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Cardiovascular physiology assignment

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

Long-term blood pressure regulation involves renal regulation of blood volume via the renin- angiotensin mechanism aldosterone mechanism and regulation of extracellular fluid volume. Kidneys play 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 can not regulate the pressure any more. In such conditions , the renal mechanisms operates efficiently to regulate blood pressure and this is called the long term regulation. This is done by two ways and they include regulation of extra cellular fluid volume and through renin-angiotensin mechanism.

- **Through regulation of extracellular fluid volume :** The kidneys, in concert with neural and endocrine input, regulate the volume and osmolality of the extracellular fluid by altering the amount of sodium and water excreted. This is accomplished primarily though alterations in sodium and water reabsorption, the mechanisms of which differ within each nephron segment. Kidneys excrete large amounts of water and salt, particularly sodium by means of pressure diuresis and pressure natriuresis when the blood pressure increases. Pressure diuresis is the excretion of large quantity of water in the urine because of increased blood pressure while pressure natriuresis is the excretion of large quantity of sodium in urine. There is a decrease in extracellular fluid volume and blood volume because of diuresis and natriuresis 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 extracellular fluid volume , blood volume and cardiac output resulting in restoration of blood pressure.
- **Through renin -angiotensin aldosterone mechanism :**
  Renin is a protein enzyme released by the kidneys when the arterial pressure falls too low. In turn, it raises the arterial pressure in several ways , thus helping to correct the initial fall in pressure. Renin is synthesized and stored in an inactive form called prorenin in the juxtaglomerular cells(JG cells) of the kidneys.. It is released in response to:

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

- Decreased blood flow to the kidney
  When Renin is released into the blood, it acts on a specific plasma protein called angiotensinogen or renin substrate. It is the alpha 2-globulin. By the activity of renin , the angiotensinogen is converted into a decade pride called angiotensinogen I.Renin facilitates the conversion of angiotensinogen to angiotensin I which is then converted to angiotensin II using angiotensin-converting enzyme (ACE) secreted from lungs and most of the conversion takes place in the lungs. Angiotensinogen II has a short half-life of about 1 to 2 minutes. Then it is rapidly degraded into a heptapeptide called angiotensinogen III by angiotensinases which are present in red blood cells and vascular beds in many tissues . Angiotensin III is converted into angiotensin IV, which is a hexapeptide.

  Actions of angiotensins

  Angiotensin I- is physiologically inactive . It serves only as the precursor of angiotensin II

  Angiotensin II – is the most active form. It's actions are

  1. On blood vessels – 1) increases arterial blood bees sure by acting directly on the blood vessels and causing vasoconstriction .2) it increases blood pressure indirectly by increasing the release of noradrenaline from postganglionic sympathetic fibers.
  2. On adrenal cortex- it stimulates zona glomerulosa of adrenal cortex to secrete aldosterone which acts on renal tubules and increases the retention of sodium.
  3. On kidney- 1) it regulates glomerular filtration rate by constructing efferent arteriole and contracting the glomerular mesangial cells leading to decrease in the surface area of glomerular capillaries .2) it increases sodium reabsorption from renal tubules
  4. On brain-1) it inhibits the baroreceptor reflex thereby increasing indirectly the blood pressure 2) increases water intake by stimulating the thirst center 3) It increases the secretion of corticotropin-releasing hormone (CRH) from hypothalamus 4) it increases secretion of antidiuretic hormone (ADH) from hypothalamus.
  5. Angiotensin II can also act as growth factor in heart and can cause muscular hypertrophy and cardiac enlargement

  Angiotensin III- increases the blood pressure and stimulates aldosterone secretion from adrenal cortex. It has 100% adrenocortical stimulating activity and 40% vasopressor activity of angiotensin II.

  Angiotensin IV- It also has adrenocortical-stimulating and vasopressor activities.

2) Write short notes on the following :

a. **Pulmonary circulation :** 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.Pulmonary circulation is otherwise known as **lesser circulation.** Blood is pumped from right ventricle to lungs through pulmonary artery. Exchange of gases occurs between blood and alveoli of the lungs at pulmonary capillaries. Oxygenated blood returns to left atrium through pulmonary veins. Thus, left side of the heart contains oxygenated or arterial blood and the right side of the heart contains deoxygenated or venous blood.

b. **Circle of Willis:** The circle of Willis (also called Willis' circle, loop of Willis, cerebral arterial circle, and Willis polygon) is a circulatory anastomosis that supplies blood to the brain and surrounding structures. it is composed of five main arteries:

- Internal carotid artery (left and right)
- Anterior cerebral artery (left and right)
- Anterior communicating artery
- Posterior cerebral artery (left and right)
- Posterior communicating artery (left and right)

The Circle of Willis is the joining area of several arteries at the bottom (inferior) side of the brain. At the Circle of Willis, the internal carotid arteries branch into smaller arteries that supply oxygenated blood to over 80% of the cerebrum. The circle of Willis 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 a safety valve function for the brain, allowing collateral circulation.. The arrangement of the brain's arteries into the circle of Willis creates redundancy (analogous to engineered redundancy) for collateral circulation in the cerebral circulation. If one part of the circle becomes blocked or narrowed (stenosed) 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.

Clinical significance :

- Aneurysms
- Subclavian steal syndrome results from a proximal stenosis (narrowing) of the subclavian artery, an artery supplied by the aorta, which is also the same blood vessel that eventually feeds the circle of Willis via the vertebral and internal carotid arteries.

c. **Splanchnic circulation:** it is also known as Visceral circulation. and constitutes three portions:
   - Mesenteric circulation supplying blood to gastrointestinal tract
     Mesenteric blood flow is regulated by local auto regulation, activity of gastrointestinal tract, nervous factors and chemical factors.
   - Splenic circulation supplying blood to spleen
     Spleen is the main reservoir for blood and it involves two structures namely splenic venous sinuses and splenic pulp
   - Hepatic circulation supplying blood to liver
     Liver receives blood from hepatic artery and portal vein.
     A feature of this circulation is that the blood from mesenteric bed and spleen forms a major amount of blood flowing to liver . Blood flows to liver from gastrointestinal tract and spleen through portal system. The splanchnic circulation is composed of gastric, small intestinal, colonic, pancreatic, hepatic, and splenic circulations, arranged in parallel with one another. The three major arteries that supply the splanchnic organs, cellac and superior and inferior mesenteric, give rise to smaller arteries that anastomose extensively. Redistribution of total blood flow between intramural vascular circuits may be as important as total blood flow. Numerous extrinsic and intrinsic factors influence the splanchnic circulation. Extrinsic factors include general hemodynamic conditions of the cardiovascular system, autonomic nervous system, and circulating neurohumoral agents. Intrinsic mechanisms include special properties of the vasculature, local metabolites, intrinsic nerves, paracrine substances, and local hormones.

d. Coronary circulation : Coronary circulation is the circulation of blood through blood vessels of the heart muscle(myocardium). It is responsible for functional blood supply to heart muscle itself. Blood flowing through chambers of heart does not nourish the myocardium. When functioning normally, blood in coronary blood vessels supply adequate oxygen to myocardium. Coronary circulation is made up of arteries, arterioles , capillaries , venules and veins. The circulation is very short and rapid and blood flow occurs mainly in diastolic phase. It is a stitch circulation with 4%cardiac output flowing to 300g of cardiac muscle and it's regulation is mainly by metabolites and not neural. Coronary circulation, part of the systemic circulatory system that supplies blood to and provides drainage from the tissues of the heart. In the human heart, two coronary arteries arise from the aorta just beyond the semilunar valves; during diastole, the increased aortic pressure above the valves forces blood into the coronary arteries and

thence into the musculature of the heart. Deoxygenated blood is returned to the chambers of the heart via coronary veins; most of these converge to form the coronary venous sinus, which drains into the right atrium.

e. **<u>Cutaneous circulation:</u>** The cutaneous circulation is the circulation and blood supply of nutrition to the skin and regulation of body temperature by heat loss. Some of the circulating blood volume in the skin will flow through arteriovenous anastomoses instead of capillaries. Arteriovenous anastomosis allow the blood to flow directly to the venous plexus of the skin without passing through the capillaries. This distinction is important for the skin's role in temperature regulation of the body.. Under normal conditions, blood flow to the skin is about 250mL/sq m/min. When the body temperature increases , cutaneous blood flow increases up to 2,800 mL/sq m/min because of cutaneous vasodilation. Hypothalamus plays an important role in regulating cutaneous blood flow. When body temperature is high, hypothalamus is activated and vasodilation occurs in skin and when body temperature is low, vasoconstriction occurs in the skin.

3. Discuss the cardiovascular adjustment that occurs during exercise ?

The major adjustments made by the cardiovascular system during exercise include:

- An increase in cardiac output or the pumping capacity of the heart, designed to enhance the delivery of oxygen and fuel to the working muscles.
- An increase in stroke volume and heart rate which coupled with a transient increase in systemic vascular resistance, elevate mean arterial blood pressure . However, long-term exercise can promote a net reduction in blood pressure at rest.

  Impulses from motor cortex, contracting muscle, baroreceptors, and chemoreceptors converge on the cardiovascular control areas situated in the medulla. These controlling centers operate an integration and modulate the cardiovascular status on the basis of motor strategy, metabolic and mechanic conditions of exercising muscle, blood pressure values, and arterial gas concentration.

  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. During

exercise, efficient delivery of oxygen to working skeletal and cardiac muscles is vital for maintenance of ATP production by aerobic mechanisms.

The major adjustments made by the cardiovascular system during exercise include an increase in cardiac output or the pumping capacity of the heart, designed to enhance the delivery of oxygen and fuel to the working muscles. 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. During exercise, more blood is sent to the active skeletal muscles, and, as body temperature increases, more blood is sent to the skin. This process is accomplished both by the increase in cardiac output and by the redistribution of blood flow away from areas of low demand, such as the splanchnic organs. There is also increased input from sympathetic nerves and increase in temperature.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.