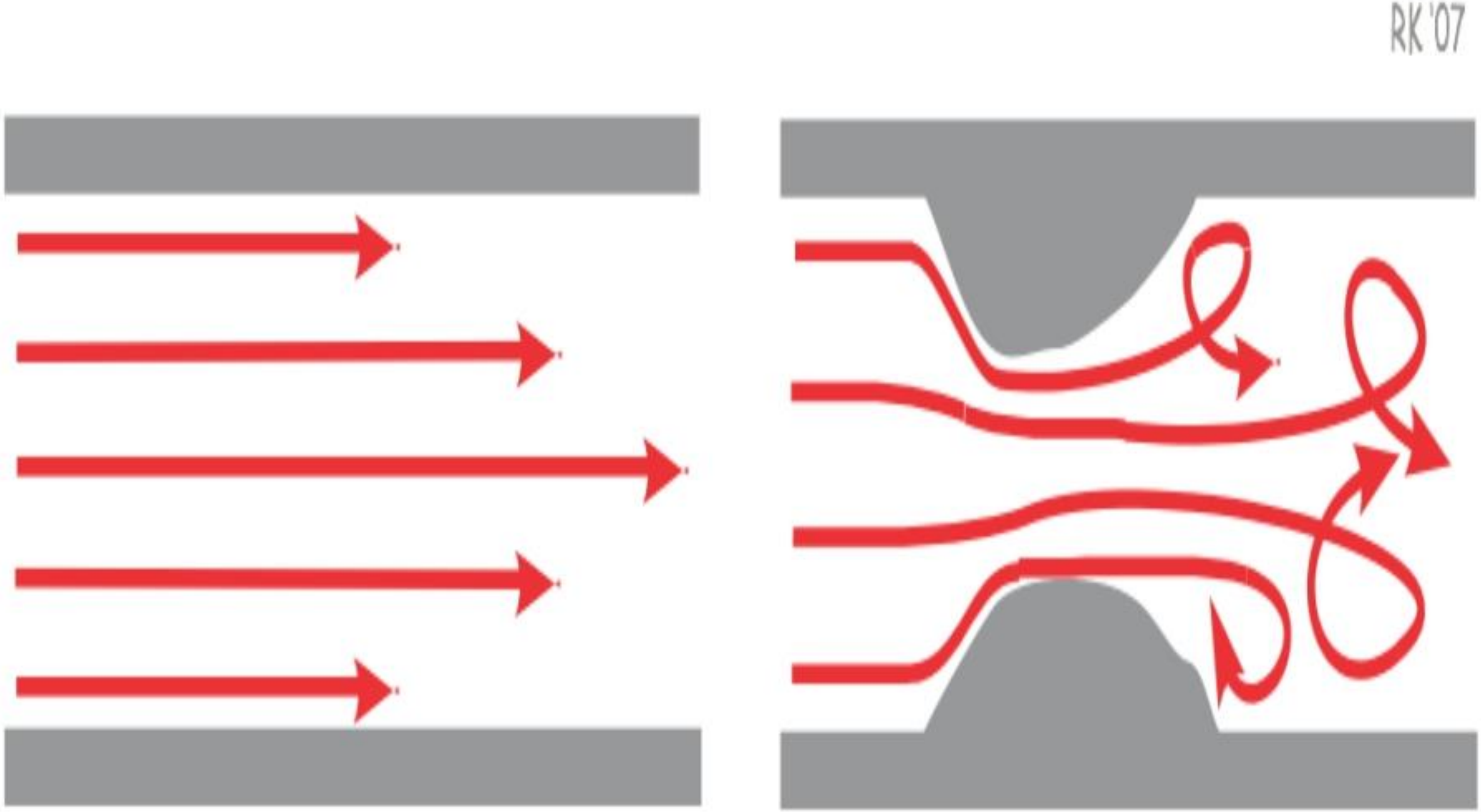
Arm to Tongue CT:

By Injection of bile salt preparation (decholin) into an antecubital vein. The time between injection and bitter taste gives rough measurement of C. T of left side of the heart = 10 seconds. It indicates the pumping power of LV (prolonged in left-sided heart failure).

Types of blood flow

(1) Laminar (streamline): this is the normal smooth flow of blood. It is silent and laminar.

(2) Turbulent: This is disturbed blood flow in the form of eddies in various directions. It produces sounds (= bruits or murmurs) which can be heard by stethoscope. It especially occurs when critical velocity exceeded.



Laminar Flow

Turbulent Flow

Cause of laminar (streamline) flow

- **Wall stress (a type of shear stress): When a fluid, in this case, blood, flows through a pipe, friction exists between the fluid and the wall of the tube. This friction decreases the velocity of the blood closest to the wall (hence the shorter lines on the diagram closer to the tube wall).**

Causes of turbulent flow

In addition to the blood velocity, its viscosity as well as diameter of the vessel are also contributing factors in producing turbulence.

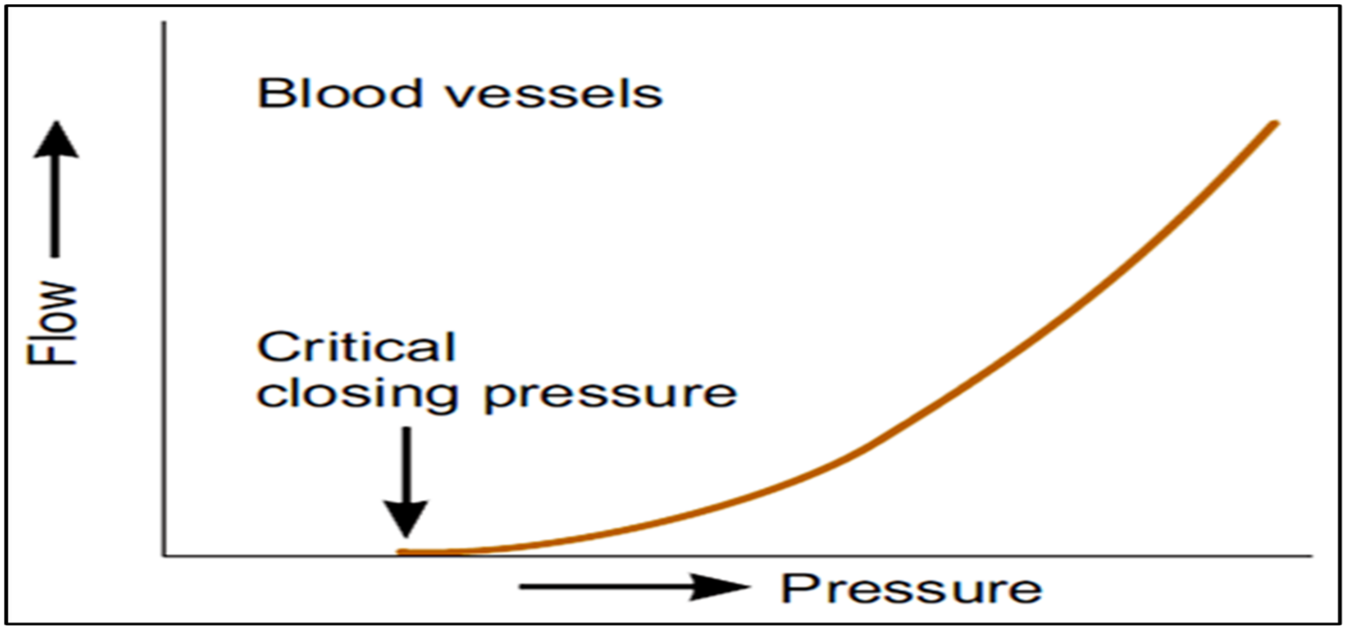
THE CRITICAL CLOSING PRESSURE

When the pressure in a small blood vessel (= intraluminal pressure) is decreased, the blood flow is proportionally decreased till it stops completely. The intraluminal pressure at which blood flow stops is called the critical closing pressure,

e.g. In severe **haemorrhage,** blood loss leads to a significant reduction in pressure. This, combined with activity in the sympathetic autonomic nerves supplying smooth muscle, leads to **vasoconstriction** to the extent that the vessels may collapse. This occurs at the critical closing pressure, closing off blood supply to tissues.

The stoppage of blood flow is due to :

- Drop of intraluminar pressure below the pressure needed to force the red cells through the narrow capillaries.
- The extraluminal pressure (pressure exerted by surrounding tissues) exceeds the intraluminal pressure resulting in collapse of the vessel.



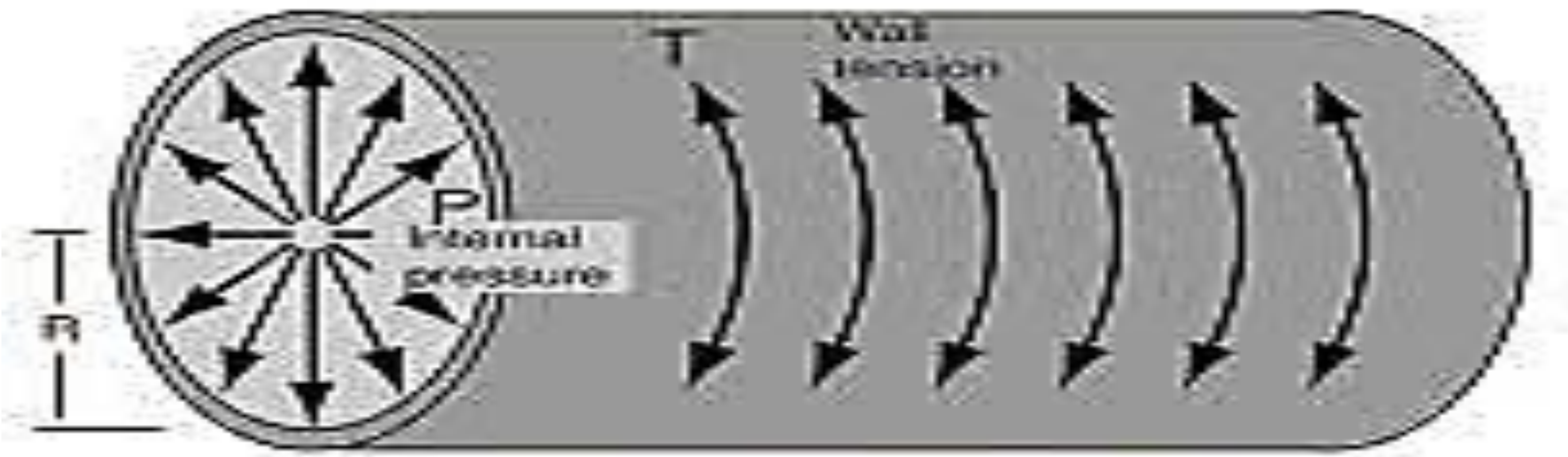
LAW OF LAPLACE

The tension (T) developed in the wall of a hollow organ= distending pressure (P) x radius of the organ (r)

T = Px r and P = T/r

It applies to several sites in the body e.g. the urinary bladder, lung alveoli, stomach, blood vessels and heart. In the latter, the element of wall thickness is also important, so the " Laplace law of heart states that the tension developed in ventricular wall during ejection= intraventricular pressure (P) x ventricular radius (r) divided by the wall thickness(h) i.e. T=Px r/h.

LAW OF LAPLACE



Cylindrical Vessel
T = PR


THANK
YOU