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DEPARTMENT: - MBBS

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QUESTION: -

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.

ANSWER

1. Long-term regulation involves mainly the regulation of extracellular fluid volume by pressure natriuresis mechanisms residing in the kidney and by widespread actions of angiotensin. There are several physiological mechanisms that regulate blood pressure in the long-term, the first of which is the renin-angiotensin-aldosterone system (RAAS).

Renin-Angiotensin-Aldosterone System (RAAS)

Renin is a peptide hormone released by the granular cells of the **juxtaglomerular apparatus** in the kidney. It is released in response to:

- Sympathetic stimulation
- Reduced sodium-chloride delivery to the distal convoluted tubule
- Decreased blood flow

Renin facilitates the conversion of angiotensinogen to angiotensin I which is then converted to angiotensin II using angiotensin -converting enzyme (ACE).

Angiotensin II is a potent vasoconstrictor. It acts directly on the kidney to increase sodium reabsorption in the proximal convoluted tubule. Sodium is reabsorbed via the sodium-hydrogen exchanger. Angiotensin II also promotes release of aldosterone.

ACE also breaks down a substance called bradykinin which is a potent vasodilator. Therefore, the breakdown of bradykinin potentiates the overall constricting effect. Aldosterone promotes salt and water retention by acting at the distal end of the convoluted tubule to increase expressions of the epithelial sodium channels. Furthermore, aldosterone increases the activity

of the basolateral sodium-potassium ATP-ase, thus increasing the electrochemical gradient for movement of sodium ions.

More sodium collects in the kidney tissue and water, then follows by osmosis. This results in decreased water excretion and therefore increased blood volume and thus blood pressure.

Anti-Diuretic Hormone (ADH)

The second mechanism by which blood pressure is regulated is release of Anti Diuretic Hormone (ADH) from the OVLT of the hypothalamus in response to thirst or an increased plasma osmolarity.

ADH acts to increase the permeability of the collecting duct to water by inserting **aquaporin channels** (AQP2) into the apical membrane.

It also stimulates sodium reabsorption from the thick ascending limb of the loop of Henle. This increases water reabsorption thus increasing plasma volume and decreasing osmolarity.

Further Control of Blood Pressure

Other factors that can affect long-term regulation of blood pressure are natriuretic peptides. These include: -

- Atrial natriuretic peptide (ANP) is synthesized and stored in cardiac myocytes. It is released when the atria are stretched indicating of the high blood pressure.
- ANP acts to promote sodium excretion. It dilates the **afferent arteriole** of the glomerulus, increasing blood flow (GFR). Moreover, ANP inhibits sodium reabsorption along the nephron. Conversely, ANP secretion is low when the blood pressure is low.
- **Prostaglandins** act as local vasodilators to increase GFR and reduce sodium reabsorption. They also act to prevent excessive vasoconstriction triggered by the sympathetic nervous and renin-angiotensin-aldosterone systems.

2.

a. <u>Pulmonary circulation: -</u>

The pulmonary 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.

Deoxygenated blood leaves the heart, goes to the lungs, and then re-enters the heart; deoxygenated blood leaves 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 pumped from the right ventricle through the pulmonary valve and into the main pulmonary artery. The pulmonary artery arteries carry deoxygenated blood to the lungs, where CO2 is released and O2 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 leaves then leave the lungs through pulmonary veins, which pumps it through the mitral valve into the left ventricle. From the left ventricle, the blood is then

distributed to the body 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: -

Blood flow to the brain is supplied by four large arteries-two carotid and two vertebral arteries- that merge to the ***circle of Willis*** at the base of the brain. The arteries arising from the circle of Willis travel along the brain surface and give rise to the ***pial*** arteries, which branch out into small vessels called *penetrating arteries* and *arterioles*. The penetrating vessels are separated slightly from the brain tissue by extension of the subarachnoid space called the Virchow-Robin space. The penetrating vessels dive down into the brain tissue, giving rise to intracerebral arterioles, which eventually branch into capillaries where exchange among the blood and the tissues of oxygen, carbon dioxide and metabolites occur.

The circle of Willis is a ring of interconnecting arteries located at the base of the brain around the optic chiasm or chiasma (partial crossing of the optic nerve – CNII; this is important for binocular vision), infundibulum of the pituitary stalk and the hypothalamus. This arterial ring provides blood to the brain and the neighbouring structures. Polygonal anastomotic shape offers the possibility of alternate pathways for the blood flow, which is essential for the brain functioning, since it is the structure that is mostly sensitive to hypoxia. Hypoxia of the brain tissue that lasts longer than 6 minutes results with the irreversible changes in the brain parenchyma, and depending on the location of the lesion, the functional damages vary widely.

This arterial circle is more accurately referred to as "**the polygon of Willis**" by the French. Although it was noticed briefly and incompletely by ancient doctors, it is described completely by an English doctor called "**Thomas Willis**" in his book – Cerebri Anatome in 1664. Hence the circle was named after him.

c. Splanchnic circulation: -

The blood vessels of the gastrointestinal system are part of a more extensive system called the splanchnic circulation. It includes the blood flow through the gut plus blood flows through the spleen, pancreas and liver. The design of this system is such that all the blood that courses through the gut, spleen and pancreas then flows immediately into the liver by way of *portal* vein. In the liver, the blood passes through millions of minute *liver sinusoids* and finally leaves the liver by way of *hepatic veins* that empty into the vena cava, allows the *reticuloendothelial cells* that line the liver sinusoids to remove bacteria and other particulate matter that might enter the gastrointestinal tract, thus preventing direct transport of potentially harmful agents into the remainder of the body.

The non-fat, water-soluble nutrients absorbed from the gut (such as carbohydrates and proteins) are transported in the portal venous blood to the same liver sinusoids. Here, both the reticuloendothelial cells and the principal parenchyma cells of the liver, the hepatic cells, absorb and store temporarily from one half to three quarters of the nutrients. Also, much chemical intermediary processing of these nutrients occurs in the liver cells. Almost all of the

fats absorbed from the intestinal lymphatics and then conducted to the systemic circulating blood by way of the thoracic duct, bypassing the liver.

d. Coronary circulation: -

Coronary circulation is the circulation of the 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. Coronary arteries supply blood to the heart muscle. Like all other tissues in the body, the heart muscle needs oxygen-rich blood to function. Also, oxygen-depleted blood must be carried away. The coronary arteries wrap around the outside of the heart.

From the tissue capillaries, the deoxygenated blood returns through a system of veins to the right atrium of the heart. The coronary arteries are the only vessels that branch from the ascending aorta. The brachiocephalic, left common carotid, and left subclavian arteries branch from the aortic arch. The right marginal coronary artery, the left main coronary, the left anterior descending, and the left circumflex coronary artery, are the four major coronary arteries.

e. Cutaneous circulation: -

The cutaneous circulation and blood supply of the skin. The skin is not very metabolically active tissue and has relatively small energy requirements, so its blood supply is different to that of other tissues. Some of the circulating blood volume in the skin will flow through arteriovenous anastomoses (AVAs) instead of capillaries. AVAs serve a role in temperature regulation.

AVAs are low-resistance connections between the small arteries and small veins that supply and drain the skin. These allow the shunt of blood directly into the venous plexuses of the skin, without it passing through capillaries. Since AVAs contain no capillary section, they are not involved in transport of nutrients to/from the tissues, but instead play a role in temperature regulation.

The skin is the body's main heat dissipating surface: the amount of the blood flow to the skin determines the degree of heat loss and therefore the core body temperature. The blood flow through AVAs is heavily influenced by the sympathetic nervous system. At rest, the SNS dominates and constricts the AVAs. Any changes in core temperature are detected by the thermoregulatory centre in the hypothalamus. It regulates temperature by altering the level of the sympathetic outflow to the cutaneous vessels, to return temperature to its normal range:

In high core temperatures:

- Sympathetic innervation is decreased, reducing the vasomotor tone in the AVAs.
- More blood flows through the AVAs and reaches the venous plexus (close to the surface of the skin), increasing heat loss to reduce core temperature.

In low core temperatures:

- Sympathetic innervation is increased, increasing the vasomotor tone in the AVAs.
- Less blood flows to the apical skin (of nose, lips, ears, hands and feet), reducing heat loss to increase the core the core temperature.

3. There are some major effects that occur during exercise that are essential for the cardiovascular system to adjust to the situation.

- Rapid increase in heart rate, stroke volume, cardiac output
  - Due to withdrawal of parasympathetic stimuli.
  - Increased input from sympathetic nerves.
- Continued increase in heart rate
  - Temperature increases.
  - Feedback from proprioceptors.
  - Accumulation of metabolites.