**NAME: EZENWIGBO JOHNPAUL OLUCHUKWU**

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## ASSIGNMENT

1. Discuss the long-term regulation of mean arterial blood pressure?

## LONG-TERM REGULATION OF MEAN ARTERIAL BLOOD PRESSURE

Kidneys play an important role in the long-term regulation of arterial blood pressure. When blood pressure alters slowly in several days/months/years, the nervous mechanism adapts to the altered pressure and loses the sensitivity for the changes. It cannot regulate the pressure any more. In such conditions, the renal mechanism operates efficiently to regulate the blood pressure. Therefore, it is called long-term regulation. Kidneys regulate arterial blood pressure by two ways:

A. By regulation of extracellular fluid (ECF) volume

B. Through renin-angiotensin mechanism.

**A. REGULATION OF EXTRACELLULAR FLUID VOLUME:** When the blood pressure increases, kidneys excrete large amounts of water and salt, particularly sodium, by means of pressure diuresis and pressure natriuresis. Pressure diuresis is the excretion of large quantity of water in urine because of increased blood pressure. Even a slight increase in blood pressure doubles the water excretion. Pressure natriuresis is the excretion of large quantity of sodium in urine. Because of diuresis and natriuresis, there is a decrease in ECF volume and blood volume, which in turn brings the arterial blood pressure back to normal level. When blood pressure decreases, the reabsorption of water from renal tubules is increased. This in turn, increases ECF volume, blood volume and cardiac output, resulting in restoration of blood pressure.

**B. THROUGH RENIN-ANGIOTENSIN MECHANISM:** When blood pressure and ECF volume decrease, renin secretion from kidneys is increased. It converts angiotensinogen into angiotensin I. This is converted into angiotensin II by ACE (angiotensin-converting enzyme). Angiotensin II acts in two ways to restore the blood pressure:

i. It causes constriction of arterioles in the body so that the peripheral resistance is increased and blood pressure rises. In addition, angiotensin II causes constriction of afferent arterioles in kidneys, so that glomerular filtration reduces. This results in retention of water and salts, increases ECF volume to normal level. This in turn increases the blood pressure to normal level.

ii. Simultaneously, angiotensin II stimulates the adrenal cortex to secrete aldosterone. This hormone increases reabsorption of sodium from renal tubules. Sodium reabsorption is followed by water reabsorption, resulting in increased.

2. Write short notes on the following:

a. Pulmonary circulation

b. Circle of Willis

c. Splanchnic circulation

d. Coronary circulation

e. Cutaneous circulation

**A. PULMONARY CIRCULATION:** Pulmonary circulation (otherwise known as lesser circulation) is the portion of the circulatory system which carries deoxygenated blood away from the right ventricle, to the lungs, and returns oxygenated blood to the left atrium and ventricle of the heart. The vessels of the pulmonary circulation are the pulmonary arteries and the pulmonary veins. Deoxygenated blood leaves the heart, goes to the lungs, and then re-enters the heart; Deoxygenated blood leaves through the right ventricle through the pulmonary artery. From the right atrium, the blood is pumped through the tricuspid valve (or right atrioventricular valve), into the right ventricle. Blood is then pumped from the right ventricle through the pulmonary valve and into the main pulmonary artery.

The pulmonary arteries carry deoxygenated blood to the lungs, where carbon dioxide is released and oxygen is picked up during respiration. Arteries are further divided into very fine capillaries which are extremely thin-walled. The pulmonary vein returns oxygenated blood to the left atrium of the heart. The oxygenated blood then leaves the lungs through pulmonary veins, which return it to the left part of the heart, completing the pulmonary cycle. This blood then enters the left atrium, which pumps it through the mitral valve into the left ventricle. From the left ventricle, the blood passes through the aortic valve to the aorta. The blood is then distributed to the body through the systemic circulation before returning again to the pulmonary circulation. From the right ventricle, blood is pumped through the semilunar pulmonary valve into the left and right main pulmonary arteries (one for each lung), which branch into smaller pulmonary arteries that spread throughout the lungs.

**B. CIRCLE OF WILLIS:** The circle of Willis is a circulatory anastomosis that supplies blood to the brain and surrounding structures. It is named after Thomas Willis (1621–1675), an English physician. The circle of Willis is a part of the cerebral circulation and is composed of the following arteries:

i. Anterior cerebral artery (left and right)

ii. Anterior communicating artery

iii. Internal carotid artery (left and right)

iv. Posterior cerebral artery (left and right)

v. Posterior communicating artery (left and right)

The left and right internal carotid arteries arise from the left and right common carotid arteries. The posterior communicating artery is given off as a branch of the internal carotid artery just before it divides into its terminal branches - the anterior and middle cerebral arteries. The anterior cerebral artery forms the anterolateral portion of the circle of Willis, while the middle cerebral artery does not contribute to the circle. The right and left posterior cerebral arteries arise from the basilar artery, which is formed by the left and right vertebral arteries. The vertebral arteries arise from the subclavian arteries. The anterior communicating artery connects the two anterior cerebral arteries and could be said to arise from either the left or right side.

The arrangement of the brain's arteries into the circle of Willis creates redundancy for collateral circulation in the cerebral circulation. If one part of the circle becomes blocked or narrowed or one of the arteries supplying the circle is blocked or narrowed, blood flow from the other blood vessels can often preserve the cerebral perfusion well enough to avoid the symptoms of ischemia.

**C. SPLANCHNIC CIRCULATION:** Splanchnic or visceral circulation consists of the blood supply to the gastrointestinal (GI) tract, liver, spleen, and pancreas constitutes three portions:

1. Mesenteric circulation supplying blood to gastrointestinal (GI) tract

2. Splenic circulation supplying blood to spleen

3. Hepatic circulation supplying blood to liver.

i. <u>MESENTERIC CIRCULATION</u>

REGULATION OF MESENTERIC BLOOD FLOW: Mesenteric blood flow is regulated by the following factors:

1. Local Autoregulation: Local autoregulation is the primary factor regulating blood flow through mesenteric bed.

2. Activity of Gastrointestinal Tract: Contraction of the wall of the GI tract reduces blood flow due to compression of blood vessels. And relaxation of wall of GI tract increases the blood flow due to removal of compression on the vessel wall.

3. Nervous Factor: Mesenteric blood flow is regulated by sympathetic nerve fibres. Increase in sympathetic activity as in the case of emotional conditions or ‘fight and flight reactions’ constrict the mesenteric blood vessels. So, more blood is diverted to organs like skeletal muscles, heart and brain, which need more blood during these conditions. Parasympathetic nerves do not have any direct action on the mesenteric blood vessels. But these nerves increase the contraction of GI tract which compresses the blood vessels, resulting in reduction in blood flow.

4. Chemical Factors – Functional Hyperemia: Functional hyperemia is the increase in mesenteric blood flow immediately after food intake. It is mainly because of gastrin and cholecystokinin secreted after food intake. In addition to these two GI hormones, digestive products of food substances such as glucose and fatty acids also cause vasodilatation and increase the mesenteric blood flow.

ii. SPLENIC CIRCULATION

IMPORTANCE OF SPLENIC CIRCULATION: Spleen is the main reservoir for blood. Due to the dilatation of blood vessels, a large amount of blood is stored in spleen. And the constriction of blood vessels by sympathetic stimulation releases blood into circulation.

STORAGE OF BLOOD: In spleen, two structures are involved in storage of blood, namely splenic venous sinuses and splenic pulp. Small arteries and arterioles open directly into the venous sinuses. When spleen distends, sinuses swell and large quantity of blood is stored. Capillaries of splenic pulp are highly permeable. So, most of the blood cells pass through capillary membrane and are stored in the pulp. Venous sinuses and the pulp are lined with reticuloendothelial cells.

REGULATION OF BLOOD FLOW TO SPLEEN: Blood flow to spleen is regulated by sympathetic nerve fibres.

iii. HEPATIC CIRCULATION

BLOOD VESSELS: Liver receives blood from two sources:

1. Hepatic artery

2. Portal vein.

NORMAL BLOOD FLOW: Liver receives maximum amount of blood as compared to any other organ in the body since, most of the metabolic activities are carried out in the liver. Blood flow to liver is 1,500 mL/minute, which forms 30% of the cardiac output. It is about 100 mL/100 g of tissue/minute. Normally, about 1,100 mL of blood flows through portal vein and remaining 400 mL of blood flows through hepatic artery. However, portal vein carries only about 25% of oxygen to liver. It is because it carries the blood, which has already passed through the blood vessels of GI tract, where oxygen might have been used. Hepatic artery transports 75% of oxygen to the liver.

REGULATION OF BLOOD FLOW TO LIVER: Blood flow to liver is regulated by the following factors:

1. Systemic Blood Pressure Systemic blood pressure is the important factor responsible for blood flow to liver and hepatic blood flow is directly proportional to systemic blood pressure.

2. Splenic Contraction During splenic contraction, blood flow to liver increases.

3. Movements of Intestine Motility of intestine increases hepatic blood flow.

4. Chemical Factors Chemical factors which increase the blood flow to liver by vasodilatation are:

a. Excess carbon dioxide

b. Lack of oxygen

c. Increase in hydrogen ion concentration.

**D. CORONARY CIRCULATION:** Coronary circulation is the circulation of blood in the blood vessels that supply the heart muscle (myocardium). Coronary arteries supply oxygenated blood to the heart muscle, and cardiac veins drain away the blood once it has been deoxygenated. Because the rest of the body, and most especially the brain, needs a steady supply of oxygenated blood that is free of all but the slightest interruptions, the heart is required to function continuously. Therefore, its circulation is of major importance not only to its own tissues but to the entire body and even the level of consciousness of the brain from moment to moment. Interruptions of coronary circulation quickly cause heart attacks (myocardial infarctions), in which the heart muscle is damaged by oxygen starvation. Such interruptions are usually caused by ischemic heart disease (coronary artery disease) and sometimes by embolism from other causes like obstruction in blood flow through vessels.

**i. Coronary Arteries:** Heart muscle is supplied by two coronary arteries, namely right and left coronary arteries, which are the first branches of aorta. Arteries encircle the heart in the manner of a crown, hence the name coronary arteries (Latin word corona = crown). Right coronary artery supplies whole of the right ventricle and posterior portion of left ventricle. Left coronary artery supplies mainly the anterior and lateral parts of left ventricle. Coronary arteries divide and subdivide into smaller branches, which run all along the surface of the heart. Smaller branches are called epicardiac arteries and give rise to further smaller branches known as final arteries or intramural vessels. Final arteries run at right-angles through the heart muscle, near the inner aspect of wall of the heart.

**ii. Venous Drainage:** Venous drainage from heart muscle is by three types of vessels.

1. Coronary Sinus Coronary sinus is the larger vein draining 75% of total coronary flow. It drains blood from left side of the heart and opens into right atrium near tricuspid valve.

2. Anterior Coronary Veins Anterior coronary veins drain blood from right side of the heart and open directly into right atrium.

3. Thebesian Veins Thebesian veins drain deoxygenated blood from myocardium, directly into the concerned chamber of the heart.

**E. CUTANEOUS CIRCULATION:** The cutaneous circulation is the circulation and blood supply of the skin. The skin is not a very metabolically active tissue and has relatively small energy requirements, so its blood supply is different to that of other tissues.

<u>ARCHITECTURE OF CUTANEOUS BLOOD VESSELS</u>

Architecture of cutaneous blood vessels is formed in the following manner:

1. Arterioles arising from the smaller arteries reach the base of papillae of dermis

2. Then, these arterioles turn horizontally and give rise to meta-arterioles

3. From meta-arterioles, hairpin-shaped capillary loops arise. Arterial limb of the loop ascends vertically in the papillae and turns to form a venous limb, which descends down.

4. After reaching the base of papillae, few venous limbs of neighbouring papillae unite to form the collecting venule

5. Collecting venules anastomose with one another to form the subpapillary venous plexus

6. Subpapillary plexus runs horizontally beneath the bases of papillae and drain into deeper veins.

FUNCTIONS OF CUTANEOUS CIRCULATION

Cutaneous blood flow performs two functions:

1. Supply of nutrition to skin:

2. Regulation of body temperature by heat loss.

NORMAL BLOOD FLOW TO SKIN

Under normal conditions, the blood flow to skin is about 250 mL/square meter/minute. When the body temperature increases, cutaneous blood flow increases up to 2,800 mL/square meter/minute because of cutaneous vasodilatation.

REGULATION OF CUTANEOUS BLOOD FLOW

Cutaneous blood flow is regulated mainly by body temperature. Hypothalamus plays an important role in regulating cutaneous blood flow. When body temperature increases, the hypothalamus is activated. Hypothalamus in turn causes cutaneous vasodilatation by acting through medullary vasomotor centre. Now, blood flow increases in skin. Increase in cutaneous blood flow causes the loss of heat from the body through sweat. When body temperature is low, vasoconstriction occurs in the skin. Therefore, the blood flow to skin decreases and prevents the heat loss from skin.

3. Discuss the cardiovascular adjustment that occurs during exercise?

**CARDIOVASCULAR ADJUSTMENTS DURING EXERCISE**

During exercise, there is an increase in metabolic needs of body tissues, particularly the muscles. Various adjustments in the body during exercise are aimed at:

1. Supply of various metabolic requisites like nutrients and oxygen to muscles and other tissues involved in exercise

2. Prevention of increase in body temperature

The integrated response to severe exercise involves fourfold to fivefold increases in cardiac output, which are due primarily to increases in cardiac rate and to a lesser extent to augmentation of stroke volume. The increase in stroke volume is partly due to an increase in end-diastolic cardiac size (Frank-Starling mechanism) and secondarily due to a reduction in end-systolic cardiac size. The full role of the Frank-Starling mechanism is masked by the concomitant tachycardia. The reduction in end-systolic dimensions can be related to increased contractility, mediated by beta adrenergic stimulation. Beta adrenergic blockade prevents the inotropic response, the decrease in end-systolic dimensions, and approximately 50% of the tachycardia of exercise. The enhanced cardiac output is distributed preferentially to the exercising muscles including the heart. Blood flow to the heart increases fourfold to fivefold as well, mainly reflecting the augmented metabolic requirements of the myocardium due to near maximal increases in cardiac rate and contractility. Blood flow to the inactive viscera (e.g., kidney and gastrointestinal tract) is maintained during severe exercise. It is suggested that local autoregulatory mechanisms are responsible for maintained visceral flow in the face of neural and hormonal autonomic drive, which acts to constrict renal and mesenteric vessels and to reduce blood flow. However, in the presence of circulatory impairment, where oxygen delivery to the exercising muscles is impaired as occurs to complete heart block where normal heart rate increases during exercise are prevented, or in congestive right heart failure, where normal stroke volume increases during exercise are impaired, or in the presence of severe anemia, where oxygen-carrying capacity of the blood is limited, visceral blood flows are reduced drastically and blood is diverted to the exercising musculature. Thus, visceral flow is normally maintained during severe exercise as long as all other compensatory mechanisms remain intact. However, when any other compensatory mechanism is disrupted (even the elimination of splenic reserve), reduction and diversion of visceral flow occur.