Cardiac Output, Blood Flow, and Blood Pressure

Cardiac Output

I. Cardiac rate is increased by sympathoadrenal stimulation and decreased by the effects of parasympathetic fibers that innervate the SA node.

II. Stroke volume is regulated both extrinsically and intrinsically.

A. The Frank-Starling law of the heart describes the way the end-diastolic volume, through various degrees of myocardial stretching, influences the contraction strength of the myocardium and thus the stroke volume.

B. The end-diastolic volume is called the preload. The total peripheral resistance, through its effect on arterial blood pressure, provides an afterload that acts to reduce the stroke volume.

C. At a given end-diastolic volume, the amount of blood ejected depends on contractility. Strength of contraction is increased by sympathoadrenal stimulation.

III. The venous return of blood to the heart is dependent largely on the total blood volume and mechanisms that improve the flow of blood in the veins.

A. The total blood volume is regulated by the kidneys.

B. The venous flow of blood to the heart is aided by the action of skeletal muscle pumps and the effects of breathing.

Blood Volume

I. Tissue fluid is formed from and returns to the blood.

A. The hydrostatic pressure of the blood forces fluid from the arteriolar ends of capillaries into the interstitial spaces of the tissues.

B. Since the colloid osmotic pressure of plasma is greater than tissue fluid, water returns by osmosis to the venular ends of capillaries.

C. Excess tissue fluid is returned to the venous system by lymphatic vessels.

D. Edema occurs when there is an accumulation of tissue fluid.

II. The kidneys control the blood volume by regulating the amount of filtered fluid that will be reabsorbed.
A. Antidiuretic hormone stimulates reabsorption of water from the kidney filtrate and thus acts to maintain the blood volume.

B. A decrease in blood flow through the kidneys activates the renin-angiotensin system.

C. Angiotensin II stimulates vasoconstriction and the secretion of aldosterone by the adrenal cortex.

D. Aldosterone acts on the kidneys to promote the retention of salt and water.

Vascular Resistance and Blood Flow

I. According to Poiseuille's law, blood flow is directly related to the pressure difference between the two ends of a vessel and is inversely related to the resistance to blood flow through the vessel.

II. Extrinsic regulation of vascular resistance is provided mainly by the sympathetic nervous system, which stimulates vasoconstriction of arterioles in the viscera and skin.

III. Intrinsic control of vascular resistance allows organs to autoregulate their own blood flow rates.

A. Myogenic regulation occurs when vessels constrict or dilate as a direct response to a rise or fall in blood pressure.

B. Metabolic regulation occurs when vessels dilate in response to the local chemical environment within the organ.

Blood Flow to the Heart and Skeletal Muscles

I. The heart normally respires aerobically because of its high capillary supply, myoglobin content, and enzyme content.

II. During exercise, when the heart's metabolism increases, intrinsic metabolic mechanisms stimulate vasodilation of the coronary vessels and thus increase coronary blood flow.

III. Just prior to exercise and at the start of exercise, blood flow through skeletal muscles increases due to vasodilation caused by cholinergic sympathetic nerve fibers. During exercise, intrinsic metabolic vasodilation occurs.

IV. Since cardiac output can increase by a factor of five or more during exercise, the heart and skeletal muscles receive an increased proportion of a higher total blood flow.

A. The cardiac rate increases due to lower activity of the vagus nerve and higher activity of the sympathetic nerve.
B. The venous return is greater because of higher activity of the skeletal muscle pumps and increased breathing.

C. Increased contractility of the heart, combined with a decrease in total peripheral resistance, can result in a higher stroke volume.

**Blood Flow to the Brain and Skin**

I. Cerebral blood flow is regulated both myogenically and metabolically.
   
   A. Cerebral vessels automatically constrict if the systemic blood pressure rises too high.
   
   B. Metabolic products cause local vessels to dilate and supply more active areas with more blood.

II. The skin has unique arteriovenous anastomoses, which can shunt the blood away from surface capillary loops when body temperature rises.
   
   A. The activity of sympathetic nerve fibers causes constriction of cutaneous arterioles.
   
   B. As a thermoregulatory response, there is increased cutaneous blood flow and increased flow through surface capillary loops when the body temperature rises.

**Blood Pressure**

I. Baroreceptors in the aortic arch and carotid sinuses affect, via the sympathetic nervous system, the cardiac rate and the total peripheral resistance.
   
   A. The baroreceptor reflex causes pressure to be maintained when an upright posture is assumed. This reflex can cause a lowered pressure when the carotid sinuses are massaged.
   
   B. Other mechanisms that affect blood volume help to regulate blood pressure.

II. Blood pressure is commonly measured indirectly by auscultation of the brachial artery when a pressure cuff is inflated and deflated.
   
   A. The first sound of Korotkoff, caused by turbulent flow of blood through a constriction in the artery, occurs when the cuff pressure equals the systolic pressure.
   
   B. The last sound of Korotkoff is heard when the cuff pressure equals the diastolic blood pressure.

III. The mean arterial pressure represents the driving force for blood flow through the arterial system.
Hypertension, Shock, and Congestive Heart Failure

I. Hypertension, or high blood pressure, is classified as either primary or secondary.

   A. Primary hypertension, also called essential hypertension, may be the result of the interaction of many mechanisms that raise the blood volume, cardiac output, and/or peripheral resistance.

   B. Secondary hypertension is the direct result of known, specific diseases.

II. Circulatory shock occurs when there is inadequate delivery of oxygen to the organs of the body.

   A. In hypovolemic shock, low blood volume causes low blood pressure that may progress to an irreversible state.

   B. The fall in blood volume and pressure stimulates various reflexes that produce a rise in cardiac rate, shift of fluid from the tissues into the vascular system, decrease in urine volume, and vasoconstriction.

III. Congestive heart failure occurs when the cardiac output is insufficient to supply the blood flow required by the body. The term congestive is used to describe the increased venous volume and pressure that results.

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