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MATRIC NO.: 18/MHS01/365

COURSE: PHYSIOLOGY

QUESTION

1. **Discuss the long-term regulation of men arterial pressure.**
2. **Write short note on the following:**
    a. **Pulmonary circulation**
    b. **Circle of Willis**
    c. **Splanchnic circulation**
    d. **Coronary circulation**
    e. **Cutaneous circulation.**
3. **Discuss cardiovascular adjustment during exercise.**

MEAN ARTERIAL BLOOD PRESSURE

Arterial Blood Pressure.

Arterial blood pressure is defined as the lateral pressure exerted by the contained volume of blood on the wall of arteries. The pressure is exerted when the blood flows through the arteries. Generally, the term 'blood pressure' refers to Arterial blood pressure. And it is expressed in four different terms.

- Systolic blood pressure
- Diastolic blood pressure
- Pulse blood pressure
- Mean arterial blood pressure.

Regulation of arterial blood pressure

Arterial blood pressure varies even under physiological conditions. However, it is brought back to normal because of homeostasis. The body has four regulatory mechanisms for such homeostasis:

- Nervous mechanism or short-term regulatory mechanism
- Renal mechanism or long-term regulatory mechanism
- Hormonal mechanism
- Local mechanism

Renal Mechanism or Long-Term Regulatory Mechanism.

In long term regulation of arterial blood, the kidney plays a vital role. The renal mechanism serves as a backup system for the neural mechanism when it loses it sensitivity for the prolonged alteration in blood pressure. This is the reason why it's called long-term regulation.

The kidneys regulate arterial blood pressure by two ways:

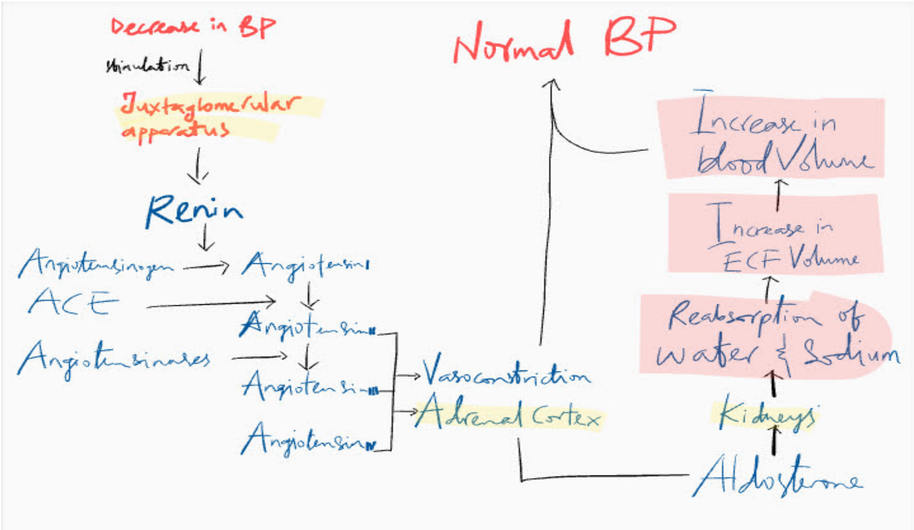
- Regulation of ECF volume
- Renin-angiotensin mechanism

Regulation of Extracellular Fluid Volume

When there's a rise in blood pressure, the kidneys excrete large amount of water and salt, especially sodium by means of pressure diuresis and pressure natriuresis. Pressure is the release of large quantity of water in urine because if increased blood pressure. Water secretion by the kidneys can be double even by a slight increase in blood pressure. Pressure natriuresis is the excretion of large quantity of sodium in urine.

By the actions of diuresis and natriuresis, the ECF volume and blood volume is decreased, bringing the arterial blood pressure back to normal. When blood pressure decreases, the reabsorption of water from renal tubules is increased. This in turn, increases ECF volume, blood volume and cardiac output resulting in restoration of blood pressure.

Renin-Angiotensin Mechanism



Regulation of blood by renin-angiotensin mechanism
ACE = Angiotensin Converting Enzyme
BP = Blood Pressure

Actions of Angiotensin II

When blood pressure and ECF volume decreases, renin secretion from kidneys is increased. It converts. Angiotensinogen into angiotensin I. This is converted into angiotensin II by ACE (Angiotensin Converting Enzyme). Angiotensin II acts in two ways to restore the blood pressure.

• It causes constriction of the arterioles in the body so that the resistance is increased, and blood oressu rises.

• At the same time, angiotensin II stimulates adrenal cortex to secrete aldosterone. This hormone increases reabsorption of sodium from renal tubules. Sodium reabsorption is followed by water reabsorption, resulting in increased ECF volume and blood volume. It increases blood pressure to normal level.

Actions 0f Angiotensin III and Angiotensin IV

Like angiotensin II, the angiotensins III and IV also increase the blood pressure and stimulate adrenal cortex to secrete aldosterone.

PULMONARY CIRCULATION

Pulmonary blood vessels include pulmonary artery, which carries deoxygenated blood to alveoli of lungs and bronchial artery which supplies oxygen blood to other structures of lungs.

Pulmonary artery

Pulmonary artery supplies deoxygenated blood pumped Fri right ventricle to alveoli of lungs (Pulmonary Circulation). After leaving the right ventricle it divides into right and left branches. Each branch enters the corresponding lung along with the primary bronchus., After entering the lung, the pulmonary artery divides into small vessels and finally forms the capillary plexus that is in intimate relationship with the alveoli. Capillary plexus is solely concerned with alveolar gas exchange. Oxygenated blood from the alveoli is carried to left atrium by one pulmonary vein from each side.

Bronchial artery

Bronchial artery arises from the descending thoracic aorta. T supplies arterial blood of bronchi, connective tissue and other structures of lung stroma, visceral pleural and pulmonary lymph nodes. Venous blood from these structures is drained by two bronchial veins from each side. Bronchial veins from right side drain into azygos vein and the left drain into superior hemiazygos or left superior intercostal veins.

Characteristic Features of Pulmonary Blood Vessels.

1. The pulmonary artery has a thin wall. Its thickness is only about ⅓ of thickness of the systemic aortic wall.
2. The pulmonary blood vessels are highly elastic and more distensible
3. The smooth muscle coat is not well developed into the pulmonary blood vessels.
4. True arterioles have less smooth muscle fibre
5. Pulmonary vascular system is a lie pressure system
6. physiology shunt is present.

Pulmonary Blood Flow

The lung receives the whole amount of blood that is pumped out from the right ventricle. The output of blood per minute is the same in both right and left ventricle. It is about 5 litres. Thus, the lungs accommodate the amount of blood, which is equal to the amount of blood accommodated by other parts of the body.

Pulmonary Blood Pressure

The pulmonary blood vessels are more distensible than the systemic blood vessels. So the blood pressure is less in pulmonary blood vessels.

Pulmonary Arterial Pressure

- Systolic pressure. : 25 mmHg
- Diastolic pressure. : 10 mmHg
- Mean arterial pressure. : 15 mmHg

Pulmonary capillary pressure

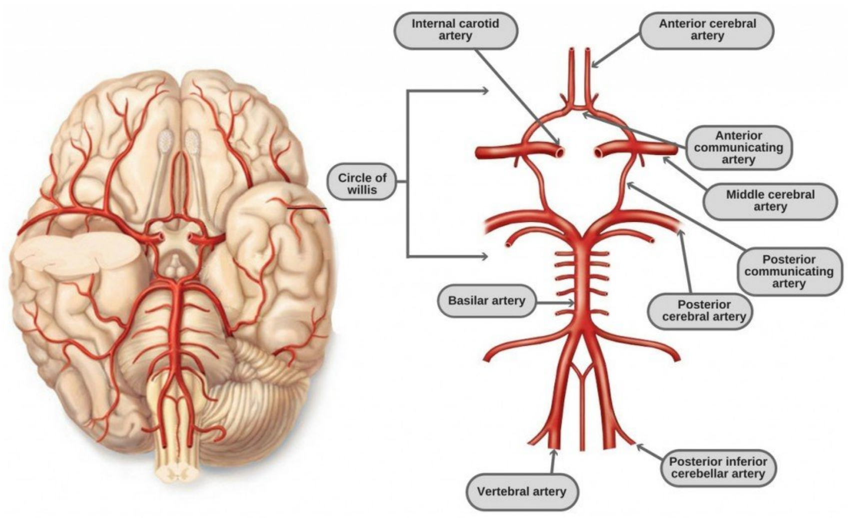
The Pulmonary capillary pressure is about 7 mmHg. This pressure is sufficient for exchange of gases between alveoli and blood.

Regulation of pulmonary blood flow.

Pulmonary blood flow is regulated by the following factors

1. Cardiac output
    - venous return
    - force of contraction
    - rate of contraction
    - peripheral resistance
2. Vascular resistance
3. Nervous factors
4. Chemical factors
5. Gravity or hydrostatic pressure.

CIRCLE OF WILLIS



The circle of Willis is a circulatory anastomosis that supplies blood to the brain and surrounding structures. It is named after Thomas Willis (1621–1675), an English physician.

It 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 crossing is important for binocular vision), infundibulum of the pituitary stalk and the hypothalamus.

This arterial ring provides blood to the brain and 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.

Formation

The circle of Willis is formed by two group of arteries - the internal carotid arteries and two vertebral arteries. These arteries provide the anterior and posterior circulation of the brain respectively.

- **Posterior source** (vertebral arteries)
This part (or half) of the circle provides the posterior circulation and basically supplies the cerebellum, brainstem and the posterior aspects of the cerebral hemispheres.

- Anterior source (internal carotid arteries)
The anterior part of the circle provides the anterior circulation of the brain and basically supplies the most part of the cerebral hemispheres and its deep structures like the caudate-putamen (striatum) as well as neighbouring structures of the cerebrum, like the orbit.

SPLANCHNIC CIRCULATION

This is a form of blood movement that constitutes of three portions, which are;

1. **Mesenteric circulation**

   This circulation is responsible for supplying blood to the gastro intestinal tract. The blood flow in this form of circulation is regulated by some factors;

a. **Nervous factor:** the mesenteric blood flow is controlled by the sympathetic nerve fibres and the mesenteric blood vessels are constricted due to a rise in the sympathetic activity, for example emotional circumstances. There is then a diversion of blood to other organs such as the heart and brain that require more blood usage as a result of such circumstances. It is important to note that no effect is made on the mesenteric blood vessels by the parasympathetic nerves, rather it results in an increase in contractions of the gastro intestinal tract that compresses the blood vessels and reduces blood flow.

b. **Local auto regulation:** this is the principal factor regulating blood flow through mesenteric bed.

c. **Activity of Gastro intestinal tract**

Distribution of Blood flow

- Stomach: 35mL/100g/min
- Intestines: 50mL/100g/min
- Pancreas: 80mL/100g/min

2. **Splenic Circulation**

The spleen happens to be the major storage of blood. There is a large amount of stored blood in the spleen due to the dilatation of blood vessels. In the spleen, two organs are responsible for storage of blood, namely splenic pulp and the splenic venous sinuses. These organs are lined in the reticuloendothelial cells and the flow of blood in the spleen is controlled by the sympathetic nerve fibre.

3. Hepatic Circulation

The liver obtains blood from two sources which are the portal vein and the hepatic artery. The liver acquires so much blood as compared to other organs of the human body why because majority of metabolic action are done in this organ. Several factors such as the systematic blood pressure, the splenic contraction, movement of intestines, excess carbon dioxide, lack of oxygen and nervous factors control/regulates the flow of blood to the liver.

CORONARY CIRCULATION

Distribution of Coronary Blood Vessels

Coronary arteries

The heart muscle is supplied by the left and the right coronary arteries, the first branches of aorta. The arteries circle the heart in the manner of a crow, hence the name Coronary arteries (Corona /Latin/ = crown). The left coronary artery supplies mainly anterior and lateral parts if left ventricle. The right coronary artery supplies whole of the right ventricle and posterior portion of left ventricle.

The coronary arteries divide and subdivide into smaller branches, which run along the surface of the heart. The smaller branches are called epicardiac arteries and give rise to further smaller branches known as final arteries or intramural vessels.

Venous drainage

1. **Coronary sinus**: it is the larger vein draining 75% of the total coronary flow. It drains blood from left side of the heart and opens into right atrium near tricuspid valve.

2. **Anterior coronary vein**: the anterior coronary veins drain blood from right side of the heart and open directly into the right atrium.

3. **Thebesian veins**: Thebesian veins drain deoxygenated blood from myocardium directly into the concerned chamber of the heart.

Physiological Shunt

Physiological shunt is the diverted route (diversion) through which the venous blood is mixed with the arterial blood. The deoxygenated blood flowing from the thebesian veins into cardiac chambers make up part of normal physiological shunt. The other components l of physiological shunt is the drainage of deoxygenated blood from bronchial circulation into pulmonary vein without being oxygenated.

CORONARY BLOOD FLOW AMD ITS MEASUREMENT

Normal Coronary Blood Flow

Normal blood flow through coronary circulation is about 200mL/minute. It forms 4% of cardiac output. It is about 65-70mL/minute/100g of cardiac muscle.

Measurement of Coronary Blood Flow

- Direct method

The coronary blood flow is measured by using an electromagnetic flow meter. It is directly placed around any Coronary artery.

- Indirect method

1. By Dick's principle
2. By using Doppler flowmeter
3. By Videodensitometry

Factors Regulating Coronary Blood Flow

Autoregulation

The heart has the capacity to autoregulate its own blood flow. Tis is known as autoregulation. The coronary blood flow is not affected when mean arterial pressure varies between 60 and 150 mmHg. Coronary blood flow is regulated by four factors:

1. **Need for oxygen**

This is the most important factor maintaining blood flow through the coronary blood vessels. The amount of blood passing through coronary circulation is directly proportional to the consumptions of oxygen by cardiac muscle. Hypoxia causes coronary vasodilation and increases the blood flow to heart.

2. **Metabolic factors**

Coronary vasodilation during hypoxic conditions occurs because of some metabolic products. The metabolic products, which increase the coronary blood flow are: adenosine, potassium ions, hydrogen ions, carbon dioxide and adenosine phosphate compounds.

3. **Coronary perfusion pressure**

Perfusion pressure is the balance between mea arterial pressure and venous pressure. Thus, the coronary perfusion pressure is the balance between mean arterial pressure in aorta and the right arterial pressure. Since right arterial pressure is low, the mean arterial pressure becomes the major factor that maintains the coronary blood flow.

4. **Nervous factors**

The coronary blood vessels are innervated by both parasympathetic and sympathetic divisions of autonomic nervous system. These nerves influence the coronary blood flow indirectly by acting on the musculature of the heart.

CUTANEOUS CIRCULATION

Architecture of Cutaneous Blood Vessels

1. The arterioles arising from the smaller arteries reach the base of the papillae of dermis.
2. After taking origin, the arterioles turn horizontally and give rise to meta-arterioles.
3. From meta-arterioles, hairpin shaped capillary loops arise. The arterial limb if the loop ascends vertically in the papillae, and turns to form a venous limb, which descends down.
4. After reaching the base of the papillae, few venous limbs I'd neighboring papillae unite to form collecting venule.
5. The collecting venules anastomose with one another to from the subpapillary venous plexus.
6. The subpapillary venous plexus runs horizontally beneath the bases of papilla and drain into deeper veins.

Functions of Cutaneous Circulation

1. The supply of nutrition to skin.

2. The loss of heat from the body and regulation of body temperature.

Normal Blood Flow to Skin.

Under normal conditions, the blood flow to skin is about 250 mL/square meter/minute. When the body temperature increases, cutaneous blood flow increases up to 2800 mL/sq. meter/minute because of cutaneous vasodilation.

Regulation of Cutaneous Blood Flow

The cutaneous blood flow is mainly regulated by body temperature. Hypothalamus plays an important role in regulating cutaneous blood flow.

When body temperature increases, the hypothalamus is activated. Hypothalamus in turn causes vasodilation by acting through medullary vasomotor centre. 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 skin. Therefore, the blood flow to skin decreases and prevents heat loss from the skin.

Vascular Response of Skin to Mechanical Stimuli

Vascular responses of skin are the reactions developed in the blood vessels of the skin when some mechanical stimuli are applied over the surface of it. These vascular responses are of two types:

1. White reaction
2. Lewis triple response

White reaction
When the surface of the skin is stroked lightly with a pointed object, a pale line appears within 20 seconds. The line takes the oath if the stroke. White reaction bis due to constriction of cutaneous capillaries. No nervous factor is involved in this process.

Lewis triple response
It is the vascular response of skin that includes three reactions if blood vessels f skin to a mechanical stimulus. It's was discovered by Lewis Sir Thomas in 1927. He noticed bthat the vascular reactions of skin to various injuries occur in three stages and named these reactions as triple response.nthe three reactions of this response are:

- Red reaction.
- Flare.
- Wheal.

CARDIOVASCULAR ADJUSTMENT DURING EXERCISE

There's an increase in metabolic needs of body tissues, particularly the muscles during exercise. Thus, the various adjustment in the body are aimed at:

• Supply of various metabolic requisites like nutrients and oxygen to muscles and other tissues involved in exercise.
• Prevention of increase in body temperature.

Types of Exercise.

Exercise is generally classified into two types depending on the type of muscle contraction. The two types of exercises are:

1. Dynamic exercise
2. Statistic exercise

Dynamic Exercise

The dynamic exercise primarily involves the isotonic muscular contraction. It keeps the joints and muscles moving. Examples are swimming, running, jogging, etc. external work. In this type of exercise, the heart rate, force of contraction, cardiac output and systolic blood pressure increase. However, the diastolic blood pressure is unaltered or decreased. It is because, during dynamic exercise, the peripheral resistance is unaltered or decreased depending on the severity of the exercise.

Static Exercise

Static exercise involves isometric muscular contraction without movement of the joints. Example is pushing heavy object. During this exercise, apart from increase in the heart rate, force of contraction, cardiac output and systolic blood pressure, the diastolic pressure also increases. It is because of increase in peripheral resistance during static exercise.

Aerobic and Anaerobic Exercises

Based on the type of metabolism involved, exercise is classified into two types:

1. Aerobic exercise
2. Anaerobic exercise

While these two exercise types involve different energy producing processes, i.e., aerobic (with air or oxygen) and anaerobic (without air or oxygen), they are both required to maintain physical wellness.

Aerobic Exercise

Aerobic exercise involves activities with lower intensity, which is performed for lomger period. The energy is obtained by utilizing nutrients in the presence of oxygen. The body starts with burning glycogen stored in liver. After about 20 minutes, when stored glocogen is exhausted the body starts burning fat. Body fat is converted to glucose, which is utilized for energy.

Examples of aerobic exercise are swimming, jogging, skating, tennis, soccer, fast walking, etc.

Anaerobic Exercise

Anaerobic exercise involves exertion for short periods followed by periods of rest. It uses the muscle at high intensity and a high rate of work for a short period. Body gets energy by burning glycogen stored in the muscle without oxygen. Burning of glycogen without oxygen liberates lactic acid. And accumulation of lactic acid leads to fatigue. Therefore this kind of exercise cannot be performed for longer period. This type of exercise helps to increase the muscle strength.

Examples of anaerobic exercise are push-ups, pull-ups, weightlifting, sprinting, any other rapid burst of strenuous exercise.

Metabolism of Aerobic and Anaerobic Execises.

When a person starts swimming or jogging, the muscled start utilizing energy. Few minutes into commencement, the body muscles burn glycogen stored in them. During this period, fat is not burned. And this is done in the absence of oxygen. This is called **anaerobic metabolism**. Lactic acid is produced during this period. Presence of lactic acid causes some sort of burning sensation in the muscles, particularly the muscles of the arms, leg and back.

The muscles burn all the muscle glycogen in about 3–5 minutes. If the person continues the exercise, glyucogen stored in the liver is converted to glucose, which is transported to muscles through blood. Now the body moves to **aerobic metabolism**. The glucose obtained in the liver is burned in the presence of oxygen. No more lactic acid is produced. So, the burning sensation in the muscles disappear. Proper breathing is essential during period so that adequate oxygen is supplied to the muscles to extract the energy from glkucose. The supply of oxygen from liver in combination with adequate availability allows for the person to continue the exercise.

The utilization of all the glycogen stored in the liver is completed in about 20 minutes. The exercise is continued beyond this, the body starts utilizing the fat. The stored fat. Called body fat is converted into carbohydrate, which is utilized by the muscles. This allows the person to do the exercise for a longer period.

Severity of Exercise

The cardiovascular and other changes in the body depend on the severity of the exercise also. Based on severity, exercise is classified into three types.

1. Mild exercise
2. Moderate exercise
3. Severe exercise

EFFECTS OF EXERCISE ON CARDIOVASCULAR SYSTEM

1. **On Blood**

   The mild hypoxia generated during exercise stimulates the juxtaglomerular apparatus to secrete erythropoietin. This stimulates the bone marrow and causes release of red blood cells. The increased carbon dioxide in the blood reduces blood pH.
2. **On Blood Volume**

   More heat is produced during exercise and the thermoregulatory system is activated. This in turn causes secretion of large amount of sweat leading to:
   - Fluid loss
   - Reduced blood volume
   - Hemoconcentration
   - Sometimes, severe exercise leads to dehydration.

3. **On Heart Rate**

Heart rate increases during exercise. In moderate exercise, the heart rate increases to 180 beats/mins. In severe muscular exercise, it reaches 240-260 beats/mins. The increased heart rate during exercise is mainly because vagal withdrawal. Increase in sympathetic tone also plays some role.

Four factors responsible for increase in heart rate during exercise are:

- Impulses from proprioceptors, which are present in the exercising muscles; these impulses act through higher centres and increase the heart rate.
- Increased carbon dioxide tension which acts through medullary centres.
- Rise in body temperature, which acts on cardiac centres via hypothalamus: Increased temperature stimulates SA node directly also
- The circulating catecholamines, which are secreted in large quantities during exercise.

4. **On Cardiac Output**

Cardiac output increases up to 20 litres/minutes in moderate exercise and up to 35 litres/minutes during severe exercise. The increase in cardiac output is directly proportional to the increase in the amount of oxygen consumed during exercise.

During exercise, the cardiac output increases because of increased heart rate and stroke volume.

5. **On Venous Return**

Venous return increases remarkably during exercise because of muscle pump, respiratory pump and splanchnic vasoconstriction

6. **On Blood Flow to Skeletal Muscles**

A large quantity of blood flows to skeletal muscles during exercise. In resting condition, the blood supply to the skeletal muscle is 3-4 mL/100 gram of the muscle/minute. It increases up to 60-80 mL in moderate exercise and up to 90-120 mL in severe exercise.

Several factors that increase blood flow to skeletal muscle by means of dilation of blood vessels of the muscles. They are: Hypercapnea, hypoxia, potassium ions, metabolites like lactic acid, rise in temperature, adrenaline secreted from adrenal medulla, increased sympathetic cholinergic activity.

7. **On Blood Pressure**

During moderate isotonic exercise, the systolic pressure is increased. It us due to to increase in heart rate and stroke volume. Diastolic pressure remains the same because peripheral resistance is not affected during moderate isotonic exercise.

In severe exercise involving isotonic muscular contraction, the systolic pressure enormously increases but the diastolic pressure decreases. The decrease in diastolic pressure is because decrease in peripheral resistance. Decrease in peripheral resistance is due to vasodilation caused by metabolites.

During exercise involving isometric contraction, the peripheral resistance increases. So, the diastolic pressure also increases along with systolic pressure.

BLOOD PRESSURE AFTER EXERCISE

Large quantities of metabolic end products are produced during exercise. These substances accumulate in the tissues, particularly the skeletal muscle. The metabolic end products cause vasodilation. So, the blood pressure falls 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 the muscles.