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PHYSIOLOGY ASSIGNMENT

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

The Mean Arterial Pressure refers to the average pressure of the blood circulating through a person’s arteries, during the cardiac cycle. The value of the mean arterial pressure is normally derived from the systolic blood pressure and diastolic blood pressure of the patient. In medicine, the mean arterial pressure (MAP) is an average blood pressure in an individual during a single cardiac cycle.

Systemic Vascular Resistance (SVR) is represented mathematically by the formula:

Mean arterial pressure

R = ΔP/Q

R is SVR. ΔP is the change in pressure across the systemic circulation from its beginning to its end. Q is the flow through the vasculature (equal to cardiac output)

In other words:

Systemic Vascular Resistance = (Mean Arterial Pressure - Mean Venous Pressure) / Cardiac Output

Therefore, mean arterial pressure can be determined from

 MVP = (CO ∙SVR) + CVP

{\displaystyle MAP=(CO\cdot SVR)+CVP}

Where:

* {\displaystyle CO}CO  is cardiac output
* {\displaystyle SVR}SVR  is systemic vascular resistance
* {\displaystyle CVP}CVP is central venous pressure and usually small enough to be neglected in this formula.

Renin-Angiotensin-Aldosterone System (RAAS)

*Renin* is a peptide hormone released by the granular cells of the juxtaglomerular apparatus in the kidney. It is released in response to:

* Sympathetic stimulation
* Reduced sodium-chloride delivery to the distal convoluted tubule
* Decreased blood flow to the kidney

Renin facilitates the conversion of angiotensinogen to angiotensin I which is then converted to angiotensin II using angiotensin-converting enzyme (ACE).

Angiotensin II is a potent vasoconstrictor. It acts directly on the kidney to increase sodium reabsorption in the proximal convoluted tubule. Sodium is reabsorbed via the sodium-hydrogen exchanger. *Angiotensin II* also promotes release of aldosterone.

ACE also breaks down a substance called bradykinin which is a potent vasodilator. Therefore, the breakdown of bradykinin potentiates the overall constricting effect.

Aldosterone promotes salt and water retention by acting at the distal convoluted tubule to increase expression of epithelial sodium channels. Furthermore, aldosterone increases the activity of the basolateral sodium-potassium ATP-ase, thus increasing the electrochemical gradient for movement of sodium ions.

More sodium collects in the kidney tissue and water then follows by osmosis. This results in decreased water excretion and therefore increased blood volume and thus blood pressure.

Anti-Diuretic Hormone (ADH)

## The second mechanism by which blood pressure is regulated is release of Anti Diuretic Hormone (ADH) from the OVLT (Vascular organ of lamina terminalis) of the hypothalamus in response to thirst or an increased plasma osmolarity.

ADH acts to increase the permeability of the collecting duct to water by inserting aquaporin channels (AQP2) into the apical membrane.

It also stimulates sodium reabsorption from the thick ascending limb of the loop of Henle. This increases water reabsorption thus increasing plasma volume and decreasing osmolarity.

1. Pulmonary circulation

**Pulmonary circulation**, system of blood vessels that forms a closed circuit between the heart and the lungs, as distinguished from the systemic circulation between the heart and all other body tissues. It 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. The term pulmonary circulation is readily paired and contrasted with the systemic circulation. The vessels of the pulmonary circulation are the pulmonary arteries and the pulmonary veins. Deoxygenated blood leaves the heart, goes to the lungs, and then re-enters the heart; Deoxygenated blood leaves through the right ventricle through the pulmonary artery. From the right atrium, the blood is pumped through the tricuspid valve (or right atrioventricular valve), into the right ventricle. Blood is then pumped from the right ventricle through the pulmonary valve and into the main pulmonary artery. The pulmonary arteries carry deoxygenated blood to the lungs, where carbon dioxide is released and oxygen is picked up during respiration. Arteries are further divided into very fine capillaries which are extremely thin-walled. The pulmonary vein returns oxygenated blood to the left atrium of the heart. The oxygenated blood then leaves the lungs through pulmonary veins, which return it to the left part of the heart, completing the pulmonary cycle. This blood then enters the left atrium, which pumps it through the mitral valve into the left ventricle. From the left ventricle, the blood passes through the aortic valve to the aorta. The blood is then distributed to the body through the systemic circulation before returning again to the pulmonary circulation. From the right ventricle, blood is pumped through the semilunar pulmonary valve into the left and right main pulmonary arteries (one for each lung), which branch into smaller pulmonary arteries that spread throughout the lungs.

1. Circle of willis

The Circle of Willis (often abbreviated as CW or CoW) gets its name from Thomas Willis, an eminent English physician, who described the arterial ring present at the base of the brain 400 years ago. Willis wasn’t the first to describe this ring of blood vessels. But he was the first one, as so often happens in science, to comprehensively describe this network of blood vessels. Thomas Willis, as his many anatomical treatises show, was a detail-oriented anatomist. He painstakingly documented cranial nerves, leading to the formalized description of the Circle of Willis. The Circle of Willis is a structure located at the base of the brain (around eye level) encircling around the brainstem and the parts of the mid-brain. that provides a blood supply to the brain and neighbouring structures. More specifically, it’s a circulatory anastomosis (i.e., a connection between two blood vessels, such as between arteries, veins, or between an artery and a vein (arterio-venous anastomosis)) that encircles the stalk of the pituitary gland and allows distribution of blood to the brain and nearby structures.

Also referred to as the Loop of Willis, the cerebral arterial circle or the Willis polygon, it is composed of five main arteries:

1. Internal carotid artery (left and right)
2. Anterior cerebral artery (left and right)
3. Anterior communicating artery
4. Posterior cerebral artery (left and right)
5. Posterior communicating artery (left and right)

The CoW encircles the pituitary stalk, optic tracts and basal hypothalamus. It must be noted that anatomically, the CoW is not the same in every individual; it is found to have anomalies in nearly 50% of people. There are two circulatory branches to supply blood to the brain. The two branches of the dorsal aorta supplies blood to the brain and the spinal cord. They are the internal carotid arteries or the anterior circulation of the brain which supplies blood to the anterior parts of the brain, the cerebral hemispheres and structures of the diencephalon (like thalamus and hypothalamus). The vertebral arteries form the posterior circulation and supply blood to the cerebellum, the brainstem and pons, as well as the posterior forebrain.

These two branches of cerebral circulation come together at the Circle of Willis.

The CoW ensure that blood reaches the brain. CoW is an arrangement of interconnected vascular channels that ensure that the (oxygenated) blood flow to the brain continues unimpeded, in case any of the principal suppliers are obstructed by injury, physical pressure or disease.

1. Splanchic circulation

The term ‘splanchnic circulation’ describes the blood flow to the abdominal gastrointestinal organs including the stomach, liver, spleen, pancreas, small intestine, and large intestine. It comprises three major branches of the abdominal aorta; the coeliac artery; superior mesenteric artery (SMA); and inferior mesenteric artery (IMA). The hepatic portal circulation delivers the majority of the blood flow to the liver. It 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. The circulation of some splanchnic organs is complicated by the existence of an intramural circulation. 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. The existence of a multiplicity of regulatory mechanisms provides overlapping controls and restricts radical changes in tissue perfusion.

 The coeliac artery is the first major division of the abdominal aorta, branching at T12 in a horizontal direction (1.25 cm in length). It shows three main divisions such as the left gastric artery, common hepatic artery, and splenic artery and is the primary blood supply to the stomach, upper duodenum, spleen, and pancreas.

 The SMA (Superior mesenteric artery) arises from the abdominal aorta anteriorly at L1, usually 1 cm inferior to the coeliac artery. The five major divisions of the SMA are the inferior pancreaticoduodenal artery, intestinal arteries, ileocolic, right colic, and middle colic arteries. The SMA supplies the lower part of the duodenum, jejunum, ileum, caecum, appendix, ascending colon, and two-thirds of the transverse colon. It is the largest of the splanchnic arterial vessels delivering >10% of the cardiac output and therefore has significant implications for embolic mesenteric ischaemia.

 The Inferior Mesenteric Artery (IMA) branches anteriorly from the abdominal aorta at L3, midway between the renal arteries and the iliac bifurcation. The main branches of the IMA are the left colic artery, the sigmoid branches, and the superior rectal artery. It forms a watershed with the middle colic artery and supplies blood to the final third of the transverse colon, descending colon, and upper rectum.

1. Coronary Circulation

Coronary circulation is the circulation of blood in the blood vessels that supply the heart muscle (myocardium). Coronary arteries supply oxygenated blood to the heart muscle, and cardiac veins drain away the blood once it has been deoxygenated. Because the rest of the body, and most especially the brain, needs a steady supply of oxygenated blood that is free of all but the slightest interruptions, the heart is required to function continuously. Therefore its circulation is of major importance not only to its own tissues but to the entire body and even the level of consciousness of the brain from moment to moment. Interruptions of coronary circulation quickly cause heart attacks (myocardial infarctions), in which the heart muscle is damaged by oxygen starvation. Such interruptions are usually caused by ischemic heart disease (coronary artery disease) and sometimes by embolism from other causes like obstruction in blood flow through vessels. The heart normally extracts 70 to 75 percent of the available oxygen from the blood in coronary circulation, which is much more than the amount extracted by other organs from their circulations—e.g., 40 percent by resting skeletal muscle and 20 percent by the liver. Obstruction of a coronary artery, depriving the heart tissue of oxygen-rich blood, leads to death of part of the heart muscle (myocardial infarction) in severe cases, and total heart failure and death may ensue.

1. Cutaneous circulation

The cutaneous circulation is the circulation and blood supply of the skin. The skin is not a very metabolically active tissue and has relatively small energy requirements, so its blood supply is different to that of other tissues.

Some of the circulating blood volume in the skin will flow through will flow through arteriovenous anastomoses (AVAs) instead of capillaries. AVAs serve a role in temperature regulation. In this article we shall consider the different adaptations of the cutaneous circulation, and its role in body temperature control. AVAs are low-resistance connections between the small arteries and small veins that supply and drain the skin. These allow the shunt of blood directly into the **venous plexus** of the skin, without it passing through capillaries. Since AVAs contain no capillary section, they are not involved in transport of nutrients to/from the tissues, but instead play a major role in temperature regulation. The skin is the body’s main heat dissipating surface: the amount of blood flow to the skin determines the degree of heat loss and therefore the core body temperature. The blood flow through AVAs is heavily influenced by the sympathetic nervous system.  At rest, the sympathetic nervous system dominates and acts to constrict AVAs.

Any changes in core temperature are detected by the thermoregulatory centre in the hypothalamus. It regulates temperature by altering the level of sympathetic outflow to the cutaneous vessels, to return temperature to its normal range:

In high core temperatures:

* Sympathetic innervation is decreased, reducing the vasomotor tone in the AVAs.
* More blood flows through the AVAs and reaches the venous plexus (close to the surface of the skin), increasing heat loss to reduce core temperature.

In low core temperatures:

* Sympathetic innervation is increased, increasing the vasomotor tone in the AVAs.
* Less blood flows to the apical skin (of nose, lips, ears, hands and feet), reducing heat loss to increase the core temperature.
1. a. Increased Cardiac Output (CO)

During exercise, the heart needs to pump more oxygenated blood to fuel the working muscles. **Cardiac output**, in human physiology, volume of blood expelled by either ventricle of the heart. It is customarily expressed as minute volume, or litres of blood per minute, calculated as the product of stroke volume (output of either ventricle per heartbeat) and the number of beats per minute. Simply put:

Cardiac Output (CO) = Heart Rate ∙ Stroke Volume

 During exercise, the heart rate increases in order for more blood to be circulated round and the stroke volume (which is the amount of blood pumped out of the heart per minute) also increases. The interaction of these two increases the Cardiac Output.

 b. Decreased blood flow to liver, kidneys and gut

As the heart pumps more blood to the working muscles, there is decreased circulation to other organs such as the liver, kidneys and the gut. It is suggested that local autoregulatory mechanisms are responsible for maintained visceral flow in the face of neural and hormonal autonomic drive, which acts to constrict renal and mesenteric vessels and to reduce blood flow. 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 anaemia, where oxygen-carrying capacity of the blood is limited, visceral blood flows are reduced drastically and blood is diverted to the exercising musculature.

 c. Loss of body water

During prolonged exercise in the heat, water may be lost as a result of sweating (3-5%), and when dehydration exceeds 3% of total body water (2% of body mass) then aerobic performance is impaired. Dehydration can lead to an increase in body core temperature, increased hyperthermia, and plasma volume reduction. This alters cardiovascular and biochemical components in the blood, which reduce VO2max. Research has shown that after 10 minutes of prolonged moderate intensity of 50-75% VO2max in both neutral and warm environments showed a cardiovascular drift.