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ASSIGNMENT

QUESTION 1

Discuss the long-term regulation of mean arterial blood pressure.

ANSWER

Definition of arterial blood pressure

Arterial blood pressure is defined as the **lateral pressure** exerted by the column of blood on the wall of arteries. The pressure is exerted when blood flows through the arteries. Generally, the term 'blood pressure' refers to arterial blood pressure.

Arterial blood pressure is expressed in four different terms:

1. Systolic blood pressure
2. Diastolic blood pressure
3. Pulse pressure
4. Mean arterial blood pressure

MEAN ARTERIAL BLOOD PRESSURE

Mean arterial blood pressure is the average pressure existing in the arteries. It is not the arithmetic mean of systolic and diastolic pressures. It is the diastolic pressure plus one third of pulse pressure. To determine the mean pressure, diastolic pressure is considered than the systolic pressure. It is because the diastolic period of cardiac cycle is longer (0.53 second) than the systolic period (0.27).

Normal mean arterial pressure: 93 mmHg (80 + 13 = 93)

Formula to calculate mean arterial blood pressure

Mean arterial blood pressure

=Diastolic pressure + 1/3 of pulse pressure

= 80+ 40/3 = 93.3 mmHg

REGULATION OF ARTERIAL BLOOD PRESSURE

Arterial blood pressure varies even under physiological conditions. However, immediately it is brought back to normal level because of the presence of well-organized regulatory mechanisms in the body. Body has four such regulatory mechanisms to maintain the blood pressure with normal limits:

A. Nervous mechanism or Short-term regulatory mechanism
B. Renal mechanism or long-term regulatory mechanism
C. Hormonal mechanism
D. Local mechanism.

<u>RENAL MECHANISM FOR REGULATION OF BLOOD PRESSURE-LONG TERM CIRCULATION</u>

Kidney play an important role in long-term regulation of arterial blood pressure. When blood pressure alters slowly in several days/month/years, the nervous mechanism adapts to the altered pressure and looses the sensitivity for the changes. It cannot regulate the pressure. Therefore, it is called long-term regulation.

Kidneys regulate arterial blood pressure by two ways:

1. By regulation of ECF volume
2. Through renin-angiotensin mechanism

1. **BY REGULATION OF EXTRACELLULAR FLUID VOLUME**

When the blood pressure increases, kidneys secret large amounts of water and salt, particularly sodium, by means of **pressure diuresis** and pressure natriuresis. Pressure diuresis is the secretion of large quantity of water in urine because of increased blood pressure. Even a slight increase in blood pressure doubles the water excretion. Pressure natriuresis is the excretion of large quantity of sodium and urine.

Because of **diuresis** and **natriuresis**, there is a decrease in ECF volume and blood volume, which in turn brings the arterial blood pressure back to normal level.

When blood pressure decreases, the reabsorption of water from renal tubes is increased. This in turn, increases ECF volume, blood volume and cardiac output, resulting in restoration of blood pressure.

2. **THROUGH RENIN-ANGIOTENSIS MECHANSIM**
   Source of renin secretion, formation of angiotensin, and secretion on renin.

Actions of Angiotensin II

When blood pressure and ECF volume decrease, renin secretion from kidney 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:

i. It causes restriction of arterioles in the body so that the peripheral resistance is increased and blood pressure rises. In addition, angiotensin II causes constriction of different arterioles in kidneys, so that glomerular filtration reduces. This results in retention of water and salts, increases ECF volume to normal level. This in turn increases the blood pressure to normal level
ii. Simultaneously, angiotensin II stimulates the adrenal cortex to secrete aldosterone. This hormone increases reabsorption of sodium from renal tubules. Sodium reabsorption is followed water reabsorption, resulting in

increased in increased ECF volume and blood volume. It increases the blood pressure to normal.

Action of Angiotensin II and Angiotensin IV
Like angiotensin II, the angiotensin III and IV also increase the blood pressure and stimulate adrenal cortex to secret aldosterone.

QUESTION 2

Write short notes on the following;

a) Pulmonary circulation
b) Circle of Willis
c) Splanchnic circulation
d) Coronary circulation
e) Cutaneous circulation

a) Pulmonary Circulation

Pulmonary circulation is otherwise known called 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 the 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 is the joining area of several arteries at the bottom (inferior) sides of the brain. At the Circle of Willis, the internal carotid arteries that supply oxygenated blood to over 80% of the cerebrum.

The **cerebral arterial circle** (of Willis) is a roughly pentagon shaped circle of vessels on the ventral surface of the brain. It is an important anastostomosis of the brain between four arteries (two vertebral and two internal carotid arteries) that supply the brain. The arterial circle is formed sequentially in an interior to the posterior direction by the:

- Anterior communicating arteries.
- Anterior cerebral arteries
- Internal carotid arteries
- Posterior communicating arteries
- Posterior cerebral arteries

The various component of the cerebral arterial circle give numerous small branches to the brain.

C) Splanchnic circulation

(Gastrointestinal Blood Flow— “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 itself 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 the *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 of the general circulation. This flow of blood through the liver, before it empties into the vena cava, allows the *reticuloendothelial cells* that line the liver sinusoids to remove bacteria and other particulate matter that might enter the blood from 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 parenchymal 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 tract *are not carried in the portal blood* but instead are absorbed into 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 blood through blood vessels of the heart muscle (myocardium). It is responsible for functional blood supply to heart muscle itself. Blood flowing through the chambers of the heart does not nourish the myocardium. When functioning normally, blood in coronary blood vessels supply adequate oxygen to myocardium. Like systematic circulation and pulmonary circulation, coronary circulation is also made up of arteries, arterioles, capillaries, venules and veins. Distribution of coronary blood vessels include coronary, venous drainage and physiological shunt.
Normal coronary blood flow through coronary circulation is about 200 mL/min, It forms 4% of cardiac output. It is about 65 to 70 mL/min/100 g of cardiac muscle.
Measurement of coronary blood flow could be by direct or indirect method.
Factors regulating coronary blood flow include the need for oxygen, metabolic factors, coronary perfusion pressure, nervous factors.
Applied Physiology- Coronary Artery Disease include coronary occlusion, myocardial ischemia and necrosis, myocardial infarction (heart attack) and Cardiac Pain (Angina Pectoris)

E) Cutaneous Circulation

This is the circulation of blood through the skin. The primary function of the skin circulation is to help maintain body temperature .blood vessels constrict to prevent heat loss and dilate to facilitate transfer of heat from the body core to the body surface .the skin comprises 4% to 5% of the total body weight and receives about 2% of the cardiac output .The arterio-venous oxygen difference is small (3vol%), indicating that most of the blood flow is non nutrient flow Skin blood vessels (arterioles)are of two types. The most numerous are composed of smooth muscle, supply capillary beds and are innervated with sympathetic constrictor fibers, like arterioles in skeletal muscle beds, they provide nutrient flow to the skin. Veins draining these vascular beds comprise large venous plexuses with slow blood flow in the fore arm, legs and thigh. These plexuses provide a large surface area for heat exchange with the environment. The second type of vessel is composed almost exclusively of smooth muscle. These provide a direct connection between arteries and the venous plexuses described above. They are known as arterio venous anastomosis and are numerous in the palms, soles and skin of the ears, nose and lips. Flow is non nutrient because there are few exchange vessels. These vessels have a low level of basal tone and are innervated by sympathetic fibre, to which they are responsive.

FUNCTIONS OF CUTANEOUS CIRCULATION

Cutaneous blood flow performs two functions:

1. Supply of nutrition to skin
2. Regulation of body temperature by heat loss.

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 2,800 mL/square meter/minute because of cutaneous vasodilatation

REGULATION OF CUTANEOUS BLOOD FLOW

Cutaneous blood flow is regulated mainly 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 cutaneous vasodilatation by acting through medullary vasomotor center. 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 the skin. Therefore, the blood flow to skin decreases and prevents the heat loss from skin.

APPLIED PHYSIOLOGY –VASCULAR RESPONSES OF SKIN TO MECHANICAL STIMULI

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

Vascular responses of skin are of two types:

- A. White reaction
- B. Lewis triple response

Question 3

Discuss the cardiovascular adjustment that occurs during exercise.

Answer

To meet the increased energy demand of muscles during exercise the primary cardiovascular response is in the form of:

_ Increase in the skeletal muscle blood flow,
_ Redistribution of blood flow in the body,
_ Increase in the cardiac output,
_ Blood pressure changes and
_ Changes in the blood volume.

SKELETAL MUSCLE BLOOD FLOW

At rest the blood flow to the skeletal muscle is about 2–4 mL/ 100 g/min of muscle tissue. During strenuous exercise muscle blood flow can increase up to 20 times, i.e. about 50–80 mL/100 g/min muscle tissue. This is called *exercise hyperaemia.*

This tremendous increase in the muscle blood flow during exercise is made possible by:

_ Arteriolar dilatation and

_ Opening up of the closed capillaries which greatly increase
the surface area and the rate of blood flow

REDISTRIBUTION OF BLOOD FLOW

The tremendous increase in the skeletal muscle blood flow is possible due to increased cardiac output and redistribution of cardiac output in following manner

Coronary blood flow. During exercise, coronary blood
flow is increased by four to five times with 100% O2 utilization

Visceral blood flow is temporarily curtailed in co-ordination with increase in muscle blood flow. It is brought about by the increased sympathoadrenal discharge.

Splanchnic blood flow is decreased by 80% in severe exercise.

Renal blood flow is also decreased by 50−80% in severe exercise.

Cutaneous blood flow at rest is about 500 mL/min.

_ *Decrease* in cutaneous blood flow occurs initially in the beginning of exercise due to reflex vasoconstriction.

_ *Increase* in cutaneous blood flow is noted in sustained exercise when body temperature rises, to dissipate the heat generated during exercise, as the blood flow through the skin is controlled predominantly by the requirements of temperature regulation.

Cerebral blood flow at rest is about 750 mL/min and remains unchanged during any grade of muscular exercise.

Adipose tissue blood flow is increased by four times during exercise. This helps to deliver fatty acids mobilized from triglyceride stores to the working muscles.

INCREASE IN CARDIAC OUTPUT

Normal cardiac output is about 5−6 L/min. During exercise, the cardiac output is increased depending upon the severity of exercise. In maximum exercise it may increase by five to six times. Since, cardiac output is the product of heart rate and stroke volume, an increase in both contributes to the increase in a cardiac output during exercise.

Increase in heart rate

Heart rate increases linearly with the severity of exercise. The increase in heart rate occurs as soon as the exercise begins or may be seen even before the exercise begins (anticipatory tachycardia).

Factors contributing to tachycardia during exercise are:

_ *Increased sympathetic discharge.*

_ *Peripheral reflexes* originating from the exercising muscles
(muscle spindles, muscle-tendon receptors and organ of Corti) and joints.

_ *Local metabolic factors.* Muscle tissue has free nerve endings which are stimulated by the lactic acid potassium ions and other metabolites which collect in exercising muscles possibly contribute to the sustained increase in heart rate during prolonged exercise.

_ *Humoral factors,* such as release of adrenaline and noradrenaline and possibly thyroid hormones during exercise.

_ *Intrinsic factors.* Stimulation of sinoatrial node in the right atrium due to increased venous return, which increase the heart rate during exercise. This is known as *Bainbridge reflex.*

_ *Increased temperature* in the myocardium due to increased activity of the heart during exercise may directly increase the rhythmicity of the pacemaker.

Increase in stroke volume

Under normal conditions, the average stroke volume is about 80 mL/beat and may increase up to twice the normal value during exercise.

Mechanisms responsible for increase in stroke volume

It has been stated that an increase in the stroke volume during exercise occurs due to gearing up of both the control mechanisms, i.e.

_ Intrinsic autoregulation or Frank–Starling mechanism

_ Extrinsic regulation or autonomic and neural mechanism

BLOOD PRESSURE CHANGES DURING EXERCISE

In systemic circulation

Systolic blood pressure is always raised by exercise since it depends upon the cardiac output which is increased in exercise. The blood pressure remains elevated during exercise and is not reflexly corrected by baroreceptor reflex. This has been explained by the fact that the neurons descending from the hypothalamic defence centre inhibit the baroreceptor afferents.

Diastolic blood pressure which primarily depends upon the peripheral resistance may mildly increase or decrease or remain unchanged depending upon the change in total peripheral resistance. Mostly, the vasodilatation in the skeletal muscles balances the vasoconstriction in other tissues, so diastolic blood pressure is usually not changed much.

Mean blood pressure is usually increased. It helps to increase the skeletal muscle blood flow by providing greater pressure head in the face of dilated resistance vessels.

In pulmonary circulation

_ *Systolic blood pressure* in the pulmonary artery may rise during heavy exercise to 25−30mm Hg from 15−20 mm Hg at rest,

_ *Diastolic blood pressure* may rise from 5−8 mm Hg at rest to 8−10 mm Hg and

_ *Mean blood pressure* may reach to 15 mm Hg from 8–12 mm Hg at rest.

CHANGES IN BLOOD VOLUME DURING EXERCISE

Blood volume during exercise is decreased by 15% resulting in haemoconcentration. Blood volume is decreased due to more plasma loss at the capillary level due to following reasons:

_ Increased hydrostatic pressure in capillaries and

_ Increased tissue fluid osmotic pressure due to accumulation of osmotically active metabolites in tissue spaces such as potassium, phosphate and lactic acid.