

MICROCIRCULATION

DR. NAJEEB LECTURE NOTES

BY FATIMA HAIDER

KGMC

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Microcirculation includes the smallest vessels (capillaries) between arterial tree and venous tree.

Microcirculation includes the pulmonary microcirculation and systemic microcirculation.

A typical tissue have arteries as input, veins as output and systemic capillaries are present between arteries and veins.

Microcirculation consist of vascular channels (capillaries) that are only one cell thick. These capillaries are lined with endothelial cells and basement membrane. **Basement membrane** is a criss-cross of collagen and is highly porous. The real barrier to the movement of particles across the capillary is provided by **endothelial cells**.

Some capillary beds are more leaky while others are less. The sinusoidal and fenestrated capillaries are more leaky capillaries. Hepatic microcirculation have sinusoidal capillaries while microcirculation of glomeruli have fenestrated capillaries.

Sinusoidal capillaries have endothelial cells with large inter-endothelial gaps. Basement membrane is not effectively present in these capillaries.

Fenestrated capillaries (glomerular capillaries) have minimal inter-endothelial gaps. The cells of these capillaries (endothelial cells) are porous which help in filtration.

In cerebral microcirculation, endothelial cells are held very tightly i.e. inter-endothelial gaps are sealed tightly.

From arterial end of capillaries, fluid is constantly coming out under filtration pressure into the interstitial fluid. Venous end of capillaries sucks back the fluid from interstitial fluid. The proteins which cannot be sucked back drains into lymphatic system. Blood cells and plasma proteins do not diffuse out into interstitial fluid.

When substances pass through endothelial cells, it is called **trans-cellular movement**. Lipid soluble substances e.g. O₂, CO₂ diffuse out through endothelial cells.

When substances move through inter-endothelial spaces, it is called **para-cellular movement**. Substances which are not lipid-soluble move paracellularly e.g. free ions, peptide hormones, glucose, amino acids.

Starling forces describe the movement of fluids between capillaries and interstitial spaces.

There are two starling forces present in capillaries that govern the movement across capillary:

1. Hydrostatic pressure
2. Colloidal osmotic (oncotic) pressure

HYDROSTATIC PRESSURE

Pressure exerted by fluid against capillary wall is called hydrostatic pressure.

Capillary Hydrostatic Pressure favors filtration i.e. tends to move fluid out of capillaries.

Interstitial fluid hydrostatic pressure opposes filtration and tends to move fluid inside capillaries.

OSMOTIC PRESSURE

The colloidal osmotic pressure is due to pressure gradient of large non-diffusible molecules e.g. plasma proteins.

Capillary osmotic pressure is created by plasma proteins and this pressure opposes filtration.

Interstitial spaces contain very little protein so interstitial osmotic pressure is lower and it favors filtration.

FLOW DIRECTION

At arterial end of capillary, blood pressure's outward driving force is greater than inward directed oncotic pressure so fluid moves out of vessel.

At venous end of capillary, oncotic pressure inward driving force is greater than outward directed hydrostatic pressure so fluid moves into vessel.

Most fluid leaving capillary at arterial end reenters capillary before leaving venous end. Fluid remaining in interstitial space is drained into lymphatic vessels.

Factors that affect the substances to move into interstitial fluid from capillaries:

1. Concentration Gradient
2. Lipid solubility
3. Molecular weight (smaller molecules move more efficiently)

EDEMA

Edema is abnormal buildup of fluid in interstitial space.

CAUSES OF EDEMA

1. Imbalance of Starling forces
2. Increased hydrostatic capillary pressure which can be due to increase in volume e.g. due to heart failure or due to obstruction such as venous thrombosis.
3. Decrease in oncotic capillary pressure i.e. decrease in plasma protein which may be due to liver failure, malnutrition or nephrotic syndrome
4. External compression e.g. if due to breast cancer, veins or lymphatics in arm are compressed. Arterial blood keeps on going to the arm while venous blood cannot come back so all capillaries in arm develop high pressure and edema develops in arm.
5. In right ventricular failure, the venous return coming to heart cannot be pumped forward and patient develops generalized edema.

HYDROSTATIC PRESSURE AND EDEMA

Increased hydrostatic pressure increases the net filtration out pressure and decreases the net re-absorption pressure so there is excessive fluid accumulation in interstitial spaces resulting in pitting edema.

HYPOPROTEINEMIA AND EDEMA

Hyperproteinemia is seen in:

1. Cirrhosis of liver
2. Protein losing gastroenteropathy
3. Protein malnutrition
4. Protein losing nephropathy

Due to hypoproteinemia, filtration out pressure is increased while inward filtration pressure decreases and fluid accumulates in interstitium and produce pitting edema.

LYMPHATIC OBSTRUCTION AND EDEMA

Due to lymphatic obstruction, there is accumulation of proteins in interstitium. These proteins bind with water molecules and causes lymph edema. This edema is called non-pitting edema.

Pitting edema responds to pressure, be it from a finger or a hand, while pitting edema does not. If you press on your skin with your finger and it leaves an indentation, you could be suffering from pitting edema. Non-pitting edema, on the other hand, does not respond to pressure or cause any sort of indentation.

PERMEABILITY OF MICROCIRCULATION

The increased capillary permeability can be seen in inflammation and burns. When microcirculation becomes pathologically more permeable e.g. during inflammation substances such as histamine, bradykinin etc. leads to intra-endothelial cells shrinkage and microcirculation during inflammation becomes highly permeable and edema is produced.

EDEMA AND VENTRICULAR FAILURE

When left ventricle fails, edema is in pulmonary circulation while when right ventricle fails, edema is in systemic circulation.

LEFT VENTRICULAR FAILURE AND EDEMA

In left ventricular failure, venous return to the left heart cannot be pumped to arterial tree. Pressure in left ventricle increases and backward pressure on atrium also increases due to which pulmonary system cannot drain well. Pressure increases in pulmonary capillaries and fluid leaks from these capillaries leading to pulmonary edema. Initially it is called pulmonary interstitial edema but may be later severe to form alveolar edema.

RIGHT VENTRICULAR FAILURE AND EDEMA

In right ventricular failure, right ventricle fails to transfer systemic venous blood to pulmonary circulation. When right ventricle fails, backward pressure goes to systemic capillaries and leads to systemic edema

CARDIAC CONGESTIVE FAILURE AND EDEMA

In cardiac congestive failure, both the ventricles fail resulting in both systemic and pulmonary edema.