Supply of vital organs

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Last update: Monday, 06 Feb 2023 at 10.21 pm.

Our heart pumps blood throughout our body. It is then distributed through blood vessels and brings oxygen and nutrients to the organs, thanks to which the organs then function. On the contrary, it removes waste substances and carbon dioxide.

Pulmonary circulation

Pulmonary circulation serves to oxygenate our blood. Compared to the systemic circulation, the arterioles and venules of the pulmonary microcirculation are shorter and have a larger lumen, the capillaries have a diameter of about 8 mm and form massive anastomoses forming a dense network on the surface of the alveoli. Regarding the functional differences, the pulmonary circulation belongs to the **low-pressure part of the circulation** (along with the venous part of the riverbed, the right atrium, the right ventricle and the left atrium). The low pressure value in the pulmonary capillaries is important in relation to the oncotic pressure of plasma proteins. In the capillaries of the pulmonary circulation, the blood pressure **must not** approach the oncotic level, otherwise there is a risk of tissue fluid filtering into the alveoli, which leads to pulmonary edema.

⚠**Attention! In the systemic circulation, on the other hand, the blood pressure in the capillaries must be comparable to the oncotic pressure in order to filter tissue fluid and ensure tissue nutrition**

We determine the blood pressure values in the pulmonary capillaries by right-sided heart catheterization, which allows us to measure the pressures in the large veins of the systemic circulation, in the right atrium, right ventricle, in the pulmonary artery and in the wedge. Wedging pressure expresses the pressure in the sealed pulmonary artery (by a balloon catheter), when its value is identical to the pressure value in the pulmonary capillaries. The shock flow of blood from the right ventricle is transformed by the elastic properties of the pulmonary arteries into a continuous one. The blood flow has a pulsatile character even in the post-capillary part of the pulmonary circulation (up to the left atrium)

VALUES OF PULMONARY CIRCULATION PRESSURES	
Mean linear velocity of blood flow in the pulmonary artery	**cca 18 cm/s**
Blood pressure in the pulmonary artery	in systole **25 mmHg**
	in diastole **10 mmHg**
	mean pressure **13 mmHg**
Mean blood pressure in capillaries	**6,5 mmHg**
Mean left atrial pressure	**5,5 mmHg**

Total peripheral resistance in the pulmonary circulation - makes up less than 1/10 of the total resistance of the systemic circulation. Compared to systemic arteries, pulmonary arteries have a thinner wall - they are easier to expand.

Central blood volume: the volume of blood in the pulmonary vessels + the volume in the left ventricle at the end of diastole (approx. 600 – 650 ml - an easily and quickly mobilized reservoir

Control of pulmonary circulation

The **sympathetic nervous system**, the mediator of which is noradrenaline, is involved in the management. Sympathetic has a vasoconstrictive effect. This vasoconstrictive innervation is involved in changes in total **peripheral resistance** in the pulmonary circulation and is the main mode of regulation. Increased stimulation of baroreceptors in the carotid sinus leads to a decrease in this peripheral resistance of the pulmonary bed. By changing the partial pressure of O2 or CO2, chemoreceptors are activated, which stimulate sympathetic and parasympathetic activity. **The baroreceptor reflex** therefore serves to **acutely regulate blood pressure.** Nervous and humoral mechanisms are used here. It is the humoral mechanisms that influence the distribution of blood in the pulmonary circulation. The main regulator here is the local humoral mechanism – **the local action of hypoxia**.The vessels then respond to hypoxia by vasodilation.

VASODILATOR SUBSTANCE	VASOCONSTRCT SUBSTANCE
▪ oxygen ▪ β-adrenergic receptor stimulators ▪ histamine ▪ acetylcholine ▪ bradykinin ▪ NO ▪ atrial natriuretic peptide ▪ adenosine and ATP	▪ H+ ionts ▪ CO_2 ▪ α-adrenergic receptor stimulators ▪ serotonin ▪ angiotensin II ▪ endothelin ▪ platelet-derived growth factor

Coronary circulation

The myocardium is supplied by two **coronary arteries**. **The right coronary artery** supplies the right ventricle, the right atrium, the lower wall of the left ventricle and the upper back part of the interventricular septum. The left coronary artery is divided into – **ramus circumflexus** and **ramus interventricularis anterior** (RIA). **The RIA** supplies the anterior part of the left ventricle and the anterior part of the interventricular septum. **The ramus circumflexus** supplies the rest of the left ventricle (lateral and upper part) and the entire left atrium. The blood flow through these arteries is about **250 ml/min** at rest and can reach values of up to 1250 ml/min during maximum physical exertion. Flow **increases during diastole** and **decreases** significantly **during systole**. It is during systole that the arteries are compressed by the contracting heart. As the heart rate increases, diastole shortens more than systole. This reduces the flow through the coronary artery. This decrease is compensated by the vasodilation effect of the increased production of metabolites by the more intensively working myocardium, when the result of tachycardia is rather vasodilation.

Control of coronary circulation

Humoral mechanisms are mainly used. As the work of the myocardium increases, the metabolic turnover and the amount of catabolites increase, which then have a significant vasodilating effect. The most important vasodilator in the case of coronary flow is **adenosine**. Sympathetic and catecholamines indirectly cause vasodilation - they increase the metabolic turnover of the myocardium. As for the collateral circulation, the collaterals are poorly developed in the heart. However, in case of impaired flow, they can develop relatively large collateral riverbeds. This mechanism **ensures cardiac activity** in terms of energy.

Mechanic work of the heart

Cardiac muscle does work by **contracting** its fibers. Its work consists in displacing a certain volume of blood against a certain resistance (it can be expressed by the pressure necessary to overcome it). This is therefore **pressure-volume work**. The heart gives the blood a certain kinetic energy - **acceleration work**. The individual quantities from which the mechanical work of the heart is calculated change during the heart action, and therefore the integral is used for the calculation.

Energetics of cardiac work

The immediate source of energy is **ATP**, which is hydrolyzed by ATPase stored in the myosin head. Energy for resynthesis is obtained exclusively **aerobically**. Oxygen consumption in the heart at rest is around **0.08 – 0.1 ml O2 per gram of tissue per minute**. This is approximately **24 – 30 ml/min**. This is about **10%** of the body's total O2 consumption. During heavy work, the consumption increases almost fourfold.

> *Consumption of oxygen determines:isovolumic contraction work + contraction force + heart rate*

A lesser role is played by the work of the heart during relaxation, the ejection phase, activation of the myocardium and its basal metabolism. Isovolumic contraction contributes more to oxygen consumption than isotonic contraction in the ejection phase of systole. In addition to ATP, the myocardium also contains creatine phosphate. It is a sensitive indicator of sufficient supply of nutrients and oxygen to the heart. It is also an immediate source of energy for **resynthesis of ATP.**

The high content of free MK and above all the ability to metabolize lactic acid contribute to the consumption of nutrients by the heart. This fact is important in connection with the performance of heavy muscular work, when skeletal muscles switch to anaerobic glycolysis and secrete lactic acid into the blood. The muscles provide the heart with fuel, and the heart in turn contributes by processing lactic acid to maintain the pH.

Cerebral circulation

The blood supply to the brain is provided by 4 arteries: 85% are provided by the internal carotid arteries, 15% by the vertebral arteries. Blood flow through the brain depends on age, in a young individual at rest it is around **750 ml/min**, after the age of 50 it decreases. It increases by up to 50% during intense neuronal activity, but it also increases in areas where activity is currently being shown. In general, the flow is unevenly distributed, about 4-5 times more blood flows through gray matter than white matter.

Control of cerebral circulation

Local humoral autoregulatory mechanisms prevail. Hypoxia and especially hypercapnia and acidosis of the perivascular space are significant vasodilatory stimuli. During vasodilation, NO is also used, and on the other hand, inhalation of pure oxygen causes vasoconstriction. Hypocapnia also causes vasoconstriction - it can be the cause of hyperventilation tetany due to impaired perfusion of brain tissue. The flow rate is determined by the pressure gradient and peripheral resistance, and due to the myogenic mechanism, it is unchanged even with relatively large changes in blood pressure. An increase in pressure causes reflex vasoconstriction, which causes an increase in peripheral resistance. In contrast, a drop in pressure leads to vasodilation. When the mean blood pressure drops **below 70 mmHg**, the flow is already restricted, when it rises above **160 mmHg**, the pressure in the cerebral circulation begins to rise (it can even cause brain edema).

Central control mechanisms are not of great importance under physiological conditions, but they can be used, for example, during a hypertensive crisis, when the activated sympathetic system causes vasoconstriction. The endothelium in the capillaries of the brain is not fenestrated, the basement membrane is thicker. Capillaries are separated from nerve cells by astrocytes and glial cells, and the brain capillary endothelium has specific transport mechanisms for ions and some important metabolic substrates. There **are no lymphatic vessels** in the brain.

Circulation of blood through the kidneys

Renal flow under resting conditions is **1,200 ml/min** (about 20% of the minute volume). It involves 2 capillary networks in a row - **the glomerular capillary network**, from which the blood is taken away by efferent arterioles and branches again into **the peritubular capillary plexus**. Blood pressure in the capillaries of the glomerulus: about **60 mmHg**, which is beneficial for filtration and blood pressure in the peritubular capillaries, on the other hand, about **13 mmHg** is favorable for reabsorption. The arrangement of the vasa recta and Henle's loop allows us to operate **the countercurrent mechanism**, which is necessary for the formation of an osmotic gradient between the blood in the vessels and the interstitial fluid in the kidney medulla. Active transport of ions out of the ascending arm of the loop leads to increased osmolarity of the interstitial fluid, when water from the descending arm passes into the medulla. Ions and urea pass through the thin segment of the ascending limb. Ions and urea diffuse into the vasa recta, water moves in the opposite direction, and from the ascending arm, solutes from the vasa recta return to the interstitium and water returns to the blood in the vasa recta. The result is a **hypertonicity of the medulla** maintained by recirculation of solutes, while water is continuously drained away by the blood vessels.

Control of blood circulation by the kidneys

Myogenic autoregulation dominates - it keeps the flow and excretory function of the kidneys constant and relatively independent of arterial BP. Sympathetic innervation of the vas afferens and efferens: increased sympathetic tone has a vasoconstrictive effect, but the vasoconstriction of the vas efferens is relatively dominant, causing an increase in filtration pressure and an increase in glomerular filtration.

Links

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Resources

- TROJAN, Stanislav. *Lékařská fyziologie.* 4. edition. Grada, 2003. ISBN 80-247-0512-5.