

system of the heart. We can then notice different types of atrioventricular heart blocks. Atrioventricular blocks, bundle branch blocks or fascicular blocks. The displaced vegetation can reach the coronary arteries, and then evoke a picture of acute myocardial infarction.

The process of treatment can be obtained by antibiotics to destroy the bacteria. Macrophages then remove the destroyed and useless **material**. Fibroblast form new collagen and in few weeks or few months time the endocardial surface is covered with epithelium. Even through we may find later during transplantation of valves the presence of microorganisms on those injured valves. The affected valve is usually thickened and calcified. During endocarditis the affected valve can be perforated.

**The most frightening complication is heart failure.** It occurs nearly in 75% of the affected individuals. The second serious complication is **meningoencephalitis and cerebral embolism**. Renal disorders are mainly caused by the embedded immunocomplexes in the basal membrane of the glomerular capillaries. In the acute form of infective endocarditis the patient is threatened by a huge distraction of the affected valves, including perforation. In long-lasting intensive use of drugs there might be a progression to a sub acute form of infective endocarditis. After the replacement of a valve (implantation) infective endocarditis occur within 60 days. During pregnancy infective endocarditis may follow infections in patients having already some kind of congenital heart disease. The untreated infective endocarditis is always a fatal disease.

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## 3.13 Pathological changes of the blood pressure

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### 3.13.1 Functional anatomy of the circulation

The circulation can perform its basic function in an optimal way only when the amount of the blood flow-

ing through the capillaries of each tissue, or organ per a time unit is fair enough to keep the homeostasis of that organ, so that it can perform its function adequately. the blood flow per minute via the capillaries of the given tissue or organ is the most important parameter of the blood flow (haemodynamics)

The vessels from the functional point of view can be divided into:

1. **Compliance vessels**, that form the large and intermediate arteries. Their function is to provide a continuous flow of blood. Ensure a fast transport of blood to the peripheries.
2. **Resistant vessels** are the major determinants of the general peripheral vascular resistance and by this even the regional blood flow.

The whole peripheral vascular resistance is an important factor upon which the intermediate arterial blood pressure depends. It includes: The elastic resistance in the arterial system, the peripheral resistance of the resistant vessels, and the resistance which is imposed by the pre capillary sphincter. We recognize two types of the resistant vessels:

- (a) **pre capillary resistant vessels** – small arteries and arterioles – which form about one half of the value of the peripheral vascular resistance.
- (b) **post capillary resistant vessels** – venules and small veins That form a small part of the resistance. The participate in the changes of the potential volume of the capacity field.

3. **precapillary sphincter** is that part of the vessel that regulates blood flow into the capillaries and selectively distributes blood into those capillaries. By opening and closing these segments we can determine the number of transition capillaries in a given organ or tissue. The pre capillary sphincter under goes systemic and local effects. That determine the metabolic of the tissue or organ.

4. **capacitance vessels** (volume) are mainly the large systemic veins. They represent the reservoir for heart filling.

5. **exchange vessels** are the *true* blood capillaries. They mediate the contact between the blood field and the interstitial place.
6. **shunt vessels** of the arterio- venous shunts. These vessels provide a fast flow of blood from the anterior to the venous side without passing through the capillaries i.e. (bypassing the capillaries). They exist in certain tissues such as skin and lungs.

The primary function of the cardiovascular system is to provide adequate flow of blood through different tissues. The power that provide this is the mean arterial pressure. There is a physical relation between the mean arterial pressure, the minute volume of the heart, and the total peripheral resistance. This relation is similar to the relation between the tension ( $E$ ), the electrical current intensity ( $I$ ) and the resistance of the electric conduction ( $R$ ) which is determined by Ohm's law:

$$R = \frac{E}{I}$$

The resistance is directly related to the tension and in indirect relation with the intensity. The tension is then equal to the intensity multiplied by the resistance. For the arterial pressure the relation looks like this:

**the mean arterial pressure = minute volume multiplied by the total peripheral resistance.**

By increasing the minute volume we lower the total peripheral resistance and vice versa, by decreasing the minute volume, the peripheral resistance increases, so that the pressure remains unchanged.

### 3.13.2 Regulation of the blood pressure

Under the headline the arterial (systemic) blood pressure we understand, the lateral hydrostatic pressure that acts on the arterial wall during the ventricular systole. The perfusion of organs and tissues is dependent upon the mean arterial pressure. The value of which depend on:

1. The volume of blood pumped by the left ventricle in a time unit. The cardiac output.
2. The resistance to the blood flow laid down by the vessels in the peripheries of the vascular field

The total peripheral resistance in the arterioles, but partially even in the larger arteries, capillaries, and venules = total peripheral resistance.

**The minute cardiac output** is regulated by four factors:

1. The end diastolic volume of the left ventricle (the preload)
2. The myocardial contractility
3. The resistance against which the left ventricle pumps the blood (the after load)
4. The frequency of the heart.

All these factors affecting the minute cardiac output are affected by the autonomic nervous system: that activated adrenergic receptors in the SA node, the myocardium, the smooth muscle in the arterial wall, venules, and veins.

**Regulation of vascular tonus.** The value of the tonus depends on the structural and functional characteristics of the individual vessels. This value is under the effect of many systemic and local factors.

**Systemic factors regulating the vascular tonus** are mainly nervous mechanisms, sympathoadrenal system, system rennin-angiotensin-aldosteron, and the vasopresin system.

Local factors can be divided into three groups:

1. the vascular myogenic reaction to the tension
2. chemical factors having metabolic origin
3. humoral factors.

1) The caliber of the blood vessels is determined by two physical antagonizing (acting against each other) factors. These are the transmural distending pressure and a tangentially acting tension on the vascular wall. In the state of equilibrium the relation between these two and the diameter of the vessel is defined by Laplace law:

$$\text{The vascular wall tension} = P \cdot \frac{r}{h}$$

$P$ ... the distending pressure,  $r$ ... the vascular diameter,  $h$ ... is the wall thickness

According to this law the smaller is the vascular diameter the lower is the pressure needed to close

the vessel. This is why as soon as the pre capillary sphincter starts to contract and its translucency is decreased (the wall thickness increases) the tendency of this sphincter to close the vessel is increasing. This **magic circle** tends to close the vessels completely.

2) An increase in the tissue metabolism is accompanied by an increase in the regional blood flow, which is known as functional hyperemia. The regional vascular tonus is decreasing and the blood flow is increasing. Contraversly in non functioning organs or tissues the blood flow drops down.

Functional hyperemia is related to the effects of local chemical factors, either by the accumulation of metabolic products or by the depletion of nutrients. Intensive hyperemia occurs during muscular exertion: there is a marked dilatation of the pre capillary and post capillary resistant vessels.

According to the vasodilatatory theory the vascular tonus is regulated by factors that originate during the exertion in the contracted muscle fibers, released to the intersitium and can affect the vascular tone directly: CO<sub>2</sub>, lactate, other carbohydrate metabolites, decreased in the pH, acetylcholin, (ATP) that evoke active vasodilatation such as histamin and bradykinin, and eventually leading to an increase of the capillary permeability. According to the oxygen theory – vascular vasodilatation in active tissues is caused by inadequate O<sub>2</sub>.

Attention is given mainly to three factors: Hypoxia, a regional increase of the extra cellular concentration of kalium, and regional hyperosmolarity. Changes in the extra cellular concentration of kalium and of the osmolarity probably influence the vascular tone via the Ca<sup>2+</sup> influx into the muscle fiber.

3) Humoral factors: a group of vasoactive substances – kinins, that have the character of local hormones. Their main function is the regulation of micro circulation. These are mainly: acetylcholin, histamin, 5-hydroxytryptamin - serotonin, prostaglandin, endothelium - derived relaxing factor EDRF, endothelin. Direct regulation of blood pressure is provided by three reflexes.

1. baroreceptor reflex
2. chemoreceptor reflex
3. ischemic reaction CNS (Cushing reflex)

1) **Baroreceptors** are situated in the carotid sinus, aortic arch, pulmonary arteries and less frequently in

other large arteries, in the upper chest. Any increase in the arterial blood pressure stimulate the baroreceptors, these will depress the activity of the vasomotor center that is followed by lowering the sympathetic tonus: resulting in peripheral vasodilatation lowering the cardiac activity and normaliyation the blood pressure. An opposite effect could be achieved when there is initial drop in the blood pressure.

2) **Chemoreceptors** react to changes in the pO<sub>2</sub> of blood flowing towards the aortic and carotid bodies and they exert their action on the blood pressure that ranges between 40–100 torr. When there is a dicers in the blood flow there is a consequent drop in the oxygen supply and a resulting conduction of activity to the vasomotor center will aim to return the pressure back to its original level.

3) **Reaction of CNS to ischemia** is a defensive mechanism against the extreme drop of the blood pressure. This is about a mechanism that ensures an adequate blood flow to the brain. When the blood pressure drops down or the brain is badly perfused due to other reason, the vasomotor centrum suffers and starts to be exclusively active. It starts to send sympathetic vasoconstricting impulses to the vessels and cardiac accelerating impulses to the heart. This mechanism is activated only when the arterial blood pressure drops below 60 torr.

The vasomotor center is mainly controlled by the hypothalamus, which posterolateral part increases the activity of the vasomotor center, the anterior part inhibits it.

Central and peripheral **sympathetic nervous systems** regulate cardiovascular function via the adrenoreceptors. The mediator is noradrenalin, which is produced by the nerve endings. Sympathetic vasoconstricting agents (eg. psycho emotional stress) stimulate the chromafin system of the adrenals as well, that will lead to the production of adrenalin and low amounts of noradrenalin. Adrenalin leads to an increment in the cardiac output, evoke tachycardia, and increases the systolic blood pressure. The total peripheral resistance is basically not changed. Noradrenalin increases the systolic and diastolic blood pressure by increasing the peripheral vascular resistance. Catecholamins lead to a decrement of the vascular blood flow through the kidneys, and hence a decrement of sodium and water excretion by the kidneys. There is also activation of rennin-angiotensin system.

**Renin-angiotensin system** is composed of a multi-step cascade of on each other dependent substances. The key substance and a limiting factor is the enzyme rennin. This enzyme is produced in the juxtaglomerular apparatus of the kidneys. Rennin-angiotensin system exists in other tissues too. This extrarenal system is subjected to an intensive study mainly in the vessels.

Angiotensin II binds to the cellular membrane receptors and stimulate  $\text{Ca}^{2+}$  influx, but do not activate adenylyclase. Angiotensin as well stimulates the biosynthesis and proliferation of smooth muscle. It causes a constriction of the systemic arterioles (by its direct effect on the pre capillary resistant vessels). During the physiological conditions there is a dynamic equilibrium between the pressor and the depressor mechanism, this equilibrium keeps the blood pressure in the optimal range. (Arterial hypertension can be the consequence of a disorder of the mentioned equilibrium being either due to the relative or the absolute excess of the pressing factors or the absolute excess of the pressing factors or the inadequacy of the depressing factors).

Differing from the nervous regulatory mechanisms, that can react within few seconds, other **regulatory mechanisms need longer time for exerting their effect.**

1) **Transcapillary shift of fluids** (the flow of fluid out of the capillaries or into the capillaries): With blood pressure change there will be a change in the capillary pressure. When the arterial blood pressure drops down there will be a consequent drop of the fluid filtration through the capillary membrane into the interstitial space and hence increasing the amount of the circulating blood. Contraversly, in cases of the increased blood pressure there will be fluid escape into the interstitial space. This mechanism reacts slowly.

2) **Mechanism of vascular adaptation:** For example after a massive blood transfusion there will be an initial raise in the blood pressure, yet after some time – 10 min. till one hour – and due to a vascular relaxation the blood pressure returns to the normal even though the blood volume increase by nearly 30 % over the normal level. Contraversly post a massive bleeding this mechanism can lead to a vasoconstriction enclosing the remaining blood volume and by this keeping the normal haemodynamic. This mechanism has its restriction by which it can cor-

rect only changes ranging between +30 % till -15 % of the blood volume.

**Long lasting regulation** of the blood pressure is obtained mainly by the **kidneys as an organ.** Aldosterone limits water and salt loss.

The renal mechanisms of sodium and water excretion have the greatest importance for the **long lasting regulation.** With the raising blood pressure there is a consequent raise of the perfusion pressure in the kidneys and sodium and water excretion in the urine. A raise in the blood pressure that results from a raise in the cardiac output (for e.g.: in cases of expansion of the body fluids) when normal renal function will evoke **pressure diuresis and natriumuresis** and hence decreasing the volume and the blood pressure. In renal function disturbance e.g. in low blood flow through the kidneys which result from the general drop of the blood pressure, or from a loss of functional kidney parenchyma there will be sodium and water retention in the organism that will consequently lead to raise in the venous return, cardiac output, and blood pressure.

There will be an establishment of a new state of equilibrium that characterizes most of the hypertension cases. A high blood pressure, a high peripheral resistance, normal cardiac output, and a normal volume of body fluids. This condition modifies the function of baroreceptors, sympatico adrenergic mechanisms, rennin-angiotensin system, mineralocorticoids and other factors.

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## 3.14 Systemic arterial hypertension

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Systemic arterial hypertension is a long-lasting, usually permanent elevated blood pressure (BP) in the systemic circulation. It might usually concern only of the systolic BP, and respectively only of the diastolic blood pressure, or it might concern both of them at the same time.

Increase of BP can be determined:

a) by the increase of the cardiac output or by the