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1. Discussion on the long-term regulation of mean arterial blood pressure

The body has various mechanisms to maintain the blood pressure. One of such is the renal mechanism which comes in place after the nervous mechanism has lost its sensitivity for changes and can no longer regulate pressure any more. The kidney regulates blood pressure in two ways:

A. By regulating the volume of extracellular fluid

When blood pressure increases, the kidney undergoes pressure diuresis (excretion of large amount of water in the form of urine) and natriuresis (excretion of large amount of sodium in urine) and this leads to a decrease in ECF and blood volume which then brings the arterial pressure back to normal. When the blood pressure decreases, the water reabsorbed from the renal tubules increases and this increase the ECF and blood volume which in turn restores the blood pressure back to the normal limit.

B. Through the renin-angiotensin mechanism

When blood pressure and ECF volume decrease, renin secretion from kidneys is increased and this converts angiotensinogen produced in the liver into angiotensin I and angiotensin I is converted to angiotensin II by angiotensin converting enzyme produced in the lungs. Angiotensin II either works by stimulating the adrenal gland to secret aldosterone which works on the collecting ducts of the kidney to aid water and sodium retention and this results in increased ECF and blood volume which increases blood pressure to the normal level or angiotensin II causes constriction of the arteries to increase peripheral resistance which in turn increases blood pressure. Apart from angiotensin II, angiotensin II and IV also increase blood pressure and stimulate the adrenal gland to secrete aldosterone.

2. Short notes

A. Pulmonary circulation

This is part of the circulatory system that 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 blood vessels involved in this circulation include the pulmonary artery, which carries deoxygenated blood from the right ventricle to the alveoli of the lungs and the bronchial artery which supplies arterial blood to the bronchi, the connective tissue and other structures of the lung stroma, visceral pleura and pulmonary lymph nodes. The component of its physiological shunt includes: the flow of deoxygenated blood from bronchial circulation into pulmonary veins without being oxygenated and flow of oxygenated blood from thebesian veins into cardiac chambers directly. The physiological shunt leads to a venous admixture (mixing of deoxygenated blood with deoxygenated blood) and the fraction of the venous blood which isn't fully oxygenated is known as wasted blood. 1% or 2% of cardiac output is the value of the normal physiological shunt of venous blood going to the left side of the heart. Although, this value may increase up to 5% and pathological increase can also occur in conditions such as acute pulmonary infections and bronchiectasis. The features of pulmonary vessels are: they are highly elastic and more distensible, the arteries have a thick wall, the capillaries are larger than those of the systemic circulation, this vascular system is a low-pressure system and the vascular resistance is very less compared to that of the systemic circulation. The lungs receive the entire amount of blood pumped out from the right ventricle, which is about 5 liters. The pulmonary vascular system is a low-pressure bed with systolic pressure of 25 mm Hg, diastolic pressure of 10 mm Hg and mean arterial pressure of 15 mm Hg while the pulmonary capillary pressure is about 7 mm Hg. We can measure pulmonary blood flow using the Fick principle. The following factors regulate pulmonary blood flow: cardiac output, chemical factors (effect of excess carbon dioxide and lack of oxygen), vascular resistance, nervous factors (sympathetic and parasympathetic nerves) and gravity and hydrostatic pressure (pressure differs indifferent parts of the lung)

B. Circle of Willis

The circle of Willis is formed by two group of arteries namely, the internal carotid arteries and two vertebral arteries, which supply blood to the anterior and posterior parts of the brain respectively. These arteries arise in the neck and move to the cranium, where their terminal branches anastomose to form the circle of Willis. The vertebral arteries originate from the subclavian arteries, move upwards and ascend the neck via the foramen magnum and enter the cranial cavity, where they give rise to branches like the meningeal branch, anterior and posterior spinal arteries and posterior inferior cerebellar artery. After this, the vertebral arteries join in order to form the basilar artery, which gives off branches like the pontine artery, superior, posterior and anterior inferior cerebellar arteries. The internal carotid arteries originate from the common carotid arteries at the bifurcation of these arteries, at the level of the fourth cervical vertebrae and then enter the brain through the carotid canal, then they pass anteriorly through the cavernous sinus and distal to this they form branches like the ophthalmic artery, middle cerebral artery and striate artery, posterior and anterior communicating arteries, anterior choroidal artery and anterior cerebral artery. It then continues as the middle cerebral artery which supplies the lateral part of the cerebrum. The three main paired constituents of the circle of Willis include: the anterior cerebral arteries, the internal carotid arteries and posterior cerebral arteries with connecting vessels such as the anterior and posterior communicating artery. The circle of Willis plays an important role, as it allows for proper blood flow from the arteries to both the front and back hemispheres of the brain. It also serves as a sort of safety mechanism if a blockage or narrowing slows or prevents the blood flow in a connected artery, the change in pressure can cause blood to flow forward or backward in the circle of Willis to compensate. It could also help blood flow from one side of the brain to the other in a situation in which the arteries on one side have reduced blood flow.

C. Splanchnic circulation

This circulation has three portions which are: the mesenteric circulation supplying the Gastrointestinal tract, the splenic circulation supplying the spleen and the hepatic circulation supplying the liver. The splanchnic circulation is unique in that the blood from the mesenteric bed and spleen form a major amount of the blood flowing to the liver. Blood to the liver from the GI tract and spleen flow through the portal system. The distribution of blood flow to the pancreas is 80 mL/100 g/min, the intestine is 50 mL/ 100 g/ min while the stomach is 35 mL/100 g/min. The following factors regulate mesenteric blood flow: local autoregulation through the mesenteric bed, contraction and relaxation of the GI tract, nervous factor (the influence of sympathetic and parasympathetic nerves) and chemical factor (the functional hyperemia). The spleen is the main blood reservoir, it stores blood through the splenic venous sinuses and the splenic pulp and it is regulated by the sympathetic nerve fibers. The liver receives blood through the portal vein and hepatic artery, it is the organ that receives the maximum amount of blood flow which is 1500 mL/min, forming 30% of the cardiac output. The following factors regulate blood flow to the liver: movements of the intestine, splenic contraction, systemic blood pressure, nervous factors and chemical factors (excess carbon dioxide and lack of oxygen).

D. Coronary circulation

The coronary arteries which supply the heart include the left and right coronary arteries, which are first branches of the aorta. The right coronary artery supplies the right ventricle and the posterior portion of the left ventricle while the left one mainly supplies the anterior and lateral parts of the left ventricle. These arteries divide and subdivide into smaller branches that run along the heart's surface. Smaller branches called epicardic arteries give rise to further smaller ones, called final or intramural arteries, that run at right angle through the heart muscle. Its venous drainage include: coronary sinus which drains 75% of total coronary flow from the left side of the heart, opening into the right atrium near the tricuspid valve, the anterior coronary veins which drains blood from the right side of the heart, opening directly into the right atrium and finally, the thebesian veins which drain deoxygenated blood from the myocardium directly into the concerned chamber of the heart. The physiological shunt is the diverted route through which the venous blood is mixed with the arterial blood. Part of it include: venous blood flowing from the thebesian veins, drainage of deoxygenated blood from bronchial circulation into pulmonary circulation without being oxygenated. The normal blood flow through the coronary circulation is about 200mL/min, forming 4% of cardiac output and about 65 to 70mL/min/100 g of cardiac muscle. The direct method of measuring the coronary blood flow is by the electromagnetic flowmeter while the indirect method involves using the doppler flowmeter, the Fick principle and by video densitometry. The blood flow through the coronary arteries is not stable, it decreases during systole because the intramural vessels are compressed, reducing blood flow while it increases during diastole because the compression is released, distending the blood vessels. The factors regulating coronary blood flow include autoregulation (when the mean arterial pressure is between 60- and 150-mm Hg, the coronary flow isn't affected), which also has some factors involved in its mechanism: need for oxygen, metabolic factors, coronary perfusion pressure and nervous factors. Some coronary artery disease includes: coronary occlusion, myocardial infarction, angina pectoris and myocardial ischemia and necrosis.

E. Cutaneous circulation

The architecture of the cutaneous blood vessels includes: the arterioles coming from smaller arteries reach the base of the dermis papillae and give rise to meta-arterioles after turning horizontally. Capillary loops then arise, its arterial limb ascend vertically in the papillae and turns to form a venous limb, which goes down. After reaching down, few of these limbs join together to form the collecting venule, which anastomose with one another to form the subpapillary venous plexus, which run horizontally beneath the bases of papillae and drain into the deeper veins. The cutaneous circulation supplies nutrient to the skin and regulates body temperature though heat loss. The normal blood flow to the skin is about 250 mL/square meter/ min but during increased body temperature it can be up to 2800 mL/square meter/ minute. The cutaneous blood flow is mainly regulated by the body temperature with the help of the hypothalamus. The vascular responses of the skin to mechanical stimuli are of two types: the white reaction and the Lewis triple response.

3. Cardiovascular adjustment during exercise

There is always an increase in metabolic needs of the tissues during exercise and the body makes various adjustments to prevent the body temperature from increasing and to supply various metabolic requisites to the muscles and tissues used in exercising.

Types of exercise

A. Based on the type of muscular contraction: dynamic exercise which involves isotonic muscular contraction and it increases systolic pressure, heart rate, force of contraction and cardiac output while the diastolic pressure isn't changed or it decreases and static exercise which involves isometric muscular contraction and both the systolic and diastolic pressure increase.
B. Based on the type of metabolism: aerobic exercise which involves using nutrients in the presence of oxygen which enables it to be performed for a longer period of time. Anerobic exercise which uses energy obtained by burning glycogen stored in the muscles leading to the liberation of lactic acid, whose accumulation leads to fatigue and hence prevents this exercise from being performed for a long period.

Metabolism in aerobic and anerobic exercises

When a person starts doing some exercise like jogging, bicycling or swimming, the person undergoes anerobic metabolism by burning the glycogen already stored in the muscle due to its need to have quick energy during the first few minutes. During this period, only glycogen is burnt in the absence of oxygen and lactic acid is produced which causes a burning sensation in the muscles particularly the muscles of arms, legs and back. Muscles burn all the muscle glycogen within 3 to 5 minutes and if the person continues the exercise past this, glycogen stored in liver is converted into glucose, which is transported to muscles through blood and now the body moves into aerobic metabolism. The glucose obtained from liver is burnt in the presence of oxygen, no more lactic acid is produced. The burning sensation in the muscles disappears. Proper breathing is important during this period so that adequate oxygen is supplied to the muscles to extract the energy from glucose. The supply of glucose from liver plus adequate availability of oxygen allows the person to continue the exercise and utilization of all the glycogen stored in liver is completed by about 20 minutes. If the exercise is continued beyond this, it starts making use of the fat. The stored fat called body fat is converted into carbohydrate, which is utilized by the muscles and this allows the person to do the exercise for a longer period.

C. Based on severity of exercise: mild exercise which is the simplest form of exercise and causes little or no change in the cardiovascular system. Moderate exercise does not involve strenuous muscular activity and so people aren't exhausted after it. Severe exercise involves strenuous muscular activity and it leads to complete exhaustion.

Effects of exercise on cardiovascular system

A. On blood: mild hypoxia occurs during exercise stimulates the secretion of erythropoietin, which in turn stimulates the bone marrow to release erythrocytes. An increased carbon dioxide content in the blood causes a decrease in the pH of the blood
B. On blood volume: more heat produced during exercise activates the thermoregulatory system causing secretion of large amount of sweat which in turn leads to fluid loss and reduced blood volume.
C. On venous return: during exercise, venous return increases because there is an increase muscle and respiratory pump.
D. On heart rate: during exercise, heart rate increases because of impulses from the cerebral cortex to the medullary centers which reduce vagal tone and partly an increase in sympathetic tone. There is an increase of up to 180 beats/min in moderate exercise while severe muscular exercise reaches up to 240 to 260 beats/min. Factors which increase heart rate during exercise include: circulating catecholamines, rise in body temperature, impulses from proprioceptors and increased carbon dioxide tension
E. On cardiac output: cardiac output increases up to 20 L/min in moderate exercise and 35 L/min in severe exercise. An increase in amount of oxygen consumed during exercise leads to an increase in cardiac output. Cardiac output increases because of increase in heart rate and stroke volume.

F. On blood flow to skeletal muscle: During exercise, there is a great increase in the amount of blood flowing to skeletal muscles. While resting, the blood supply to the skeletal muscles is 3 to 4 mL/100 g of the muscle/minute. It increases up to 60 to 80 mL in moderate exercise and up to 90 to 120 mL in severe exercise. During the muscular activity, stoppage of blood flow occurs when the muscles contract due to the compression of blood vessels during contraction. And in between the contractions, the blood flow increases. Other factors also responsible for the increase in blood flow to muscles during exercise include: hypercapnia, potassium ions, adrenaline etc.
G. On blood pressure: During moderate isotonic exercise, the systolic pressure is increased because of an increase in heart rate and stroke volume. Diastolic pressure is not altered because peripheral resistance is not affected during moderate isotonic exercise. In severe exercise, the systolic pressure enormously increases but the diastolic pressure decreases because of the decrease in peripheral resistance which occurs due to vasodilatation caused by metabolites. During exercise involving isometric contraction, the peripheral resistance increases and the diastolic pressure also increases.

Blood Pressure after Exercise

Large quantities of metabolic end products produced during exercise accumulate in the tissues, especially the skeletal muscle and these products cause vasodilatation, leading to a fall in the blood pressure slightly below the resting level after the exercise. However, the pressure returns to resting level quickly as soon as the metabolic end products are removed from muscles.