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Assignment 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.

Answers

[1] There are several physiological mechanisms that regulate blood pressure in the long term but long term regulation involves mainly the renin-angiotensin-aldosterone system (RAAS) and the regulation of extracellular fluid volume by pressure natriuresis mechanisms residing in the kidney.

Renin is a peptide hormone released in the juxtaglomerular apparatus in the kidney. It released in response to decreased sodium chloride delivery to the convoluted tubules, reduced blood flow to the kidney or sympathetic stimulation. It facilitates for the conversion of angiotensinogen to angiotensin I which is also converted to angiotensin II by the action of angiotensin converting enzyme. Angiotensin II acts to increase sodium reabsorption in the proximal convoluted tubules of the kidney hence it being a potent vasoconstrictor, it also allows for the release of aldosterone.

Aldosterone allows for increased water and salt retention by increased expression of epithelial sodium channels in the distal convoluted tubule. It increases the activity of basolateral sodium-potassium ATP-ase. More sodium collects in the kidney and water follows through osmosis thereby decreasing water excretion, this increases blood volume which in turn increases blood pressure.

The release of Anti-Diuretic Hormone is another method by which blood pressure is regulated. It is released from the hypothalamus in response to thirst or increased plasma osmolarity. It acts to increase the permeability of the collecting duct to water by inserting aquaporin channels to the apical membranes. It allows for sodium reabsorption in the loop of henle which in turn increases water reabsorption which in turn increases plasma volume and decreases osmolarity.

Atrial natriuretic peptide is another factor that affects long term regulation of blood pressure. It is released when the atria is stretched and this indicates high blood pressure.

Prostaglandins also affect long term regulation of blood pressure, they prevent excessive vasoconstriction triggered by the sympathetic nervous system and the renin-angiotensin-aldosterone system.

[2] [A] Pulmonary Circulation: Pulmonary circulation has to do with the movement of blood from the right ventricle through the pulmonary artery, which divides into the right and left pulmonary artery carrying blood into the right and left lungs. In the lungs each artery branches into smaller arteries, arterioles and capillaries. The pulmonary capillaries surrounds the alveoli of the lungs and it is here there is exchange of carbon dioxide and oxygen. These capillaries then unite to form venules which merge to form veins and finally into the two pulmonary veins that return oxygenated blood to the left atrium.

[B] Circle of Willis: This is the joining area of several arteries of the bottom side of the brain. The brain receives oxygenated blood from branches of the inferior carotid, artery posterior cerebral artery and posterior communicating artery, these branches form the circle of willis. It helps blood flow from both the front and back sections of the brain. It acts to provide collateral blood flow between the anterior and posterior circulations of the brain.

[C] Splanchnic Circulation: It consists of the blood supply to the gastrointestinal tract, liver, spleen and pancreas. It consists of two large capillary beds partially in series. The small splanchnic arterial branches supply the capillary beds and then the efferent venous blood flows into the PV. The splanchnic circulation receives over 25% of the cardiac output and contains a similar percentage of the total blood volume under normal conditions. It can act as a site for regulation of distribution of cardiac output and also a blood reservoir.

[D] Coronary Circulation: This is the circulation of the blood vessels that supply the heart muscle. Coronary arteries supply oxygenated blood to the heart muscle and cardiac veins drain away the blood once it has been deoxygenated. From the tissue capillaries, the deoxygenated blood returns through a system of veins to the right atrium of the heart. The aorta which is the main blood supplier to the body branches of into two main coronary blood vessels that branch off into smaller arteries which supply oxygen rich blood to the entire heart muscle.

[E] Cutaneous Circulation: Cutaneous circulation is the circulation and blood supply of the skin. Some of the circulating blood volume in the skin will flow through arteriovenous anastomoses rather than capillaries. Arteriovenous anastomoses are low-resistance connections between the small arteries and small veins that supply and drain the skin, they allow for shunting of blood flow directly into the venous plexus without passing it through capillaries. They serve a role in temperature regulation.

[3] During exercise there is a lot of physical stress on the cardiovascular system because of this there is the demand for increase in oxygen and nutrients to the exercising muscles. There is also a proportional removal of metabolic waste and heat. The cardiovascular system makes some adjustments by which the body can be able to cope with the physical strain on it. Some of these adjustments include: Changes in cardiac function, change in arterial blood pressure, redistribution of cardiac output, increased oxygen delivery to the tissues, temperature regulation.

[I] Changes in Cardiac Function: The cardiac function changes include; increase in stroke volume, heart rate and cardiac output. In exercise, cardiac output can increase from 5L to 30L per minute. The changes in force of contraction of the heart, are brought about by increase sympathetic discharge to the heart, reduced parasympathetic tone to the heart etc. Also, venoconstiction, muscle pump, thoracic pump, mobilization of blood from the viscera and increased pressure transmitted through the dilated arterioles to the veins increase venous return to the heart. An increased venous return will raise cardiac output.

[II] Change in Arterial Blood Pressure: There is usually an increase in arterial pressure in exercise. The increase can be as little as 20mmHg or as great as 80mmHg depending on the type of exercise and condition under which the exercise is performed. The increase in arterial pressure in exercise is due to a number of factors:

Vasoconstriction of the arterioles and small arteries in most tissues of the body, except in the exercising skeletal muscles. Increased pumping activity of the heart. Both heart rate and stroke volume increase in exercise, leading to tremendous increase in C.O. There is mixed vasoconstriction leading to a great increase in venous return.

[III] Redistribution of Cardiac Output: Blood flow to the exercising muscle increases enormously during maximal exercise from about 750ml/min to more than 20L per minute. The proportion of the cardiac output that goes to the exercising muscles may rise from the resting value of 15% to 85%. The increase is due to marked arteriolar dilation in the exercising muscles, cardiac output are strongly vasodilated by the local vasodilator substances such as low O_2 tension, K^+, acetylcholine ATP, lactic acid and CO_2 in the muscles themselves when most of the arterioles of the peripheral circulation are strongly contracted. Thus, there is marked increase in blood flow to the active muscles, while blood flow through most of the non-muscular areas of the body is temporarily reduced.

[IV] Increased Oxygen Delivery to the Tissues: This is achieved by the combined effects of the following:

a) Increased pulmonary ventilation-The rate and depth of breathing is increased

b) Increased CO-This ensures that more blood gets to the tissues. The combined effect of {a} and {b} bring about an enormous increase in the O_2 load transported to the tissues.

c) At the tissue level, the following adjustments ensure increased O_2 delivery to the tissues.

d) I) more capillaries are open and the capillaries are dilated.

e) ii) The dilated vessels reduce the distance of diffusion between the capillary walls and the body cells.

f) iii) Because the muscle cells are very active, PO_2 inside them could be 15mmHg or less. Since arterial PO_2 is 97mmHg, the diffusion gradient for O_2 is increased and this leads to a more rapid diffusion of O_2 to the tissues

g) iv)Increased temperature, increased CO_2 production, fall in pH and increase 2, 3-DPG{diphosphateglycerate} level cause the oxygen-haemoglobin dissociation curve to shift to the right thereby increasing O_2 release to the tissues.

h) All the factors (I) to (IV) above operate in a synergistic manner to increase O_2 delivery to the exercising muscles by up to 20 times the resting value.

[V] Temperature Regulation: Due to increased pulmonary ventilation and the skin heat loss is increased. Most of the heat produced in the body is generated in the deep organs, especially in the liver, brain, heart& skeletal muscles during exercise. The rate at which heat is lost is determined by two factors:

How rapidly the heat produced in the core of the body can be carried to the skin and how rapidly heat can be transferred from the skin to the surroundings.

Blood vessels are distributed profusely immediately beneath the skin. There is a continuous venous plexus beneath the skin that is supplied by inflow of blood from the skin capillaries. When the vessels are fully dilated, 30% of C.O can supply the skin. A high rate