SIM – PHYSIOLOGY E-BOOK

(SIM LAB GUIDE for 2nd YEAR MEDICAL STUDENTS)

B1

- Introduction to Simulation Medicine in Physiology Course
- Primary Investigation and Evaluation

B2

- Handover (SBAR)
- Circulation, Blood Pressure, Determinants of Blood Pressure

B3

- Respiration
- Relationship between Respiration and Circulation
- Oxygen Supply (DO2)
- Determinants of Oxygen Delivery (DO2)

B4

- CO2 elimination
- Capnometry
- etCO2 variables
- Monitoring of the Organism during General Anesthesia
- Reaction to a Change in Condition

B5

- Invasive Blood Pressure Measurement
- Determinants of Glomerular Filtration

B6

- Consciousness (determinants and evaluation)
- Intrinsic Environment

B2

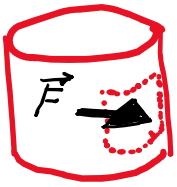
HANDOVER

A **systematic approach to the patient** (**examination, evaluation (reaction) and balance)** includes a structured **transfer of information about the patient.** The better the transfer of information, the easier it will be for the attending physician to navigate the problem.

SBAR: One of the established methods of oral communication or transfer of information about the patient amongst health professionals.

		Content	*SBAR example*
S	**SITUATION** **What happened**	▪ Who and where am I? ▪ Who is the patient? ▪ **The patient's main difficulty**	*I am a medical student on Albertov Street* *I have a 40-year-old confused, sweaty lady here*
B	**BACKGROUND** **What led to this**	▪ **Circumstances of the occurrence of difficulties** ▪ + known complicating factors (e.g. chronic diseases - diabetes)	*She is a diabetic, she didn't eat much in the morning, she recieved her insulin.* *Now she drank half a liter of sweet cola and ate cookies, the condition is better.*
A	**ASSESMENT** **Examination result** **+** **Severity rating**	**Dr. ABC** 	*At first, the patient was restless and disoriented to time and place.* *She is now calmer, communicates better,* *She is breathing regularly with a respiratory rate of 16/minute. Her skin is sweaty, pink, her peripheral pulse is easily palpable and regular, her HR 100/min, the blood supply in the periphery is good (CRT 2s), the pupils are isochoric, they react to light directly and indirectly.* *I suspect that the development of unconsciousness was due to hypoglycemia, therefore I assess her condition as threatening.*
R	**RECOMMENDATION** **What I need**	**Transfer to custody**	*I need advice on what to do next* *I need to measure blood sugar and transport the lady to the hospital….*
	Check if they understood !!!		***When will you arrive?***

CIRCULATION, BLOOD PRESSURE, HYPOTENSION
DETERMINANTS OF BLOOD PRESSURE

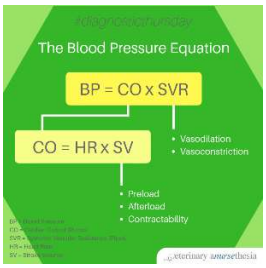


- **Blood pressure is** the force of the blood filling action on the area of the vessel wall.
- It is an essential parameter because based on the BP value, the organism maintains **tissue blood flow** (i.e. the level of O2 supply, energy substrates and removal of waste products) in the appropriate range*
- The value of blood pressure and its fluctuations are measured by mechanoreceptors in the circulation.
- Sufficient blood pressure values must also be achieved to maintain the filtration capacity of the kidneys and the exchange of substances in the tissues (see Starling's forces on the glomerular capillary membrane and on the capillary membrane of the systemic circulation).

* Note : The flow rate is determined by the necessary O2 supply. A cardiac output of approx. 0.5L/min would be sufficient to ensure the supply of energy substrates

Blood Pressure Depends on:

- Volume of Circulating Fluid (Blood Volume)
- Heart Function (Cardiac Output)
- Vascular Wall Resistance (Total Peripheral Resistance TPR/ Systemic Venous Resistance SVR)



Detection of Current Blood Pressure in The General Circulation

- Mechanoreceptors in the vessel walls have mechanically gated ion channels that detect the change in vessel wall tension.
- Those receptors that serve to regulate **the volume of blood** (and body fluids) are called **volumoreceptors** and are located in the atria and large veins, where the wall is more pliable and therefore more responsive to changes in volume than the arteries.
- Those receptors responsible for the regulation **of cardiac output** and **vascular resistance** are called **baroreceptors** and are located in the carotid bodies and the arch of the aorta, i.e., in the place where the change in the CO and the change in the TPR are best reflected in the pressure values.

- In addition to the vascular wall tension receptors mentioned, the organism also has a number of other local receptors (e.g., kidneys, brain etc.).

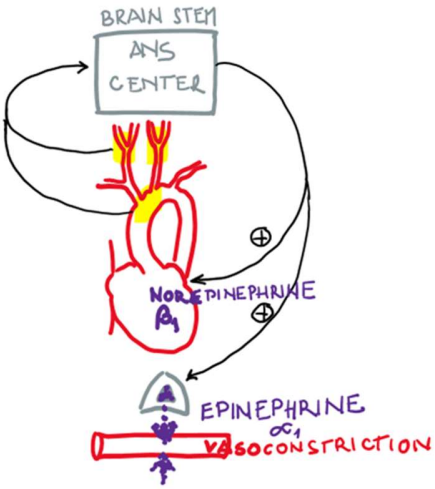
- The given examples are to explain the principle of blood pressure regulation in the general circulation and to realize the importance of maintaining the blood flow through the tissues at the appropriate level for maintaining the integrity of the organism.

- It further illustrates the adaptation of compensatory mechanisms: a drop in pressure below a critical value is a strong activator of the sympathetic system. This is a life-threatening condition.

Compensatory Mechanisms of The Organism During Drop in Arterial Blood Pressure

(see textbook, blood pressure regulation for details)

1. Nervous Regulation and Baroreceptor Reflex



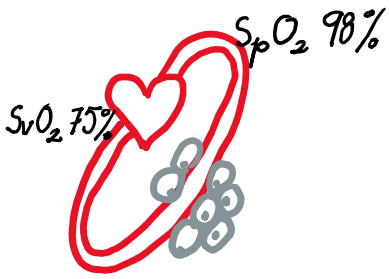
- As the blood pressure in the arterial circulation drops, the tension in the vessel wall decreases and the mechanically gated ion channels of the carotid body and aortic arch close. (The flow of ions through the channel and the generation of action potentials are reduced.)

- This stops the inhibitory effect on the trunk center of the sympathetic, and the cardiac output increases (the effect is seen immediately).

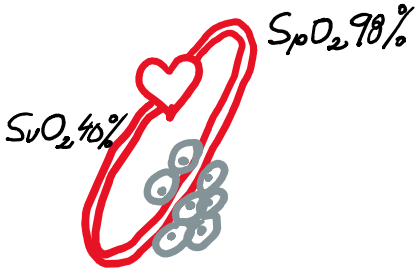
- Adrenal glands are stimulated to produce adrenaline and vasoconstriction of systemic arterioles takes place (it manifests itself with a latency of seconds to tens of seconds).

2. Maintenance of oxygen supply during reduced tissue blood flow by increased O2 extraction

If the tissue blood flow falls below the required limit and the metabolic needs and thus tissue O2 uptake continue (do not decrease), this automatically leads to higher tissue O2 extraction. Saturation of venous blood (leaving the tissue), SvO2 is then lower than usual physiological conditions.



Adequate tissue blood flow

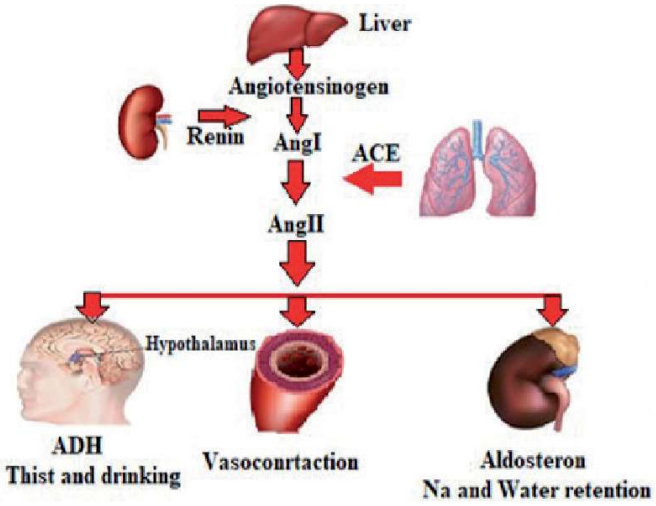


Decreased tissue blood flow

3. Hormonal regulation aimed at limiting intravascular fluid volume losses:

- The drop in arterial pressure is also detected by the vascular baroreceptors in the kidneys (afferent renal arterioles).

- As a result, the kidneys release renin, angiotensin is produced, and the adrenal cortex produces aldosterone, causing increased sodium and water resorption. (For more details, see the textbook, the renin-angiotensin-aldosterone system and B5.)



- A decrease in stimulation of the volume receptors (in the wall of large vessels, in the atria of the heart, in the pulmonary veins) leads to the production of antidiuretic hormone (ADH), which increases the resorption of water in the kidneys and leads to the feeling of thirst.

- The development of hormonal regulation takes longer (hours, days) than metabolic or nervous regulation.

4. Redistribution of blood flow in hypotension

- Under conditions of falling/low arterial blood pressure, the brain, heart and kidneys are perfused better than peripheral tissues (centralization of circulation).

- This is ensured by the **autoregulation** of blood flow in these organs. In other words: these organs have their own perfusion regulation mechanisms, which are somewhat superior to the central control. (For more detail, textbooks and B5.)

The Importance of Regulation of Blood Pressure

- **Hypotension is a critical condition,** because the imbalance between the demand of the tissues and the supply of blood (the circulation) can exceed the ability of compensation and medical interventions and this may lead to death.

- **A compensatory reaction** is desirable (it maintains flow in preferred areas (brain, heart and lungs, to some extent kidneys), but if it lasts long, it may lead to irreversible changes in tissues suffering from long-term vasoconstriction (GIT, skin, muscles etc.).

- This leads to undesirable tissue damage due to hypoperfusion, and is also a threat to the whole organism after the restoration of peripheral blood flow (if the circulatory failure can be managed therapeutically).

- This occurs because the breakdown products of the poorly supplied tissues (during the period of temporary hypotension) enter into the circulation (e.g. phospholipids of membranes – lead to activation of coagulation, potassium – causes changes in potentials of membranes, heart rhythm disorders, H+ from anaerobic metabolism – pH shift, protein dysfunction).

Therapeutic Principles

Therefore, it is important to resolve the hypotensive state and restore physiological circulatory conditions as early as possible. This is done based on the cause of development of hypotension:

- Volume loss -> volume replacement
- Decrease in cardiac output -> support of cardiac output according to the cause of the disorder (Impairment of filling? electrical activity? contractility?)
- Loss of peripheral resistance -> vasoconstriction of arterioles

One of the conditions for success is a careful examination, knowledge of the values of circulation parameters and their development over time.
(See also B5, Invasive Blood Pressure Monitoring and Hourly Diuresis Monitoring).

Intravascular Volume Loss

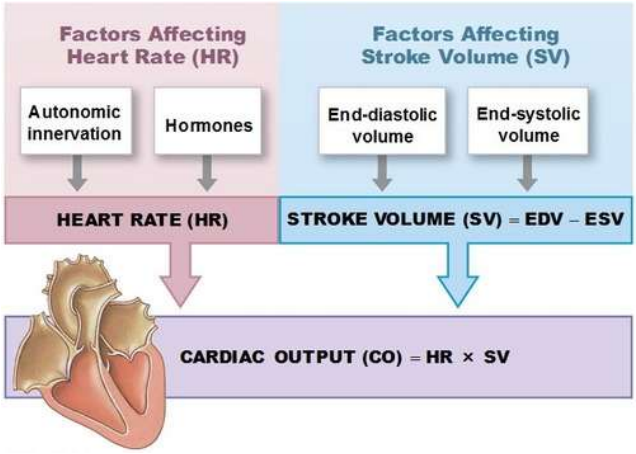
- Intravascular volume fluctuation to a certain extent is physiological.
- For example, blood volume increases by resorption of fluids from the gastrointestinal tract, and decreases by the formation of urine or sweat (in more detail, fluid balance B5).
- Within a certain range, changes are compensated by regulatory mechanisms.
- However, if there is a sudden and significant drop in blood volume (for example, massive bleeding), the regulatory mechanisms are insufficient to compensate, even though they are maximally engaged, and blood pressure inevitably falls.

A Decrease in Cardiac Output

- Physiologically, cardiac output varies widely (5l/min at rest - 30l/min during maximum exercise).

- It is determined by:
  The product of Stroke Volume and Heart Rate.

- A severe decrease in cardiac output may occur due to either:
  1. Decrease in **stroke volume** (reduced contractility, impaired filling, uncoordinated contraction of the myocardium)
  2. **Decrease** in **heart rate**
  3. Critical **increase** in **heart rate** (the diastolic phase is shortened such that the heart does not have time to fill ideally)



A Decrease in Peripheral Resistance

- Vasoconstriction increases peripheral resistance and thus blood pressure also increases.

- This applies to sections of the vessel in front of the region that undergoes the lumen change, as well as parallel sections adjacent to the regulating vessel.

- In addition, this only applies if the flow through such a regulated section does not change much, because if the flow decreases significantly, e.g., due to reduced cardiac output, then even generalized vasoconstriction cannot increase or maintain the pressure.

- The lumen of muscular '**arterioles'** have the greatest influence on total peripheral resistance.

- When a large amount of chemicals with a vasodilating effect are released into the blood, the lumen of the arterioles increases significantly, and accordingly the peripheral resistance and thus the blood pressure will decrease (with a relatively unchanged cardiac output).

- If the cardiac output increases more than the total resistance of the arterioles decreases, then the pressure does not decrease, but vice versa rises - see heavy physical load).

- Examples of critically serious conditions caused by a decrease in peripheral resistance due to inadequate, pathological, large dilation of the arterial bed are generalized inflammatory or allergic reactions or transfusion of incompatible blood.