**Microcirculation**

**Capillary circulation**

* The capillaries contain 5 % of the total circulatory blood volume.
* This relatively small amount of blood is very important because the exchange of materials between the blood and the interstitial tissue fluids take place in the capillaries.

**Morphology of the Microcirculation**

* It can be simplified to Microcirculation unit.
* In Microcirculation unit the blood does not move directly from the arteriole into the capillary but it passes into thoroughfare vessel which connect the arteriole and the venule, it contain a smooth muscle layer which is not continues but sparse and mainly located at the arteriolar end .
* At the proximal end of the thoroughfare vessel, there is the opening of the true capillaries which are controlled by small rings of smooth muscle called the **precapillary sphincters.**
* When all the precapillary sphincters are contracted the blood is rapidly passed from arteriole to the venule, and when they are relaxed, the blood passes into the capillary beds.



Fig.(58): Microcirculation unit

**Structural features of the capillaries**

* Capillaries are about 10 microns in diameter, and about 700 microns in length,
* There are nearly about 10 billions of capillaries in the human body with a total surface area of about 100 m2 for exchange of materials between the blood and the interstitial fluid.
* The capillary wall is formed of endothelial cells with flattened nuclei, the cells are applied closely to one another, where they meet they leave narrow spaces between them about 80 – 90 Angstrom in width which are called pores or fenestration’s.
* Outside the endothelial cells there is a basement membrane which is mucopolysacride in nature it is about 0.5 micron thick.
* The capillary contains no smooth muscles.

Fenestrations

Endothelial cells

Capillary lumen

Fig.(59): Cross section of capillary

**Classification of Capillaries**

They are classified according to the size of pores and the development of the basement membrane into:

1. **Capillaries of the skeletal muscles, heart, skin and lungs** which have no fenestrations and well developed basement membrane.
2. **Intestinal and kidney capillaries** have thin fenestrations with continues but faint basement membrane.
3. **Liver capillaries** have large fenestrations and a faint discontinuous basement membrane.

According to the diameter of pores and the degree of development of the basement membrane, the permeability of the organ is determined. So the liver has very high permeability, intestine and kidney have intermediate permeability. Muscle, skin, heart, and lungs have no permeability.

**Capillary fragility**

* The capillary wall is extremely thin (about 1 micron), so they are extremely fragile but they can withstand high pressure without rupturing as 100 mmHg in the standing position.
* This can be explained by Laplace`s law (T = P X r)
* As the radius of the capillary is extremely small , the tension on the wall is very law and not affected greatly by increased pressure.

Capillary fragility is affected by:

2. Defect in the blood as:

- Decreased platelet count which leads to poetical hemorrhage because there are no sufficient platelets to plug the breaks which occur in the capillary wall from time to time.

1. Capillary wall:
* As weakness of the capillary wall leads to capillary fragility.
* The most common causes of weakness of the wall are:
* Old age.
* Vit C deficiency (scurvy).
* Certain toxic and allergic states

Capillary fragility test: See practical book

**Capillary blood pressure**

* The pressure at the arteriolar end of the capillary is about 35 - 40 mmHg.
* At the ventral end of the capillary it is about 15 mmHg.

Capillary hydrostatic pressure is affected by:

1. Dilatation of the arterioles and the precapillary sphincters: This → ↑ blood flow in the capillaries & ↑ capillary pressure, while constriction of the arterioles and the precapillary sphincters decreases it.
2. Increased venous pressure due to venous obstruction leads to rise of the capillary pressure.

 15 mmHg 35 - 40 mmHg

Arteriolar end

venular end

Fig.(60): Capillary hydrostatic pressure

**Factors affecting the capillary blood pressure**

1. Arteriolar diameter:
* Arteriolar V.D → ↑ capillary blood pressure.
1. Venous pressure:
* Increased venous pressure → ↑ capillary pressure.
* Decreased venous pressure → ↓ capillary pressure.
1. Effect of gravity: Gravity → ↑ capillary pressure.
2. Nervous factors:
* Sympathetic stimulation → contraction of the precapillary sphincter & reduction of the capillary blood pressure.
1. Metabolites.
* Metabolites → relaxation of the precapillary sphincter
* That leads to Increased capillary blood flow & increased capillary blood pressure.
1. Temperature.
* Heat → relaxation of the precapillary sphincter & ++ capillary blood pressure.
* Cooling → contraction of the precapillary sphincter & - - capillary blood pressure.

**N.B**

1. Changes in the diameter of the capillary affect the color of the skin i.e. capillary V.C give pale skin, while capillary V.D give red skin.

2. Changes in the diameter of arterioles affect the temperature of the skin i.e arteriolar V.C decreases the skin temperature, while arteriolar V.D increases the temperature of the skin.

**Capillary blood flow and vasomotion**

1. The blood flow in the capillaries is intermittent and the capillary show rhythmic opening and closing which occur 6 to 12 times / min.
* The closure of the capillaries is a passive process (contraction of the arterioles and the precapillary sphincters when tissue activity is decreased) → reduction of the blood flow in the capillaries and decreased capillary pressures. When capillary pressure drops below the critical closing pressure, the capillary is closed and the flow stops.
* On the other hand when tissue activity increased the metabolites accumulates as Co2, lactic acid, hydrogen ions, K ions and O2 lack. These metabolites produce relaxation of the plain muscles of the arterioles and precapillary sphincters increasing the blood flow to the capillary bed.
* Capillary blood flow is also under neural control as the arterioles and precapillary sphincters are richly supplied with sympathetic fibers that discharging continuously giving the basal V.C tone. It can increased leading to V.C and decreased capillary blood, or decreased leading to V.D and increased capillary blood flow.
1. The flow is slow:
* As the cross sectional area of the capillaries is 100 times greater than the cross sectional area of the aorta
* The velocity in the capillaries is 1000 times slower than in the aorta i.e 0.5 meter/ sec.

**N.B:** The majority of the capillaries are closed at rest but during activity the number of opened capillaries is increased up to 30 folds. If all the capillaries are opened the vascular capacity would exceed the blood volume leading to marked drop in venous return and C.O.P and ABP drop markedly.

**Exchange of materials across the capillary wall**

Trans-capillary exchange occurs by the following mechanisms.

1. **Capillary diffusion**
* It is a passive process through which water and dissolved substances traverse the capillary wall from the plasma and interstitial fluid.
* Diffusion depends on:
1. Substance factors
2. Capillary membrane factors

Molecular weight

Conc. gradient

Solubility

Surface area

Permeability

1. **Substance factors:**
2. Molecular weight (M.W):
* Substances with M.W < 5000 appear to cross the capillary wall easily
* While, substances with M.W > 5000 cross with more difficulty.
* Albumin has M.W 70.000 can pass through capillary wall due to its cigar shape.
* Water can pass across the capillary wall in both directions at a very high rate as its molecular size is 18. A volume of water about 65% of the total blood volume crosses the capillary wall / min.
* The rate of diffusion of electrolytes as Na+, CL ions as well as crystalloid as glucose and urea is less than that of water.
1. Concentration gradient of the substance across the capillary wall:
* Diffusion is directly proportional to the concentration gradient as the substance move from the area of high concentration to the area of low concentration.
1. Solubility
* Water-soluble substances can diffuse only through the aqueous functional pores, and its diffusion depends upon its molecular size.
* Respiratory gases as Co2 and O2 are water and fat soluble so they can diffuse through the entire surface area of the capillaries so their rate of diffusion is much greater than water and its soluble substances.
* Anesthetic gases and ethanol are fat soluble and transmitted rapidly through the capillary wall.
1. **Capillary membrane factors**
2. Surface area
* Diffusion is directly proportional to the total surface area of the capillary wall.
1. Capillary permeability

Factors affecting capillary permeability

1. **PH:** Acids increases capillary permeability while alkaloses decreases it , as acids ionize Ca ion salts and alkalis precipitate it in the capillary pores.
2. **Histamine**: It opens capillary pores and increases its permeability.
3. **Ca+2 ions**: Its reduction opens the capillary pore & increases its permeability and vice versa.
4. **Hypoxia**:It causes damage of the capillary wall and metabolites accumulate leading to increased permeability.
5. **Excessive heat or cold:** It leads to capillary V.D and increased capillary permeability. Excessive cold causes initial V.C leading to accumulation of metabolites, which causes VD
6. **Irritant gases and some bacterial toxins**: It leads to capillary V.D and increased capillary permeability.
7. **Trans- capillary filtration (bulk flow).**
* This mechanism shows that fluids are filtered at the arteriolar end of the capillary and reabsorbed at the venular end of the capillary.
* The amount filtered is slightly greater than the amount reabsorbed, and the remaining amount is drained by the lymph vessels to the venous circulation.

**Forces that control the bulk flow**.

1. **The capillary hydrostatic pressure**
* It is about 35 mmHg at the arteriolar end of the capillary and 15 mmHg at the venular end of the capillary.
* It acts as the force driving fluid from inside of the capillaries to the interstitial fluid i.e. it is the filtering force.
1. **Tissue hydrostatic pressure.**
* It is the pressure in the interstitial fluid outside the capillary wall
* It acts as a force moving fluids from interstitial spaces to the intravascular compartment
* It is about 3 mmHg.
1. **Colloidal osmotic pressure of plasma proteins.**
* The colloidal osmotic pressure of plasma proteins is 25 mmHg,
* It acts as a force absorbing fluids from the interstitial tissue spaces to the plasma.
1. **Colloidal osmotic pressure of the tissue fluids.**
* It is provided by tissue plasma proteins that have passed through the capillary wall into the tissue spaces.
* It is about 3 mmHg.
* It acts as a force absorbing fluids from the capillaries.

Cap. Hydrostatic p = 35

Cap. Hydrostatic p = 15

Cap. osmotic p= 25

Tissur Hydrostatic p = 3

Cap. Osmotic

 p= 3

Arteriolar end

Venular end

* The resultant net force for fluid movement is the difference between forces moving fluids from the capillaries (Capillary hydrostatic pressure, and tissue colloidal osmotic pressure) and forces that move the fluids to the inside of the capillaries (colloidal osmotic pressure of plasma proteins, and tissue hydrostatic pressure).
* At arteriolar end of the capillary the net force = 35 + 3 – 25 – 3 = +10 mmHg.

It is filtering force

* At venular end of the capillary the net force = 15 + 3 – 3 – 25 = - 10 mmHg.

It is reabsorbing force.

* Normally the fluid filtered is slightly greater than the fluid absorbed, and lymph vessels return the excess amount to venous circulation.

**The net exchange of fluids across the capillary wall is affected by variations in**

1 – Changes in the capillary hydrostatic pressure.

* Arteriolar V.D → ↑ capillary blood flow & ↑ capillary hydrostatic pressure → ↑ filtration.
* Arteriolar V.C : the opposite effect
* Increased venous pressure → ↑ capillary hydrostatic pressure & ↑ filtration.

2- Changes in plasma colloidal osmotic pressure

* The plasma colloidal osmotic pressure is mainly determined by albumin concentration. So, reduction in plasma albumin concentration as in liver disease, nutritional deficiency and kidney diseases → ↓ in colloidal osmotic pressure & decreased absorption force. So, the filtration forces increase.
* Increased plasma colloidal osmotic pressure (dehydration& hyperprotenemia) → ↑ absorption force from interstitial to the intra-vascular compartment.

3- Changes in tissue pressure.

* ++ tissue pressure as a result of increased filtration or reduced lymphatic drainage →↓ in filtration force at the arteriolar end of the capillary & increased absorbing force at the venous end. So that, filtration of fluid from the circulation is self – limited & edema is considered as a self-limited disease.
1. – Changes in capillary permeability.: Increased capillary permeability → ↑ diffusion of albumin to interstitial tissue spaces. So, colloidal o.p is deceased and the absorbing force leading to an increased filtration force.

**CYTOPEMPESIS:**

* The large molecules are engulfed at the vascular border, and then transported through the cell and discharged at the interstitial border.
* The large molecules transported by this method are globulins and fibrinogen.

Capillary

Large molecule

Vesicle

Fig.(61): Cytopempesis

**DIAPEDESIS**

* It is the passage of leukocytes through spaces between endothelial cells of the capillaries as polymorph that passes near areas of inflammation or tissue damage as they are attracted to areas of inflammation by chemical substances released from the inflamed or damaged tissue.