Internal environment (pediatrics)

The body's **internal environment** is **body fluids**. Water is a solvent in body fluids and substances in ionized or non-ionized form are dissolved in it. The ionized form is represented by **electrolytes**, ie substances which, when dissolved in water, form positive or negatively charged particles: cations and anions. All metabolic processes take place in body fluids. Maintaining the optimal amount and composition of body fluids is a necessary condition for the activity of organs, for basic vital functions. The stability of the internal environment is called **homeostasis**.

Total body water

While most vital processes take place in ICF, ECF primarily serves as a medium for transporting the substances that are necessary for these processes. During the development of an individual, not only the total volume of fluids changes, but also the concentration of solutions in both relatively and relatively individual bodies.

Total body water distribution (TBW)

- intracellular fluid (ICF),
- extracellular fluid (ECF),
    - intravascular fluid (IVF = plasma): is bounded by endothelial cells and creates an environment for blood elements,
    - interstitial fluid (ISF) a lymph: form the largest part of the ECF, is inserted between the ICF and another part of the ECF, takes place in the exchange of water and solutes between the ICF and the ECF,
    - transcellular fluid = GIT secretions, urine, liquor, intraocular fluid, sweat in sweat glands etc.,
    - connective tissue, cartilage and bone fluid: it is actually part of the interstitial fluid, but some solutions such as glucose or larger molecules do not pass freely into this space.

It is true that the younger it is, the greater the proportion of fluid in body weight, and the greater the proportion of body fluid is extra cellular, especially as ISF. The younger the child, the smaller the volume of the adult and the organs compared to it (it contains more ICF). ECF is also exchanged 4 times more intensively in an infant over 24 hours, per unit body weight or body surface area, than in an adult. Critical conditions in children are always complicated by considerable instability of body fluids (rapid dehydration) and relatively high physiological need.

Normal blood volume per kg body weight

- newborn: 90 mL,
- 1 to 6 years: 80 mL,
- 6 to 8 years: 75 mL,
- adult: 60 až 70 mL.

Representation of major solutes

	ICF	ECF
cations	▪ potassium ▪ magnesium	▪ sodium ▪ potassium
anions	▪ phosphates ▪ proteins	▪ chlorides ▪ bicarbonate

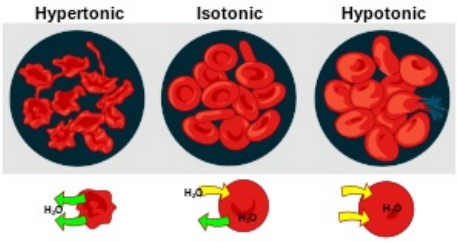
Osmolality

The osmolality of body fluids is determined by the amount of particles dissolved in them, which are able to act on the water around them or on the other hand water permeable membranes. It does not matter the particle size. The amount of particles (solutes) per unit weight (kg body weight, expressed in liters of water) is called **osmolality** and is given in mmol/kg or mOsm/kg, respectively. The difference between the amount of osmotically active (water-acting) particles on both sides of the water-permeable membranes is the **osmotic pressure**, the osmotic concentration gradient. We are able to measure and treat the osmolality of IVF. Because the main osmotically active component of ECT and blood plasma is sodium, significant variations in water management typically manifest themselves in the form of hyponatremia (Na < 130 mmol/L), hypernatremia (Na > 150 mmol/L), respectively. The organism must ensure not only isoosmolality, but also isoionia, not only in the ECT, but also in other compartments.

Effective osmolality (tonicity)

Tonicity (effective osmolarity):

From a clinical point of view, the so-called **effective osmolality** (tonicity) is more important, which is related to the number of "non-penetrating" particles in ECF (especially sodium and anions) and ICF (especially potassium and phosphate with their anions). It is these solutes that form the osmotic concentration gradient, which continues the osmotic activity and thus the distribution of water between ICF and ECF, ie it keeps water on its side of the cell membrane.



Influence of different osmotic pressure on erythrocytes

The values of tonicity and osmolality are usually identical, but there may be cases where this is not the case: so-called "penetrating" solutes, eg. urea easily passes through cell membranes, but a change in its concentration has no (or only temporary) effect on osmotic movement of water between individual body compartments. In other words, although azotemia increases the overall plasma osmolality, it does not affect its tonicity. Uncritically accepted total osmolality values at the end may lead to an incorrect follow-up patient.

On the other hand, some substances satisfy the effective osmolality and at the same time we do not affect them in the calculation according to the formula (see formula 2). These may be substances that we use therapeutically (eg. mannitol) or substances that we find in intoxication (alcohol, methanol). If no other exogenous osmotically active substances (eg mannitol) are present in the plasma, the osmolality or tonicity can be calculated according to simple formulas:

- *Formula 1:* **S-osmolality = 2x Na + glycemia + urea**
- *Formula 2:* **Effective osmolality, S-tonicity = 2x (Na + glycemia)**; 2x Na + 10

[1]

S-tonicity calculates only with "non-penetrating" solutes and represents the so-called effective osmolality from a clinical point of view. It only calculates with ions and glucose.

The osmolality of individual compartments is maintained by the organism in a narrow range and we consider the values of 280 to 295 mmol/kg to be the physiological range of S-osmolality.

Plasma hypoosmolality S-osmo < 275 mmol/kg indicates a relative excess of body water relative to body solutes. **Plasma hyperosmolality** S-osmo > 295 mmol/kg indicates a relative body water deficit relative to body solutes.

🔎 *For more information see Serum Osmolality.*

Idiogenic osmoles

When a patient's ECF osmolality suddenly changes, a water transfer occurs that immediately compensates for differences in osmotic concentration on both sides of the cell membrane. This rapid compensation will reduce the magnitude of the osmotic load in the ECF, but only at the cost of simultaneous drainage and wrinkling of the cells (in case of plasma hyperosmolality), their swelling (in case of plasma hypoosmolality), respectively. CNS cells have another compensatory mechanism to avert osmotic damage, which, however, does not show up in full parade until 6 to 12 hours of plasma hyper / hypoosmolality lasts. With a long-term increase in osmolality, osmotically active particles, so-called **idiogenic osmoles** are formed by the gradual degradation of cellular macromolecules. Their formation is accompanied by a subsequent increase in intracellular osmolality and adjustment of CNS cell volume. Thanks to this compensation, patients with chronic hypernatremia or diabetic ketoacidosis are able to tolerate extremely high levels of plasma osmolality. Conversely, with a prolonged decrease in osmolality, CNS cells are able to reduce the number of intracellular solutes and thus regain their original volume despite persistent plasma hypoosmolality. The existence of this secondary "delayed" compensation should be taken into account when correcting prolonged disorders of aqueous homeostasis.

Osmotic gap

In some clinical situations, it is useful to determine an **osmolal/osmotic gap** (OG),that expresses the difference between a directly measured osmolality osmometer and a calculated osmolality according to formula 1.

The physiological value of the osmotic gap is 4 - 12 mmol/kg.

OG is created by measuring solutes that are not included in the formula with an osmometer. If the plasma contains a significant amount of these uncounted osmotically active substances (eg methanol, ethanol, mannitol, idiogenic osmols in diabetic ketoacidosis) there will be a large difference between the measured and calculated value of osmolality. We will use OG especially in the diagnosis of poisonings. With an osmotic window value> 20 mOsm/L with the current MAC of unclear etiology, intoxication with osmotically active substances such as ethanol, methanol, ethylene glycol.

Regulation of body fluid volume

The stability of body fluid volume is monitored very anxiously. Deviations in the range of plus or minus 1% from steady state are already registered. From various compartments of body fluids, plasma volume, which is monitored by special **volume receptors (volumoreceptors)**, plays a key role in the regulation of TBW. These are high pressure baroreceptors in the arterial bed (arcus aortae and sinus caroticus) and low pressure volumoreceptors in the large veins, heart and chest. Signals from these receptors are transmitted to regulatory centers in the CNS via the n. glossopharyngeus, n. vagus and sympathetic system. Here in medulla oblongata, pons Varoli and hypothalamus stimuli are processed and, depending on the volume and osmolality of body fluids, effector mechanisms are activated, such as ADH, systems renin-angiotensin-aldosterone, kalikrein-bradykinin, renal prostaglandines, natriuretic peptides, autonomic nervous system and more. All of these mechanisms maintain the balance of volume (and osmolality) of body fluids by altering heart function, vascular lumen, sodium and water excretion. Excretion occurs mainly through the kidneys, skin, exhaled gases and digestive tract, and is affected by an increase or decrease in thirst and fluid intake.

The primary mechanism of ECF and ICF volume regulation is renal sodium excretion and increased or decreased fluid intake by the mechanism of thirst. Interestingly, changes in volume in the body are detected independently of sodium concentration: via volumoreceptors, but volume regulation is mediated mainly by regulation of sodium excretion by the kidneys.

Regulation of osmolality of body fluids

Stable osmolality of body fluids is maintained by the ability of the kidney to change osmolality of urine and by influencing water intake by the mechanism of thirst. The kidneys are able to change the osmolality of the urine in a wide range of 50 to 1400 mmol/kg and thus change the amount of excreted solutes and water as needed.

Osmolality changes are monitored by **osmoreceptors** of the osmoregulatory center in the hypothalamus, which already trigger regulatory mechanisms to adjust osmolality when the osmolality changes by 1 %. The increase in serum osmolality is mainly due to an increase in water intake by the mechanism of thirst and the secretion of ADH with the formation of concentrated urine. Opposite processes start when the osmolality decreases. The stimulus for ADH secretion is the increasing osmolality of serum and some non-osmolar factors such as hypovolemia, pain, hypoxia, RAAS. Secretion is inhibited by S-osmolality <280 mmol/kg, hypervolemia, left atrial distension. The osmolality at which we feel thirsty (thirst mechanism) is 290 mmol/kg.

Electroneutrality of body fluids

Electroneutrality of body fluids salong with osmolality are determinants of body fluid composition. The so-called **Gibbson-Donnan equilibrium**. The electroneutrality of the extracellular fluid can be expressed by the equation (*Formula 3*):

$$Na + K + Ca + Mg + H = OH + Cl + HCO3 + CO2 + albumin + phosphates$$

But just to maintain electroneutrality, the ion concentration in all ECF compartments is not the same. ISF has more chlorides than plasma, because it is high in protein. In Equation (*Formula 3*) this expresses albumin on the anion side. The negative charge of proteins also contributes to sodium retention in IVF and ISF. **Starling's law** states that intracapillary hydraulic pressure predominates on the arterial side of the capillary, while at the venous end, plasma proteins play a major role in the return of fluid from ISF to IVF by their oncotic pressure. Pathological influences, such as hypoalbuminemia or arterial hypertension, can affect water transport.

Active **enzymatic mechanisms**, such as *Na-K-ATPase*, play an important role in maintaining electroneutrality between ECF and ICF. The electric forces of non-filterable intracellular anions attract cations from the ECF, especially sodium. It is actively transported back from the cell. To maintain both electroneutrality and osmolality, it is exchanged for potassium actively transported intracellularly, where it is the major cation. Maintaining Na and K concentration gradients is a very energy-intensive process and the factors that influence it can cause serious disorders in the composition of ECF and ICF.

Too rapid adjustment of hyperosmolality can lead to CNS cell edema => intracranial hypertension, rapid adjustment of hypoosmolality carries the risk of "wrinkling" CNS cells => central pontine myelinolysis.

Electrolyte homeostasis in newborns

Water and electrolyte homeostasis of newborns born in term or premature babies differ in many ways from other age groups of children. The water balance of newborns is characterized by very rapid changes in the distribution of water from ECF, but also ICF, and this is mainly done by the kidneys. Water loss is accompanied by sodium loss, with premature babies losing more sodium than term newborns. This can be well documented when investigating the sodium excretion fraction (FE Na), which is usually> 5%. It usually decreases during the first month of life, in premature infants this interval is longer. It is a consequence of the tubular immaturity of the kidneys. Both newborns and premature infants are in a negative sodium balance shortly after birth, which sometimes requires supplementation. Achieving a positive sodium balance is important for further sound growth and development. It is not uncommon for premature breast-fed infants, to develop late hyponatremia at 4 to 6 weeks of age. This is not the result of excessive losses, but is the result of increased sodium incorporation into tissues as growth accelerates.

The most common causes of hyponatremia in neonates/premature infants

- excessive parenteral delivery of glucose solutions,
- diarrhea,
- severe sepsis (sodium pump dysfunction),
- heart failure,
- drugs (diuretics, indomethacin).

The most common causes of hypernatremia in neonates/premature infants

- phototherapy
- congenital skin defects
- front abdominal occlusion defects (increased insensible losses)
- resuscitation with excessive bicarbonate delivery

Recommendations on the issue of the internal environment

When monitoring changes in homeostasis and their possible correction, we must keep in mind some **general attitudes**.

- The **patient's clinical condition** is crucial. The goal is not "normál" serum osmolality, but a good condition of the patient: proper gas exchange, adequate efficient circulating blood volume ECKO, good state of consciousness and diuresis, good peripheral blood circulation. If there is a discrepancy between the clinical findings and the results of laboratory tests, then we repeat the tests and evaluate the results using as much information as possible. The mere fact that the serum potassium concentration is 4.8 mmol/L does not mean anything. To interpret this result, we need to know at least what the pH value, serum Na and Cl concentrations, hydration status of the patient, kidney function, EKG curve and muscle strength.
- **Each parameter** has a very limited meaning. What is important is the trend of changes in homeostasis, monitoring changes in many parameters over time. The balance, monitoring of waste Na, K, Cl, urea and water, etc. is used for this. The stability of the indoor environment is a dynamic process.
- hanges in homeostasis usually occur **slowly**, within 48 hours or longer. The body registers, compensates for and adapts to the changes. Trying to correct the deviation from the homeostasis reference range quickly, within minutes, is usually dangerous for the patient. We only correct changes in homeostasis that threaten the patient's vital functions.
- **Quick** fix in seconds to minutes requires :
    - hypoxia,
    - hypotension,
    - hypoglycemia,
    - convulsions.

All other changes in homeostasis give us the opportunity to comprehensively examine and monitor the patient clinically and with the help of laboratory tests. They will need to carefully consider possible homeostasis disorders so as not to disrupt the body's adaptive and compensatory changes.

Links

Related articles

- Serum osmolality
- Diabetic ketoacidosis

References

1. ŠAŠINKA, M. *Pediatria, zv. I a II.* 1. edition. Košice : Satus, 1998. ISBN 80-967963-0-5.

Source

- HAVRÁNEK, Jiří: *Vnitřní prostředí*. (edited)