Lecture 2:

Physics of Cardiovascular System

By

Dr. Noor Al-Huda Talib Al-Aaraji

Objectives: after the end of this lecture, the student must know:

1- The principle laws that govern the heart structure and function

2- Blood pressure and its measurement

3- Types of blood flow (laminar and turbulent) and its application in diseases.

The blood is pumped by contraction of the heart muscle, from left ventricle at pressure of 125 mmHg and finally into very fine meshwork **or capillary bed** for few seconds the blood supplies O2 to cells and picks up CO2. Adult has about 4.5 liters of blood, each section of heart pumps 80 ml with each contraction.The combination of RBC and plasma causes blood to have flow properties different from those of fluid like water.

Starling law: fluid movement through capillary wall= the hydrostatic pressure (p) across the capillary wall+ osmotic pressure bringing fluid in.

Work Done By The Heart

Left side of the heart systole pressure= 120 mmHg Right side of the heart diastolic pressure=80mmHg Above caused by following:

1- The left side of the heart three times thicker than right side.

2- The circular shape of left ventricle producing pressure larger than elliptical shape of right ventricle.

The work done=$P\Delta V$

Blood Pressure And Its Measurement

The instruments called **Sphygmomanometer**, the sound heard with stethoscope called **Kortokoff** or K sounds.

The onset of K indicate systolic pressure precision

± 2 mmHg The fade of k indicates diastolic pressure precision

± 5 mmHg

Pressure Across Blood Vessel Wall

The pressure drops in the capillaries which have thin walls (1 μm) permit easy diffusion of O2 and CO2, the capillary do not burst according to **Laplace law**

Consider a tube of radius R

$F = 2RP$

P blood pressure

T tension in the wall

$2T = 2RP$ $T = RP$

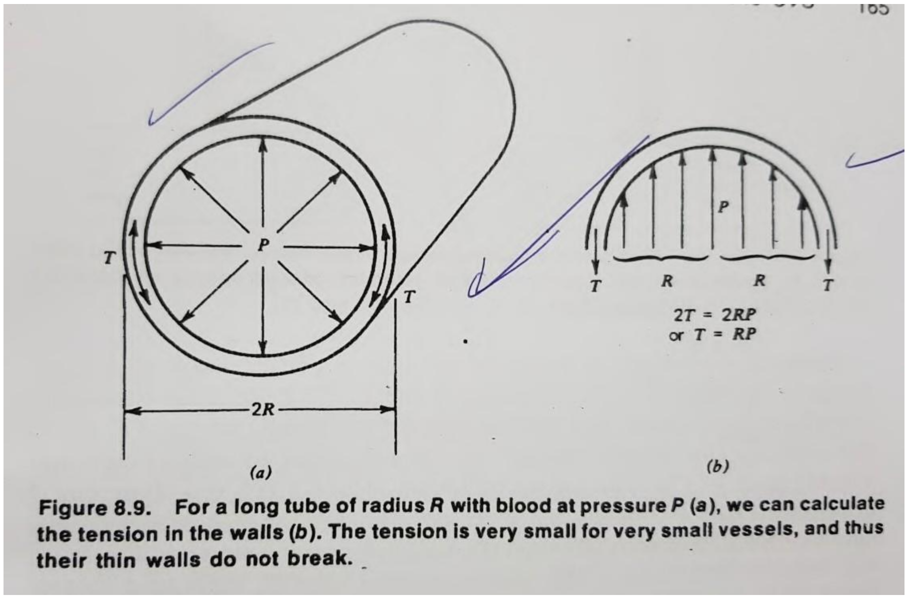


Figure 8.9. For a long tube of radius *R* with blood at pressure *P* (*a*), we can calculate the tension in the walls (*b*). The tension is very small for very small vessels, and thus their thin walls do not break.

Bernoulli's principle Applied To Cardiovascular System

Bernouli's principle is based on the law of conservation of energy Increasing KE (kinetic energy) obtained by reduction of PE, the pressure in the tube

Average K E of 1 gm (1 cm^3) of blood as it leaves the

heart KE= $1/2\,mv^2$ v= 30cm/ sec

KE=1/2x1x(30)= 450 erg/ cm^3

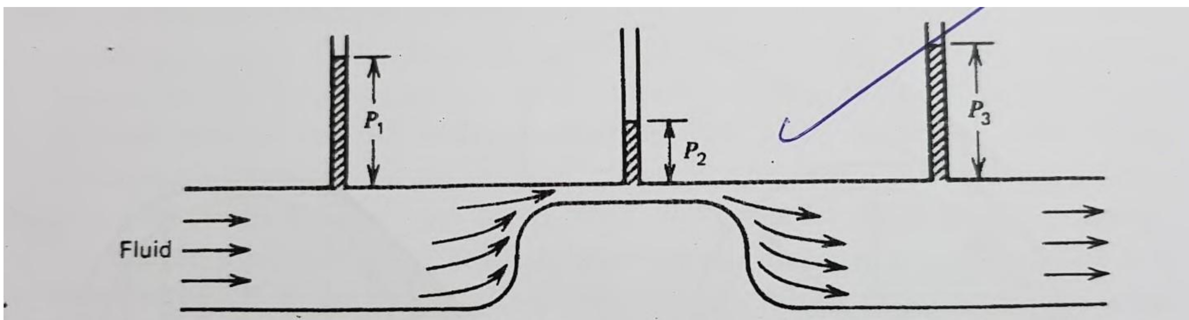


Figure 8.10. As the velocity of the fluid increases in the narrow section of the tube, part of the potential energy (pressure) is converted into kinetic energy so there is a lower pressure P_2 in this section. P_2 is less than P_1 and P_3.

How Fast Does Your Blood Flow

Capillaries about 20 μm diameter, there total cross-sectional area 30 cm. The blood velocity V inversely related to the total cross-section area of the vessels carrying blood.

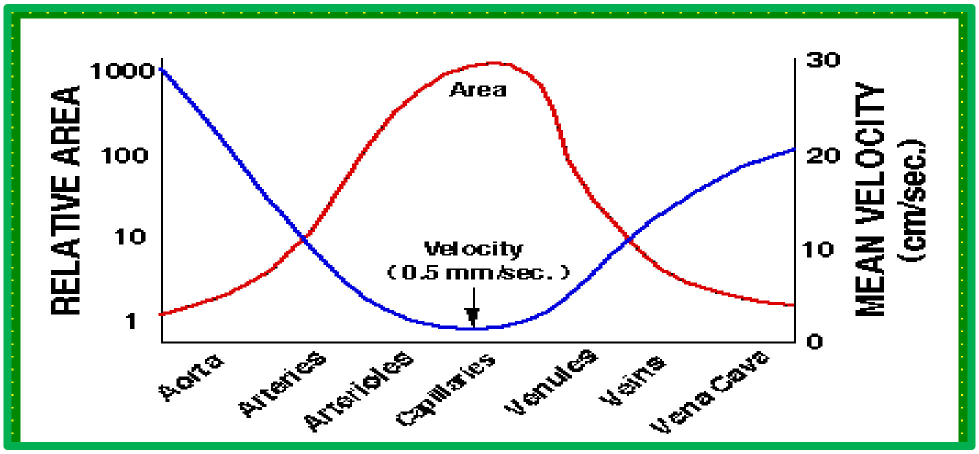


Figure7-1:relation ship between cross section alarea of vesseland velocityof blood flow.

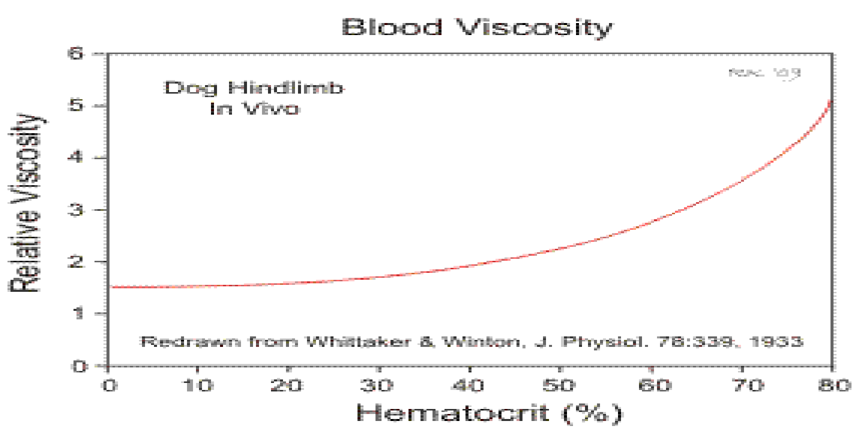
Viscosity of blood= $3x10^{-3}$ to $4x10^{-3}$ Pas. Depending on RBC in the blood or Hematocrit.

Hematocrit α

Viscosity Viscosity α

Temperature

Figure 7-2: relationship between hematocrit and velocity of blood flow



Blood Flow Laminar And Turbulent

Laminar (silent) if all blood flow were laminar information could not be obtained from the heart with stethoscope

If increase the velocity of the fluid in the tube by reduction the radius it will reach the critical velocity Vc, when laminar flow change into turbulent flow. The critical velocity will be lower if there is restriction or obstruction in the tube.

Osborne Rynold studied the property in

1883 $V_c = k\ \eta\ /\ \rho\ R$

R ; radius of the tube
K ; constant 1000 for many fluid

For aorta has radius = 1 cm in adults

$V_c = (1000)\ (4 \times 10^{-3}\,\text{pas})\ /\ (10^{3}\ \text{kg}/\text{cm}^3)\ (10^{-2}\,\text{m}) = 0.4\ \text{m/s}$

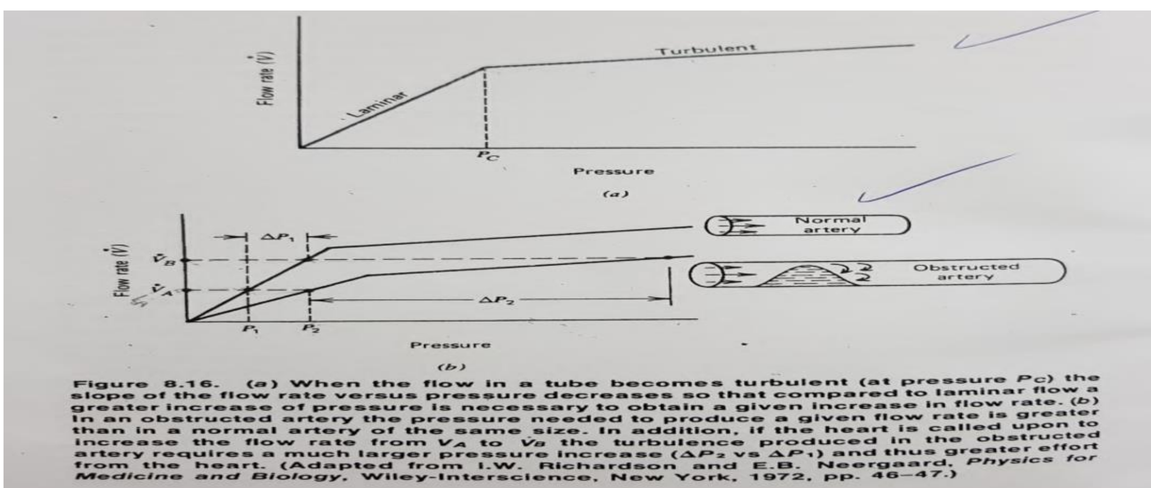


Figure 7-3: effect of gradual tapering of tube on velocity

The Physics Of Some Cardiovascular Diseases

Work load of heart increases

by ;

1- Hypertension

2- Tachycardia

Disease

1- Heart attack, caused by blockage one or more arteries of the heart muscle.

person has heart attach may still have normal ECG.

2- Congestive heart failure, characterized by enlargement of the heart and reduction in the ability of the heart to provide adequate circulation.

Medical treatment of congestive heart failure help to reduce the work load on the heart.

3- Heart valve defects are of two types, the valve either does not open enough (stenosis) or it does not close well enough (insufficiency)

The Physics OF Cardiovascular Diseases Involving In The Blood Vessels

1- A more common vessel problems is the formation sclerotic plaques on the wall of the artery, increase the velocity in that region with a decrease in wall pressure because of Bernoulli effect.

2- If the valve defective and let the blood run back down it will pool in the vein, and the vein will become varicose.

The viscosity of blood depends on temperature change from (37-0) increases the velocity of blood by a factor 2.5 in addition to viscosity , other factors affect the flow of blood in the vessel; the pressure difference from one end to the other, the length of the vessel, and its radius.

Poiseulle's law stats that the flow of a given tube depends on the pressure difference from one end to the other P1-P2, the length of the tube L, the radius R and viscosity of blood.

Flow rate = (P1- P1) (Π / 8) (1/ η) (R4 / L)

If radius is doubled the flow rate increases by 24 or by 16. This law applies to the rigid tubes of constant radius, since the major arteries have elastic walls and expand slightly at each heartbeat, so blood does not obey this law exactly

in addition the blood viscosity changes slightly with flow rate, however this effect is negligible.

A disease clinically causes varicose vein, these enlarged surface veins in the legs results from a failure of the one way valves in the veins.

The pressure in the leg vein is about 90 mmHg (115 cm of blood) due to a column of blood above it.

The slandered treatment for varicose veins is surgical removal of offending vessels. There are usually adequate parallel veins to carry the blood back to the heart.