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QUESTIONS:

1. Discuss the long term regulation of mean arterial blood pressure?
2. Write short notes on the following:
    a. Pulmonary circulation
    b. Circle of Willis
    c. Splanchnic circulation
    d. Coronary circulation
    e. Cutaneous circulation
3. Discuss the cardiovascular adjustment that occurs during exercise

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

LONG TERM REGULATION OF MEAN ARTERIAL BLOOD PRESSURE

Mean arterial blood pressure is the average arterial pressure throughout one cardiac cycle (systole and diastole). Mean arterial blood pressure is roughly equal to the diastolic pressure (DP) plus one third of pulse pressure (PP) (difference between systolic and diastolic blood pressure) i.e. MAP = DP + 1/3 PP. Mean arterial blood pressure is the same for each organ and thus regional flow depends on it. Normal blood pressure is usually about 120/90mmHg. The normal value of mean arterial pressure is usually about 93mmHg (90-100mmHg). Mean arterial blood pressure can be regulated in a short term via chemoreceptor reflex and baroreceptor reflex but these mechanisms cannot be relied upon for a long period of time, the mean arterial pressure can therefore be regulated in a prolonged(long-term) manner via the Renin-Angiotensin-Aldosterone System (RAAS).

The Renin-Angiotensin-Aldosterone System (RAAS) is a hormone system within the body that is essential for the long regulation of blood pressure and fluid balance. This system is manly comprised of three hormones, renin, angiotensin II and aldosterone. It involves the kidneys, lungs, systemic vasculature and the brain. Primarily it is regulated by rate of renal flow. The mechanism of RAAS is as follows;

When there hemorrhage, dehydration or sodium ion(Na^+) deficiency, this causes decrease in blood pressure which in turn leads to low renal perfusion (rate of renal flow is reduced), the juxtaglomerular cells of the kidney detects the low renal perfusion and secretes renin in response to this. Renin then acts on angiotensinogen. Angiotensinogen is secreted by the liver into the plasma. Renin then converts Angiotensinogen into Angiotensin I. Angiotensin I is converted to Angiotensin II by the Angiotensin Converting Enzyme (ACE) found on surface of the epithelial cells of the kidney and lungs. Angiotensin II is the active form and it acts on the kidney, adrenal cortex, arterioles and brain.

Angiotensin II directly acts on the blood vessels particularly the arterioles by causing vasoconstriction of the blood vessels, this reduces the diameter of the blood vessels and increases total peripheral resistance. An increase in peripheral resistance (systemic vascular resistance) causes an increase in blood pressure.

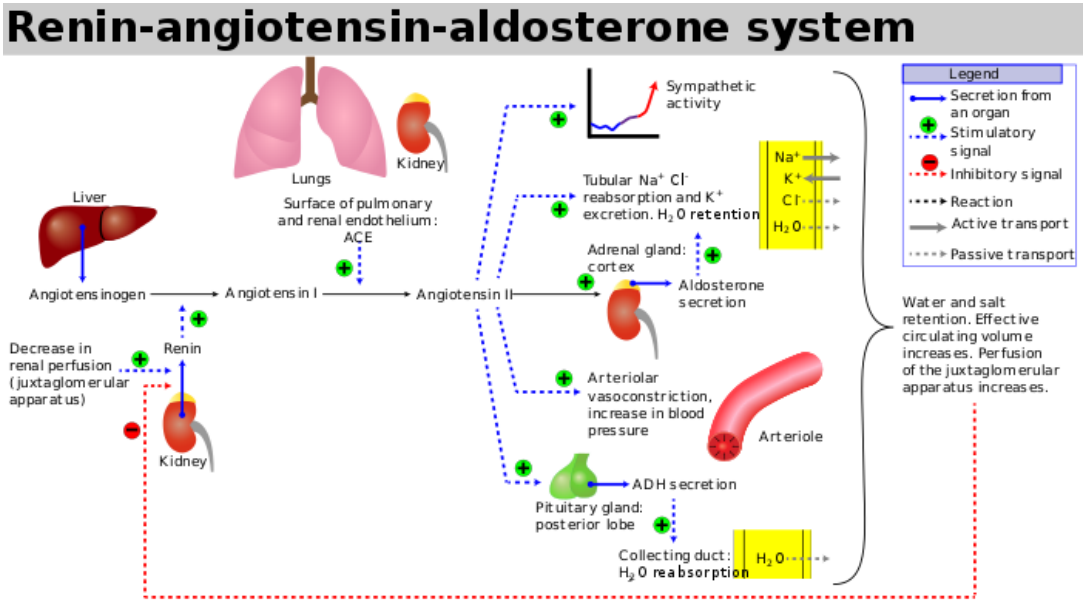
Angiotensin II acts on the adrenal cortex specifically the zona glomerulosa. Here, it stimulates the release of aldosterone. Aldosterone causes an increase in sodium and water reabsorption and potassium excretion in the kidney. This increases the osmolarity and increases in blood and ECF (extracellular fluid) volume. Increase in blood volume causes increase in stroke volume, cardiac output and in turn causes increase in blood pressure.

Angiotensin also acts on the kidney by causing increase in Na-H exchange in the proximal convoluted tubule of the kidney which increases sodium reabsorption. Increased sodium ion (Na^+) in the body serves to increase osmolarity of blood and this increases blood volume which in turn leads to increase in cardiac output and then blood pressure.

Finally, Angiotensin II acts on the brain. It has 2 effects here. First it binds to the hypothalamus, stimulating thirst and increased water intake. Second, it stimulates the release of antidiuretic hormone (ADH) by the posterior pituitary gland. Antidiuretic Hormone (ADH) or Vasopressin acts to increase

water reabsorption in the kidney and this increase blood volume (cardiac output) which in turn increases blood pressure. The Renin Angiotensin Aldosterone System (RAAS) is therefore very important in the long term regulation of blood pressure.

Clinical Significance: The RAAS serves to manage blood volume and blood pressure on a long-term basis. RAAS can also be activated inappropriately in several conditions that may lead to the development of hypertension, heart failure, diabetes mellitus, and acute myocardial infarction. ACE inhibitors e.g. enalapril, Angiotensin Receptor blockers e.g. losartan and aldosterone antagonists e.g. spironolactone all act to decrease the effect of the RAAS system.



2. Write short notes on the following:

a. **<u>Pulmonary Circulation:</u>** Pulmonary circulation involves the heart and the lungs. The pulmonary circulation function in respiratory gas exchange, reservoir for left ventricle, synthesis of angiotensin converting enzyme (ACE). The main arteries which constitute the pulmonary circulation are the pulmonary arteries and pulmonary veins. Pulmonary trunk arises from the right ventricle and divides into right and left pulmonary arteries which convey deoxygenated blood to the right and left lung respectively. The blood circulates through a capillary plexus in the walls of the alveoli and receives oxygen from the alveolar air. This blood then becomes oxygenated is returned to the heart (left atrium) via the four pulmonary veins. The pulmonary circulation is also known as smaller circulation or low pressure, low resistance and high capacitance system and the pressure in the smaller circulation is about 25/10mmHg. Pulmonary vessels contain about 600mL of blood at resistance. Since pulmonary vessels act as capacitance vessels, their blood content can vary from 200 to 900mL.

b. **Circle of Willis**: The circle of Willis is an anatomical structure that provides an anastomotic connection between the anterior and posterior circulation providing collateral flow to affected brain regions in the event of arterial incompetency. The circle of Willis is functional in cerebral circulation. The circle of Willis is a junction of several important arteries at the bottom part of the brain. It helps blood flow from both the fore and hind brain. It also allows blood to flow across the midline of the brain if an artery on one side is occluded. The circle of Willis thereby serves as a safety valve function for the brain allowing collateral circulation to take place if flow is reduced to one area. The circle of Willis begins to form when the right and left internal carotid artery (ICA) enters the cranial cavity and each one divides into two main branches: the anterior cerebral artery (ACA) and middle cerebral artery (MCA). The anterior cerebral arteries are then united and blood can cross flow by the anterior communicating (ACOM) artery. The ACAs supply most midline portions of the frontal lobes and superior medial parietal lobes. The MCAs supply most of the lateral surface of the hemisphere, except the superior portion of the parietal lobe (via ACA) and the inferior portion of the temporal lobe and occipital lobe. The ACAs, ACOM, and MCAs form the anterior half, better known as the anterior cerebral circulation. Posteriorly, the basilar artery (BA), formed by the left and right vertebral arteries, branches into a left and right posterior cerebral artery (PCA), forming the posterior circulation. [3] The PCAs mostly supply blood to the occipital lobe and inferior portion of the temporal lobe.

c. **Splanchnic Circulation:** Splanchnic circulation is also known as mesenteric circulation. It consists of blood supply to the gastrointestinal tract, liver, spleen, and pancreas. Splanchnic circulation involves three circulations, mesenteric circulation supplying blood to GI tract, splenic circulation supplying blood to spleen and hepatic circulation supplying blood to liver. Arteries supplying blood to these organs include the coeliac trunk which divides into three main branches the left gastric artery, hepatic artery and splenic artery, superior mesenteric artery, inferior mesenteric artery. The veins of the splanchnic circulation form the hepatic portal system. Hepatic portal system carries blood from the GIT viscera to the liver. 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. During rest the abdominal GIT, viscera and liver receive about 1500 mL blood per minute (about 30% of cardiac output) via coeliac, superior mesenteric and inferior mesenteric arteries. Splanchnic circulation is regulated via auto regulation and neural mechanisms as well.

d. **Coronary circulation:** Coronary circulation involves the blood supply to the heart itself i.e. the heart muscles (myocardium). It consist of two coronary arteries (right and left) which arises from the root of the ascending aorta and supply blood to the myocardium. Left coronary artery supplies the left atrium, left ventricle and left interventricular septum. It divides into circumflex artery and anterior interventricular artery. Right coronary artery supplies the right atrium, supplies right atrium, right ventricle, part of left ventricle, electrical conduction system. It divides into right marginal artery and right interventricular artery. In about 50% of individuals the predominant supply to the heart is by the right coronary artery and in about 20% of individuals, the predominant supply o the myocardium is by the left coronary artery. In 30% of individuals it is the balanced supply i.e. equal supply by the two arteries. The veins involved in coronary circulation are called the cardiac veins and they retrieve deoxygenated blood from the heart. Coronary circulation is essential because a continuous flow of blood to the heart

maintains an adequate supply of O_2 and nutrients. Coronary circulation is managed primarily by local (intrinsic) control, secondarily by sympathetic nervous system.

e. **Cutaneous circulation:** Cutaneous circulation is the circulation and blood supply of the skin. The cutaneous tissue has a relatively low metabolic activity compared to other tissues and organs. Therefore under normal conditions, circulation to the skin makes up about 4% of the total cardiac output. However, cutaneous circulation plays an important role in the regulation of core body temperature. Cutaneous arterioles form a dense network just under the dermis layer of the skin. . Venules form an extensive sub papillary venous plexus which holds large quantity of blood and lie parallel to the surface of skin and play an important role in maintaining the body temperature. Arteriovenous anastomoses are located in the distal parts of the extremities (hands and feet), the nose, lips and ear lobules. These vessels serve as shunts and allow blood to bypass the superficial capillary loops and play a major role during control of body temperature. Under normal conditions, the blood flow to the skin is about is about 10–15 mL/min/ 100 g of skin tissue and this is increased or decreased in response to exposure to heat or cold respectively. Cutaneous circulation is regulated mainly by neural mechanisms rather than metabolic mechanisms. When body temperature increases, the hypothalamus is activated. Hypothalamus in turn causes cutaneous vasodilatation by acting through medullary vasomotor center. 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 REGULATION DURING EXERCISE

Exercise is a form of endurance activity. Exercise places an increased demand on the cardiovascular system to pump more oxygen to supply the working muscle to produce energy (aerobic oxidation). During exercise, oxygen demand by the muscles increases, more nutrients are needed and more waste is produced. At rest, heart rate is 60-80 beats/min, stroke volume is 50-70ml/beat, blood pressure is 120/80mmHg and cardiac output is about 5L/min. Before exercise, there is anticipatory response (increased heart rate before exercise) caused by release of Epinephrine and Norepinephrine (Adrenaline and Noradrenaline). During exercise, there is increased uptake (usage) of oxygen and increased release of carbon dioxide into the blood. There is also increased muscular contractions in the heart and skeletal muscles as well as increased blood pressure. The chemoreceptors in the aortic arch and carotid sinus detect hypoxia (reduced oxygen content in blood) and hypercapnia (increased carbon dioxide content in blood). Baroreceptors also present in the aortic arch and carotid sinus detect the increased blood pressure. Mechanoreceptors (Proprioceptors) detect increased muscular contractions. Chemoreceptors, Baroreceptors, Mechanoreceptors will then send impulse (information) to the cerebral cortex which then sends impulse to the medulla. In the medulla, the Cardioaccelatory Center (CAC) is stimulated and the Cardioinhibitory Center (CIC) is inhibited. The cardioaccelatory center initiates sympathetic discharge and this causes stimulation of the SA node and the ventricular muscles. This causes increase in heart rate and contractility in heart (ventricular) muscles and skeletal muscles. This in turn causes increase in stroke volume and

cardiac output. Increase in cardiac output helps deliver more oxygen to working muscles in order to produce more energy during exercise. Also, the capillaries and arteries to the organs vasoconstrict and the capillaries and arterioles vasodilate in order to redistribute blood flow so that working muscles receive more blood compared to during rest. This also helps deliver more oxygen to working muscles in order to produce more energy during exercise.