

MINISTRY OF HEALTH OF UKRAINE

Zaporizhzhia State Medical University

Pathophysiology Department

**DISORDERS OF ACID-BASE BALANCE
AND WATER-ELECTROLYTE
METABOLISM**

Part 1. General Pathophysiology

Section 3. Typical Disorders of Metabolism

*Manual for independent work for the students of the 3rd course of international
faculty specialty “General medicine” English medium of instruction*

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Introduction

Constancy of internal environment pH is the necessary condition of higher organisms' life. Metabolic reactions in body cells result in diversity of byproducts among which hydrogen ions are of special meaning. Even slight changes in hydrogen ion concentration from the normal indices can cause marked alterations in the rates of chemical reactions in the cells, some being depressed and others accelerated. For this reason the regulation of hydrogen ion concentration is one of the most important aspects of homeostasis. H^+ concentration determines activity of biologically active substances and enzymes, influences neural and muscular excitability, blood vessels tonus, hydrochloric acid secretion in the stomach etc.

Normal pH level in the human organism is maintained with certain correlation of acids and bases, therefore if we speak about regulation of hydrogen ion concentration in the body fluids we mean the regulation of acid-base balance.

Acid-base imbalance may be observed in the course of different diseases and complicate them. Knowledge of ABB disorders pathogenesis and their compensation mechanisms is important for understanding the ways of prophylaxis and pathogenetic treatment of acidosis and alkalosis.

The changes in water and electrolytes metabolism in the organism and their redistribution between the separate sectors of water can alter such parameters as constancy of volume, osmotic pressure and ion content in blood, extracellular and intracellular fluid. It can cause disorders of blood circulation, decrease of heart function, edema, contribute to acid-base imbalance etc.

A lot of diseases and the pathological states are accompanied with the changes of water-electrolyte metabolism which complicates their course. Knowledge of edema pathogenesis is of special importance because this alteration of water metabolism is observed in the course of different diseases and can cause serious violations of vitally important organs function.

THE AIM AND LEARNING OBJECTIVES OF PRACTICAL CLASS

1. General aim: to study pathogenesis and mechanisms of compensation of acid-base balance (ABB) and water-electrolyte metabolism disorders in different diseases.

2. Learning objectives (basic educational and training issues for extracurricular self-study):

1) Students should know:

a) the mechanisms of ABB maintenance: buffer systems of blood and other fluids, physiological mechanisms of ABB regulation by lung, kidney, liver, GIT;

b) main indices of acid-base balance and methods of ABB assessment in clinical practice;

c) types of acidosis, their etiology, pathogenesis, mechanisms of compensation and clinical manifestation;

d) types of alkalosis, their etiology, pathogenesis, mechanisms of compensation and clinical manifestation;

e) neural and endocrine mechanisms of water electrolyte balance maintenance;

f) hypohydration types, their etiology, pathogenesis and clinical manifestation;

g) hyperhydration types, their etiology, pathogenesis and clinical manifestation ;

h) mechanisms of edema pathogenesis in different diseases;

2) Students should be able to:

a) differentiate compensatory/adaptive reaction and pathogenic events in the pathogenesis of ABB disorders;

b) define type of ABB disorder its etiology and pathogenesis using laboratory and instrumental data of patient examination;

c) define the factors which play the leading role in the pathogenesis of hypohydration and hyperhydration;

d) explain the mechanisms of edema development in inflammation, starvation and diseases of heart and kidney;

e) explain the mechanisms of the alteration in electrolyte (Na, K, Ca) content and their consequences;

f) to solve situational problems on the basis of pathophysiological analysis of clinical and model situations related to the disorders of ABB and water-electrolyte metabolism.

QUESTIONS TO STUDY:

- 1. Mechanisms of ABB maintenance (buffer systems and physiological processes).**
- 2. Main indices of acid-base balance. Classification of ABB disorders.**
- 3. Respiratory acidosis: etiology, pathogenesis, clinical manifestation, mechanism of compensation.**
- 4. Metabolic acidosis: etiology, pathogenesis, clinical manifestation, mechanism of compensation.**
- 5. Respiratory and metabolic alkalosis: etiology, pathogenesis, clinical manifestation, mechanism of compensation.**
- 6. Neural and endocrine mechanisms of water electrolyte balance maintenance.**
- 7. Hypohydration: types, etiology, pathogenesis, clinical manifestation.**
- 8. Hyperhydration: types, etiology, pathogenesis, clinical manifestation.**
- 9. Edema etiology and pathogenesis in inflammation, starvation, diseases of heart and kidney.**
- 10. Alterations in Na blood plasma content: etiology and consequences.**
- 11. Alterations in K blood plasma content: etiology and consequences.**
- 12. Alterations in Ca blood plasma content: etiology and consequences.**

THEORETICAL MATERIAL

1. Mechanisms of ABB maintenance

Acid-base balance (ABB) acid-base balance is a state of equilibrium between acidity and alkalinity of the body fluids. In order to maintain a state of equilibrium chemical exchanges of H^+ must take place continuously. An optimal pH (H^+ concentration) between 7.35 and 7.45 must be maintained; otherwise, the enzyme systems and other biochemical and metabolic activities will not function normally. The shift of blood pH for 0,1 causes expressed disturbances of respiratory, cardiovascular and other systems of the organism. The shift of pH for 0,3 causes the development of coma, and the shift for 0,4 is not compatible with life.

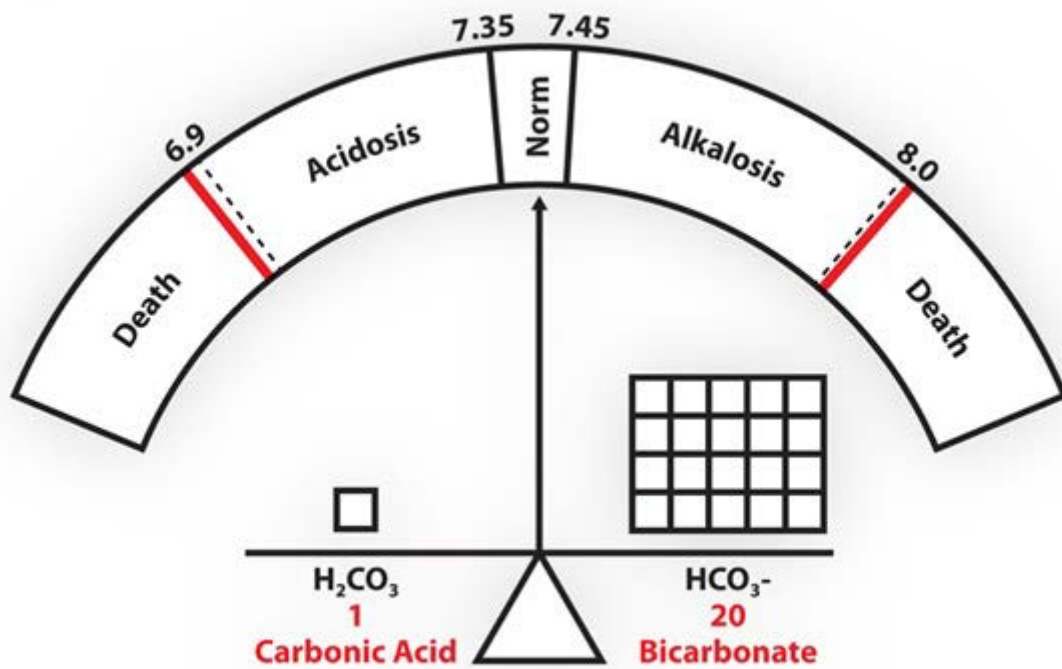


Figure 1. Range of blood pH indices

ABB is regulated by the buffer systems of blood and physiological processes in lungs, kidneys, liver, and GIT.

Buffer systems of blood (chemical mechanisms of regulation).

Chemical buffers (intracellular and extracellular) are solutions that neutralize changes in pH and provide an immediate response to acid-base disturbances. Bone also plays an important buffering role, especially of acid loads.

A buffer consists of a weak acid and the base salt of that acid or of a weak base and its acid salt. The base salt can accept H^+ and the weak acid can donate it, thereby minimizing changes in free H^+ concentration. A buffer system works best to minimize changes in pH near its equilibrium constant (pKa); so, although there are potentially many buffer pairs in the body, only some are physiologically relevant.

The relationship between the pH of a buffer system and the concentration of its components is described by the Henderson-Hasselbalch equation:

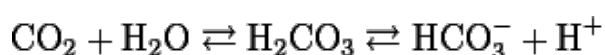
$$pH = pKa + \log\left(\frac{[anion]}{[weak\ acid]}\right)$$

where pKa is the dissociation constant of the weak acid

Body Buffer Systems		
Site	Buffer System	Comment
Interstitial fluid	Bicarbonate	For metabolic acids
	Phosphate	Not important (too low concentration)
	Protein	Not important (too low concentration)
Blood	Bicarbonate	Important for metabolic acids
	Haemoglobin	Important for carbon dioxide
	Plasma protein	Minor buffer
	Phosphate	Concentration too low
Intracellular fluid	Proteins	Important buffer
	Phosphates	Important buffer
Urine	Phosphate	Responsible for most of acidity
	Ammonia	Important - formation of NH_4^+
Bone	Ca carbonate	Important in prolonged metabolic acidosis

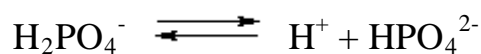
Table 1. Body Buffer Systems

Bicarbonate buffer system is very important in plasma of blood. It consists of H_2CO_3 and its salts – Na_2CO_3 in blood plasma and Mg-, K salts in the cells. All these salts are presented in the form of bicarbonate ion.



The mechanism of this buffer system is that after relatively big quantities of acids enter blood, hydrogen ions H^+ of acids combine with ions of bicarbonate HCO_3^- , forming low-dissociating carbonic acid H_2CO_3 . If the amount of bases increases in blood, they interact with weak carbonic acid and form water and bicarbonate ions. Thus, both excesses of H^+ and OH^- are neutralized by this buffer. Buffer capacity of bicarbonates is 7-9% of general buffer capacity of blood. This system is not very powerful but it is very important in ABB maintenance because it is very mobile – concentration of each of the two elements of the bicarbonate system can be regulated: carbon dioxide by the respiratory system and bicarbonate ion by the kidneys.

The phosphate buffer system acts in almost identically the same manner as the bicarbonate buffer system, but it is composed of the following two elements: NaH_2PO_4 and Na_2HPO_4 in the form of ions:



If additional hydrogen ions enter the cellular fluid, they are consumed in the reaction with HPO_4^{2-} , and the equilibrium shifts to the left. If additional hydroxide ions enter the cellular fluid, they react with $H_2PO_4^-$ producing HPO_4^{2-} , and shifting the equilibrium to the right.

However, despite the fact that this buffer system operates in a reasonably good portion of the buffer curve, its concentration in the extracellular fluid is only one-twelfth that of the bicarbonate buffer. Therefore, its total buffering power in the extracellular fluid is even far less than that of the bicarbonate system. This buffer works mainly in intra-cellular medium and in regulation of active urine reaction.

Proteins, especially hemoglobin, are the most powerful buffer system in blood. Proteins are the largest buffer pool in the body and are excellent buffers. Proteins can function as both acids and bases, so they are amphoteric. They contain many ionizable groups, which can release or bind H^+ ions. Serum albumin and plasma globulins are the major extracellular protein buffers, present mainly in the blood plasma. Hemoglobin possesses buffer qualities because of its capability to be

in 2 forms – reduced and oxygenized. Oxy-hemoglobin is 70 times stronger acid and increases the entrance of H^+ into blood. Reduced hemoglobin becomes a weaker acid and its capability to combine H^+ increases.

Entering erythrocytes, the product of tissue metabolism – carbon dioxide – form H_2CO_3 under the effect of carboanhydrase. Rising on account of dissociation of H_2CO_3 , the excess of hydrogen ions combines with reduced hemoglobin that gave away oxygen, and anions HCO_3^- come out of erythrocytes into plasma. Cl^- ions enter erythrocytes in exchange to HCO_3^- ions.

Plasma Potassium–Hydrogen Exchange. Potassium ions (K^+) and H^+ ions interact in important ways in the regulation of ABB. Both ions are positively charged, and both ions move freely between the intracellular and extracellular compartments. In situations of acidosis, excess H^+ ions move into the intracellular compartment for buffering. When this happens, another cation, in this case the K^+ ion, must leave the cell and move into the extracellular fluid. When extracellular potassium levels fall, K^+ ions move out of the cell and are replaced by H^+ ions. Thus, alterations in extracellular potassium levels can affect ABB, and its changes can influence extracellular potassium levels. Potassium shifts tend to be more pronounced in metabolic acidosis than respiratory acidosis. Also, metabolic acidosis caused by an accumulation of nonorganic acids (e.g., HCl that occurs in diarrhea, phosphoric acid that occurs in renal failure) produces a greater increase in extra cellular potassium than does acidosis caused by an accumulation of organic acids (e.g., lactic acid, ketoacids).

Physiological mechanisms of ABB regulation

Respiratory system.

Respiratory regulation refers to changes in pH due to pCO_2 changes from alterations in ventilation. This change in ventilation can occur rapidly with significant effects on pH. Carbon dioxide is lipid soluble and crosses cell membranes rapidly, so changes in pCO_2 result in rapid changes in $[H^+]$ in all body fluid compartments.

By changing the $p\text{CO}_2$ and, hence, carbonic acid (H_2CO_3) of the blood, the respiratory system can rapidly and profoundly affect blood pH. A fall in blood pH – high H^+ concentration and high arterial blood $p\text{CO}_2$ is a powerful stimulus to increase ventilation; it acts on both peripheral and central chemoreceptors which respond to arterial $p\text{CO}_2$ as well as to some other factors. When ventilation is stimulated, the lungs blow off more CO_2 , making the blood less acidic. Oppositely, a rise in blood pH inhibits ventilation, it causes rise in CO_2 , accumulation of carbonic acid and then pH decreases.

Kidneys actively participate in ABB regulation. There are 4 main mechanisms described:

Acidogenesis: in renal tubules hydrogen ions are secreted into primary urine in the quantity equivalent to its plasma amount. In return of H^+ ions secretion, reabsorption of Na^+ together with HCO_3^- from the primary urine occurs. This provides the formation and returning to blood of Sodium bicarbonate which took part in neutralization of acids in blood before that. As a result, acids are excreted with urine. This causes souring of urine and switches on another renal mechanism of ABB support – ammoniogenesis.

Ammoniogenesis: greater than normal quantity of ammonia begins to be produced from amino-acids in channel epithelium. It combines with hydrogen ions (secreted in the process of acidogenesis) in the lumen of channels. Ions of NH_4^+ are formed in this process. They replace Na^+ ions in salts of corresponding acids with the formation of ammonium salts, which are excreted with urine.

Berliner's exchange: consists in exchange of Na^+ of primary urine to K^+ , secreted into it. Na is reabsorbed providing support of Sodium bicarbonate concentration in blood. K salts are excreted with urine.

Excretion of phosphates in the distal part of the channels is one more mechanism of participation of kidneys in ABB support.

The liver role in ABB maintenance is important because it is a metabolically active organ which may be either a significant producer or consumer of hydrogen ions. The amounts of acid involved may be very large. Liver can

produce carbon dioxide as a result of substrates complete oxidation. Metabolism of lactic acid includes H^+ consumption. Hepatic production of ketoacids produces H^+ and the oxidation of the keto-anion in the tissues consumes H^+ and thereby regenerates the HCO_3^- which had buffered it in the blood stream. The conversion of NH_4^+ to urea in the liver results in an equivalent production of H^+ . Nearly all plasma proteins are produced by the liver which are essentially needed for ABB maintenance.

Blood pH to some extent depends on the **GIT** secretion (production of HCl and alkaline intestinal juice).

2. Main indices of acid-base balance. Classification of ABB disorders.

pH – an index expressing the acidity or alkalinity of a solution on a logarithmic scale on which 7 is neutral, lower values are more acid and higher values more alkaline. The pH is equal to $-\log_{10} c$, where c is the hydrogen ion concentration in moles per litre. **Normal value for pH is 7,35-7,45.**

Standard bicarbonate (SB) is the plasma bicarbonate concentration of a sample of whole blood that has been equilibrated at $37^\circ C$ with a carbon dioxide pressure of 40 mm Hg and an oxygen pressure that exceeds 100 mm Hg; abnormally high or low values indicate metabolic alkalosis or acidosis, respectively. **Normal value for HCO_3^- (SB) is 21-25 mmol/L.**

Buffer base (BB) refers to the total concentration of all carbonic buffer anions plus the non-carbonic anions. **Normal value for BB 45-52 mmol/l**

The Base Excess (BE) of the extracellular fluid is calculated as the concentration difference of buffer bases in the actual sample and in the same sample following titration with strong acid or base and equilibration to standard conditions (pH 7.4, $PaCO_2$ 5.3 kPa or 40 mmHg). The difference is given in mmol of strong acid or base, which must be added to 1 l of the sample. The base excess remains normal (zero) in acute respiratory acid-base disorders. **Normal value for BE is (-2,3) - (+2,3) mmol/L.**

pCO₂ -partial pressure of carbon dioxide in the arterial blood sample.

Normal value for pCO₂ is 35-45 mmHg.

pO₂ -partial pressure of oxygen in the arterial blood sample. **Normal value for pCO₂ is 74-105 mmHg.**

There are 2 forms of ABB disturbances: **acidosis** (the excess of acids in blood) and **alkalosis** (the excess of alkali). Generally acidosis is said to occur when arterial pH falls below 7.35, while its counterpart (alkalosis) occurs at a pH over 7.45.

There are 2 types of acidosis and alkalosis: **respiratory** and **metabolic**. Sometime excretory forms of non-gas acidosis or alkalosis occur (in vomiting, diarrhea).

Uncompensated Acid-Base Disturbances	pH	pCO ₂ (mmHg)	HCO ₃ ⁻ (mEq/L)	Common Cause
None (normal values)	7.35-7.45	35-45	22-26	
Respiratory acidosis	↓	↑	Normal	Respiratory depression (drugs, CNS trauma), COPD, pneumonia
Respiratory alkalosis	↑	↓	Normal	Hyperventilation (emotions, pain)
Metabolic acidosis	↓	Normal	↓	Diabetes, shock, renal failure
Metabolic alkalosis	↑	Normal	↑	Sodium bicarbonate overdose, prolonged vomiting, NG drainage

Figure 2. Common causes of ABB disorders

According to the origin of ABB disturbances they are divided into **exogenous** (as a result of excessive or insufficient inflow of acidic or alkaline products into the organism) and **endogenous** (as a result of excessive formation of acidic products in the organism or disturbance of their excretion).

According to the degree of compensation ABB disturbances they are divided into **compensated** and **uncompensated**.

3. Respiratory acidosis: etiology, pathogenesis, clinical manifestation, mechanism of compensation.

Respiratory acidosis develops in the case of carbon dioxide (CO₂) accumulation (hypercapnia) due to a decrease in respiratory rate and/or respiratory volume (hypoventilation).

The arterial pCO₂ is normally maintained at a level of about 40 mmHg by a balance between production of CO₂ by the body and its removal by alveolar ventilation. Therefore, an increase in arterial pCO₂ can theoretically occur in the one the following possible situations:

- when excess CO₂ is present in the inhaled air hypercapnia can be induced even in the presence of normal alveolar ventilation;

- increased production of CO₂ (more than 200ml per minute) by the body.

But the system controlling arterial pCO₂ is very efficient (rapid and effective) and any increase in pCO₂ fastly results in a ventilation increase. Nevertheless, in the patient who is under artificial ventilation this response can't be developed and in the case of acute malignant hyperthermia: the arterial pCO₂ will rise. But most cases of respiratory acidosis occur due to decreased alveolar ventilation.

Inadequate alveolar ventilation may result from conditions that impair CNS respiratory stimuli:

- Drug depression of respiratory center (opiates, sedatives, anaesthetics);
- CNS trauma, infarct, hemorrhage or tumor;
- Hypoventilation of obesity (eg Pickwickian syndrome);
- Cervical cord trauma or lesions (at or above C4 level);
- Infections: poliomyelitis, tetanus;
- Cardiac arrest with accompanying cerebral hypoxia.

Low rate of alveolar ventilation may complicate nervous or muscular disorders:

- Guillain-Barre syndrome;
- Myasthenia gravis;

- Muscle relaxant drugs;
- Toxins: organic phosphates, snake venom;
- Various myopathies.

The defects in the chest wall or in the lung itself may seriously impair ventilation:

- Chronic obstructive pulmonary diseases;
- Chest trauma, contusion, haemothorax, pneumothorax;
- Diaphragmatic paralysis or splinting;
- Pulmonary edema;
- Acute respiratory distress syndrome in newborns and adults;
- Restrictive lung disease (pneumofibrosis, silicosis).

Impassability of upper or lower respiratory airways and external factors influence will also lead to respiratory acidosis

- Aspiration of foreign body or fluid;
- Upper airway obstruction;
- Laryngospasm;
- Bronchospasm which occurs in bronchial asthma;
- Inadequate mechanical ventilation to due chest squeezing (accidents).

Clinical manifestation depends on the rate and degree of pCO₂ increase. Symptoms and signs are a result of high CO₂ concentrations and low pH in the CNS and any accompanying hypoxemia. As CO₂ rapidly and easily crosses lipid barriers, a respiratory acidosis has rapid and generally depressing effects on intracellular metabolism. Carbon dioxide has a direct vasodilating effect on many blood vessels and a sedative effect on the nervous system. Raised levels of pCO₂ greatly increase cerebral blood flow, causing headache, increased cerebral spinal fluid pressure, and sometimes papilledema. There is a headache due to dilation of the cerebral vessels; the conjunctivae are hyperemic; and the skin is warm and flushed. Hypercapnia has nervous system effects similar to those of an anesthetic

(hence the term carbon dioxide narcosis). There is progressive somnolence, disorientation, and, if the condition is untreated, coma.

Effects of hypercapnia include:

- Stimulation of ventilation via both central and peripheral chemoreceptors
- Cerebral vasodilation increasing cerebral blood flow and intracranial pressure
- Stimulation of the sympathetic nervous system resulting in tachycardia, peripheral vasoconstriction and sweating
- Peripheral vasodilation by direct effect on vessels
- Central depression at very high levels of pCO₂/

Carbon dioxide also rapidly diffuses across the blood-brain barrier and affects CNS causing increased cerebral blood flow, increased intracranial pressure, and potent stimulation of ventilation. This can result in dyspnoea, disorientation, acute confusion, headache, mental obtundation or even focal neurologic signs. Patients with marked elevations of arterial pCO₂ may become comatose

Respiratory acidosis can manifest in the acute and chronic form. Typically, the patient is warm, flushed, sweaty, tachycardic and has a bounding pulse. The clinical picture may be modified by effects of hypoxaemia, other illnesses and the patient's medication. Acute (or acutely worsening chronic) respiratory acidosis causes headache, confusion, anxiety, drowsiness, and stupor (CO₂ narcosis). Slowly developing, stable respiratory acidosis (in chronic obstructive pulmonary disorders) may be well tolerated, but patients may have memory loss, sleep disturbances, excessive daytime sleepiness, and personality changes. Signs include gait disturbance, tremor, blunted deep tendon reflexes, myoclonic jerks, asterixis, and papilledema.

Acute compensatory mechanisms are carried out by the increased rate of respiration (if it is possible) and chemical buffering. Buffering mostly takes place intracellularly (phosphate buffer) and takes place over minutes to hours. Cellular buffering elevates plasma bicarbonate values, but only slightly. Other buffer

compensatory mechanisms are carried out with participation of hemoglobin and protein buffer binding CO₂ (5-10 minutes).

Long-term compensation is renal compensation that occurs over 3-5 days. With renal compensation, renal mechanisms of hydrogen ions secretion is increased, and bicarbonate reabsorption is increased. Increased arterial pCO₂ increases intracellular pCO₂ in proximal tubular cells that causes increased H⁺ secretion from the proximal convoluted tubule cells into the tubular lumen.

4. Metabolic acidosis: etiology, pathogenesis, clinical manifestation, mechanism of compensation.

Metabolic acidosis is a pH imbalance in which the body has accumulated too much acid and does not have enough bicarbonate to effectively neutralize the effects of the acid. At this state pH is usually lower than 7,35 and HCO₃ level less than 22 meq/L. It may result from:

- Increased acid production or acid ingestion;
- Decreased acid excretion;
- GI or renal HCO₃⁻ loss.

Causes include accumulation of ketones and lactic acid, renal failure, and drug or toxin ingestion (high anion gap) and GI or renal HCO₃⁻ loss (normal anion gap). The anion gap is the difference between primary measured cations (sodium Na⁺ and potassium K⁺) and the primary measured anions (chloride Cl⁻ and bicarbonate HCO₃⁻) in serum. The calculation of the anion gap can be helpful to define the types of metabolic acidosis.

Metabolic Acidosis with High Anion-Gap	
Ketoacidosis	
<ul style="list-style-type: none"> • Diabetic ketoacidosis • Alcoholic ketoacidosis • Starvation ketoacidosis 	
Lactic Acidosis	
<ul style="list-style-type: none"> • Type A Lactic acidosis (Impaired perfusion) • Type B Lactic acidosis (Impaired carbohydrate metabolism) 	
Renal Disorders	

<ul style="list-style-type: none"> • Uraemic acidosis • Acidosis with acute renal failure
<i>Metabolic Acidosis with Normal Anion-Gap (Hyperchloraemic acidosis)</i>
Renal Disorders
<ul style="list-style-type: none"> • Renal tubular acidosis • Carbonic anhydrase inhibitors
GIT Disorders
<ul style="list-style-type: none"> • Severe diarrhea • Drainage of pancreatic or biliary secretions • Small bowel fistula

Table 2. Metabolic acidosis classification by anion gap

There are various causes of metabolic acidosis.

- failure of the kidneys to excrete the metabolic acids normally formed in the body with the subsequent uremia development
- loss of bases (sodium bicarbonate) from GIT – excretory form of non-gas acidosis. The main reason of it is diarrhea which is one of the most frequent causes of metabolic acidosis. In young children severe diarrhea may be the reason of the death; due to dehydration and acidic shift of blood pH.
- in some cases vomiting of contents not from the stomach but from deeper parts of GIT, which often occurs in much more quantity than loss of the stomach contents, will cause loss of alkali and result in metabolic acidosis.

Exogenous acidosis arises after:

- long excessive consumption of sour food;
- exogenous injection of acids into organism (poisoning with acetic acid, long or uncontrolled usage of salicylates, ammonium chloride, HCl).

Frequently, the reason of metabolic acidosis is formation of excessive quantities of metabolic acids in the body:

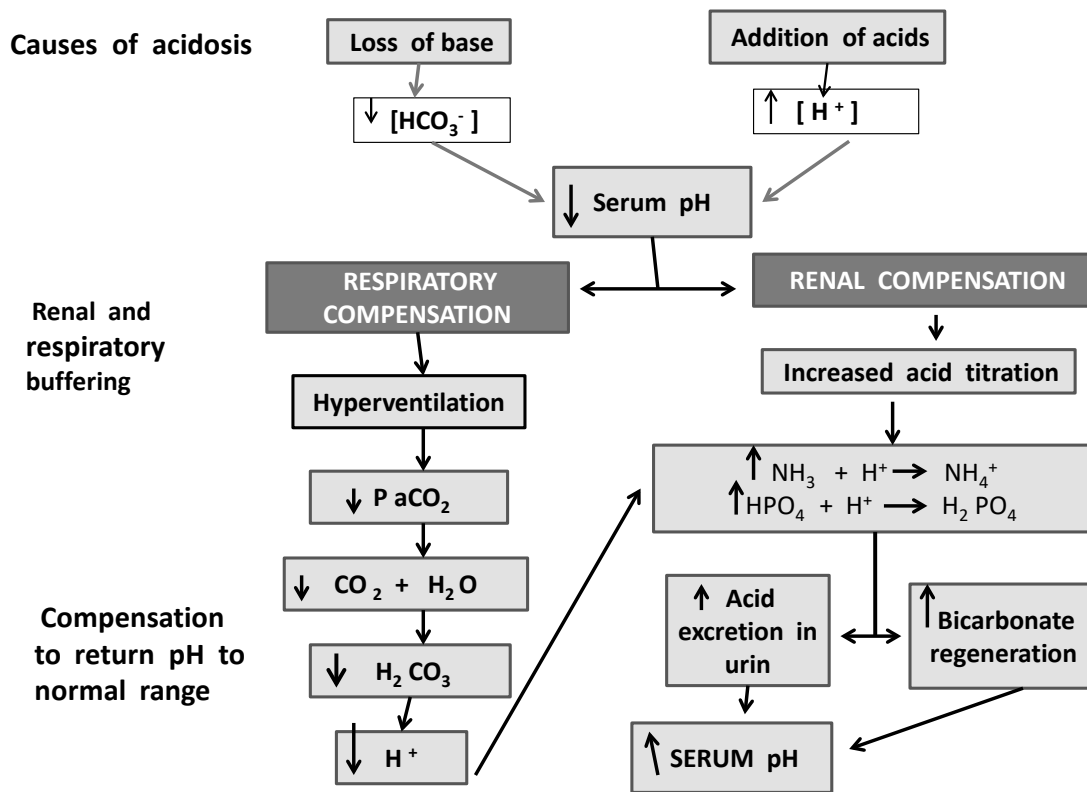


Figure 3. Common mechanisms of metabolic acidosis

Ketoacidosis – occur in diabetes mellitus. In this condition, fat is transformed into acetoacetic acid, and this in turn is metabolized by the tissues for energy instead of glucose. Side products of these reactions – ketone bodies are accumulated in blood.

Lactate-acidosis occurs during incomplete oxidation of carbohydrates and accumulation of lactic acid. It develops during intensive physical work, hypoxia, cardiogenic shock, severe hepatic diseases (cirrhosis, toxic dystrophy), infectious diseases with durable fever conditions

Hyperchloremic metabolic acidosis is a pathological state that results from bicarbonate loss, rather than acid production or retention. Bicarbonate loss leading to hyperchloremic metabolic acidosis occurs in a variety of ways: gastrointestinal (GI) causes, renal causes, and exogenous causes. GI loss of bicarbonate occurs through severe diarrhea, pancreatic fistula, nasojejun tube suctioning from the duodenum, and chronic laxative use. Renal sources of hyperchloremic acidosis include proximal renal tubular acidosis, distal renal tubular acidosis, and long-term

use of carbonic anhydrase inhibitors. Exogenous causes include ingestion of acids such as ammonium chloride and hydrochloric acid and volume resuscitation with 0.9% normal saline.

Compensation of metabolic acidosis

It was pointed out earlier that the high H^+ hydrogen ion concentration of metabolic acidosis causes increased pulmonary ventilation, which in turn results in rapid removal of carbon dioxide from the body fluids and reduces the H^+ concentration back toward normal.

Another way of compensation includes blood buffer systems, especially protein and hemoglobin buffer. Excess of H^+ is accumulated by the erythrocytes by the exchange of these ions with sodium and calcium ions. From the one hand, above mentioned changes are compensatory, because they accumulate excess of H^+ . From the other hand they lead to increased Na, K and Ca level in the blood.

Kidneys also take part in the compensation of metabolic acidosis. Process of acidogenesis and reabsorption of bases are increased. Urine pH is decreased.

Clinical manifestation of acidosis:

The major clinical effect of acidosis is depression of the CNS from simple disorientation to coma in uncontrolled acidosis.

High concentration of H^+ leads to decreased blood vessels tone in brain and heart circulation and later results in circulatory hypoxia.

The changes in respiration depend on the type of acidosis: in metabolic acidosis the high H^+ concentration causes increased rate and depth of respiration. Specific type of respiration – noisy Kussmaul respiration with deep inhalation and exhalation phase occurs. This hyperventilation was first described by Kussmaul in patients with diabetic ketoacidosis in 1874.

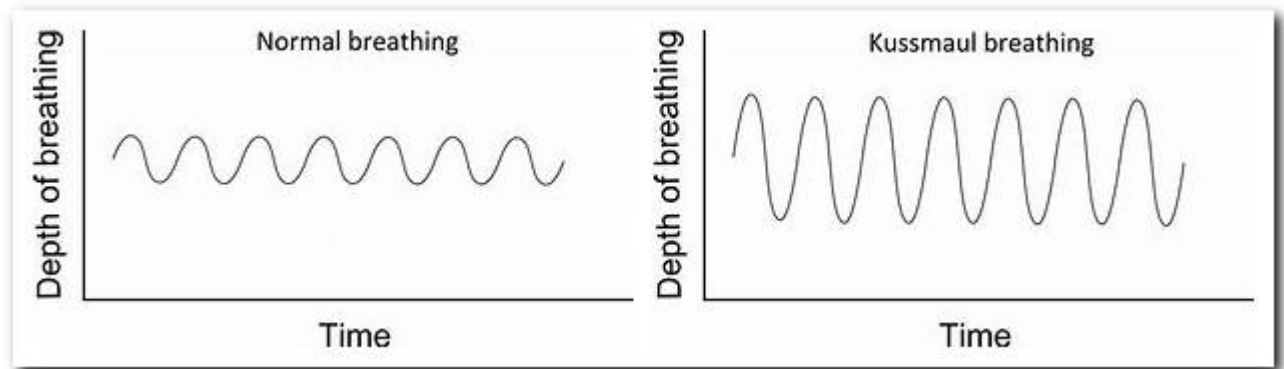


Figure 4. Kussmaul pattern of breathing

On the other hand, in respiratory acidosis, respiration is usually depressed because this is the cause of the acidosis

Cardiovascular effects of acidosis include the following:

- Depression of myocardial contractility;
- Sympathetic overactivity (including tachycardia, vasoconstriction, decreased arrhythmia threshold);
- Resistance to the effects of catecholamines;
- Peripheral arteriolar vasodilatation;
- Venoconstriction of peripheral veins;
- Vasoconstriction of pulmonary arteries;
- Effects of hyperkalaemia on heart (cardiac arrhythmias).

A disturbance of heart activity is explained by the following facts. The cardiac stimulatory effects of sympathetic activity and release of catecholamines usually counteract the direct myocardial depression. At systemic pH values less than this, the direct depression of contractility usually predominates.

The direct vasodilatation is offset by the indirect sympathetically mediated vasoconstriction and cardiac stimulation during a mild acidosis. The venoconstriction shifts blood centrally and this causes pulmonary congestion. Pulmonary artery pressure usually rises during acidosis.

Hydrogen ions are also neutralized by the intracellular buffer systems. Excess of H^+ causes inflow of it into the cells. This results in loss of potassium,

calcium and partly sodium from the cells. Blood level of potassium is increased; it impairs the work of heart and causes arrhythmia development.

Loss of Ca from the cells may result in decalcification of bones, which can manifest as osteoporosis in the patients with chronic renal failure.

5. Respiratory and metabolic alkalosis: etiology, pathogenesis, clinical manifestation, mechanism of compensation.

Respiratory alkalosis can occur in rare conditions which are accompanied by hyperventilation:

1. Central Causes (direct action via respiratory centre)
 - Head Injury
 - Stroke
 - Anxiety-hyperventilation syndrome (psychogenic)
 - Other 'supra-tentorial' causes (pain, fear, stress, voluntary)
 - Various drugs (eg analeptics, propanidid, salicylate intoxication)
 - Various endogenous compounds (eg progesterone during pregnancy, cytokines during sepsis, toxins in patients with chronic liver disease)
2. Hypoxaemia (act via peripheral chemoreceptors)
 - Respiratory stimulation via peripheral chemoreceptors
3. Pulmonary Causes (act via intrapulmonary receptors)
 - Pulmonary Embolism
 - Pneumonia
 - Pneumosclerosis
 - Asthma
 - Pulmonary edema (all types)
4. Iatrogenic (act directly on ventilation)
 - Excessive incorrect artificial respiration

Physiological type of respiratory alkalosis occurs when a person ascends to a high altitude. The low oxygen content of the air stimulates respiration, which

causes excess loss of carbon dioxide and development of mild respiratory alkalosis.

Compensation of respiratory alkalosis:

- low level of CO₂ decreases respiration rate
- excess of bases is excreted by the kidneys in the process of ammoniogenesis.
- the buffering is predominantly by protein and occurs intracellularly; this alters the equilibrium position of the bicarbonate system.

The most common causes of metabolic alkalosis are:

Administering Diuretics (except the carbonic anhydrase inhibitors). All diuretics cause increased flow of fluid along the tubules, and this increase usually causes a great excess of Na⁺ flowing in the tubules. These sodium ions should be rapidly reabsorbed by the kidneys. This rapid reabsorption is coupled with enhanced hydrogen ion secretion because of the Na⁺-H⁺ countertransport mechanism in the tubular cells. It results in excessive loss of hydrogen ions from the body and alkalosis development.

The second most common cause of alkalosis is excessive ingestion of alkaline drugs, such as sodium bicarbonate, for the treatment of gastritis or peptic ulcer.

Loss of Chloride ions. Excessive vomiting of gastric contents without vomiting of lower gastrointestinal contents causes excessive loss of hydrochloric acid secreted by the stomach mucosa. This type of alkalosis occurs in newborn children who have pyloric obstruction caused by a greatly hypertrophied pyloric sphincter muscle.

Excess aldosterone. The aldosterone promotes extensive reabsorption of Na⁺ ions from the distal segments of the tubular system, but coupled with this secretion of H⁺ ions increases (as explained earlier), which promotes alkalosis.

Clinical manifestation of alkalosis

Nervous system of the patient is overexcited. The symptoms may manifest themselves as extreme nervousness or, in susceptible persons, as convulsions. If

the person is prone to epileptic seizures hyperventilation may provoke it. Other influences on the nervous system include:

- increased neuromuscular irritability (paraesthesias, tingling, numbness; carpopedal spasm);
- decreased intracranial pressure (secondary to cerebral vasoconstriction);
- inhibition of respiratory drive via the central & peripheral chemoreceptors.

During gaseous alkalosis the intensified excretion of H_2CO_3 carbonic acid occurs, hypocapnia and pH shift to alkaline side are developed. The decrease of pCO_2 causes the drop of vascular tonus in all vessels. As a result, BP and cardiac output decreases, brain and coronary blood supply decreases too. In kidneys it manifests as decrease of urine formation. Alkalosis is also characterized with cardiac arrhythmias and decreased myocardial contractility.

In the state of alkalosis ionized Ca is bounded to proteins; its concentration in blood plasma is decreased. It results in convulsions and muscles tetany.

The level of potassium is also decreased because reabsorption of H^+ occurs in kidney and K^+ is secreted. The deficiency of potassium is manifested with the weakness of all the muscles of the body. In the heart muscle – disturbances of electrical conductivity, weakness of respiration, dynamic intestinal obstruction in GIT.

Deficiency of H^+ increases the affinity of oxygen to hemoglobin. As a result tissue hypoxia and further cellular acidosis develop.

6. Neural and endocrine mechanisms of water electrolyte balance maintenance.

Water is the main constituent of the body. The fluids of the body are distributed among functional compartments or spaces. They are: intracellular and extracellular; extracellular divided into smaller compartments – interstitial and intravascular. Water moves freely among body compartments and is distributed by

osmotic, oncotic and hydrostatic forces. The sum of fluids within all compartments constitutes the total body water. Total body water depends on weight, ages and sex. Its amount decreases with age and negatively correlates with fat tissue amount.

	% of body water	Volume (liters)
Intracellular fluid	40	28
Extracellular fluid	20	14
intrastitial	15	11
intravascular	5	3
Total body water	60	42

Table 3. Distribution of body fluids

Because fat is hydrophobic, very little water is contained in adipose cells. Individuals with more body fat have proportionally less body water and tend to be more susceptible to fluid imbalances that cause dehydration. Although daily fluid intake may fluctuate widely, the body regulates water volume within a relatively narrow range. The primary sources of body water are drinking, ingestion of water in food, water derived from oxidative metabolism.

The average daily fluid intake is about 2.5 L. The amount needed to replace losses from the urine and other sources is about 1 to 1.5 L/day in healthy adults. However, on a short-term basis, an average young adult with normal kidney function may ingest as little as 200 mL of water each day to excrete the nitrogenous and other wastes generated by cellular metabolism. More is needed in people with any loss of renal concentrating capacity. Renal concentrating capacity is lost in

- elderly people
- diabetes insipidus, certain renal disorders, hypercalcemia, severe salt restriction, chronic overhydration, or hyperkalemia
- people who ingest ethanol, phenytoin, lithium, demeclocycline, or amphotericin B

- osmotic diuresis (eg, due to high-protein diets or hyperglycemia)

Other obligatory water losses are mostly insensible losses from the lungs and skin, averaging about 0.4 to 0.5 mL/kg/h or about 650 to 850 mL/day in a 70-kg adult. With fever, another 50 to 75 mL/day may be lost for each degree C of temperature elevation above normal. GI losses are usually negligible, except when marked vomiting, diarrhea, or both occur. Sweat losses can be significant during environmental heat exposure or excessive exercise.

Water intake is regulated by thirst. Thirst is triggered by receptors in the anterolateral hypothalamus that respond to increased plasma osmolality (as little as 2%) or decreased body fluid volume. Rarely hypothalamic dysfunction decreases the capacity for thirst.

Water intake decreases plasma osmolality. Low plasma osmolality inhibits vasopressin secretion, allowing the kidneys to produce dilute urine. The diluting capacity of healthy kidneys in young adults is such that maximum daily fluid intake can be as much as 25 L; greater amounts quickly lower plasma osmolality.

Normally, the largest amount of water are lost through renal excretion, lesser amount are eliminated through the stool and vaporization from the skin and lungs. Water and electrolytes balance is regulated by kidney, lungs, circulating system, skin, muscles, intestine, bones and hormones: ADH, aldosteron.

Osmotic forces determine the movement of water through all three compartments. Osmosis is the movement of water “down” a concentration gradient. That is, across a semipermeable membrane from a region of higher water concentration to a lower. Osmosis directly related to both hydrostatic pressure and solute concentration but not to particle size and weight. For example, particles of plasma albumins are small but more concentrated in body fluids than the larger and heavier particles of globulins. Therefore albumin exerts a greater osmotic force than globulin.

The main osmotically active particles of the extracellular space are Na, CL, HCO₃. IN the intracellular compartment they are: K, Mg < PO₂ (phosphates). A molar solution of undissociated molecules has an osmolality of one osmole/kg

and would exert an osmotic pressure of 22,4 atmospheres (1 milliosmole exerts an osmotic pressure of about 17 mm Hg). Osmolality or the total concentration of dissolved or colloidal particles is the most important determinant of water movement. The normal osmolality of body fluids is 280 to 294 mosm/kg.

If water is added to the extracellular space it will dilute all compartments until the osmolality on either side of membrane become equal. If on the other hand , isotonic NaCl is injected intravenously the volume expansion is confined to the extracellular fluid. Water moves freely between plasma and interstitial fluid. When blood glucose is raised, it attracts water from the intracellular compartment and produces a lowering of serum Na concentration (for every 100 mg/dl decreased 1,6 mEq/l Na).

The distribution of water and movement of nutrients and waste products among capillary, plasma and interstitial spaces occur as a result of changes in hydrostatic pressure and osmotic forces at the arterial and venous ends of capillary. Because water, Na, and glucose readily move across the capillary membranr, the plasma proteins maintain the effective osmolality by generating plasma oncotic pressure. Osmotic forces within the capillary are balanced by hydrostatic pressure which arises from cardiac contraction. The movement of fluid back and forth across the capillary wall is called NET FILTRATION and is described by Starling hypothesis.

Net filtration = forces favoring filtration – forces opposing filtration

The forces favoring filtration or movement water out of the capillary into interstitial space include: the capillary hydrostatic pressure and oncotic interstitial pressure. The forces opposing filtration are the plasma oncotic pressure and interstitial hydrostatic pressure. Normally, the interstitial forces are negligible because only a very small percentage of plasma proteins crosses the capillary membrane. Thus the major forces for filtration are within the capillary. As the plasma moves from arterial to the venous end of the capillary, changes in the forces of hydrostatic pressure facilitate the movement of water across the membrane. 1) Oncotic pressure remains constant (25-28 mm Hg) because proteins

do not cross the capillary membrane. 2) At the arterial end hydrostatic pressure is greater than the capillary oncotic pressure and water filters into interstitial space. 3) At the venous end of the capillary oncotic pressure exceeds hydrostatic pressure. Fluids then are attracted back into circulation, balancing the movement of fluids between the plasma and interstitial space. The overall effect is filtration at the arterial end and reabsorption at the venous end.

Mechanisms that maintain normal serum osmolality (280 mOsm/kg) are thirst and effect of antidiuretic hormone (ADH). When serum osmolality increases, central osmoreceptors in hypothalamus become activated. This leads to thirst behavior and increased secretion of ADH. Both increase water in serum and decrease serum osmolality, then the negative feedback loop switches on and ADH secretion decreases.

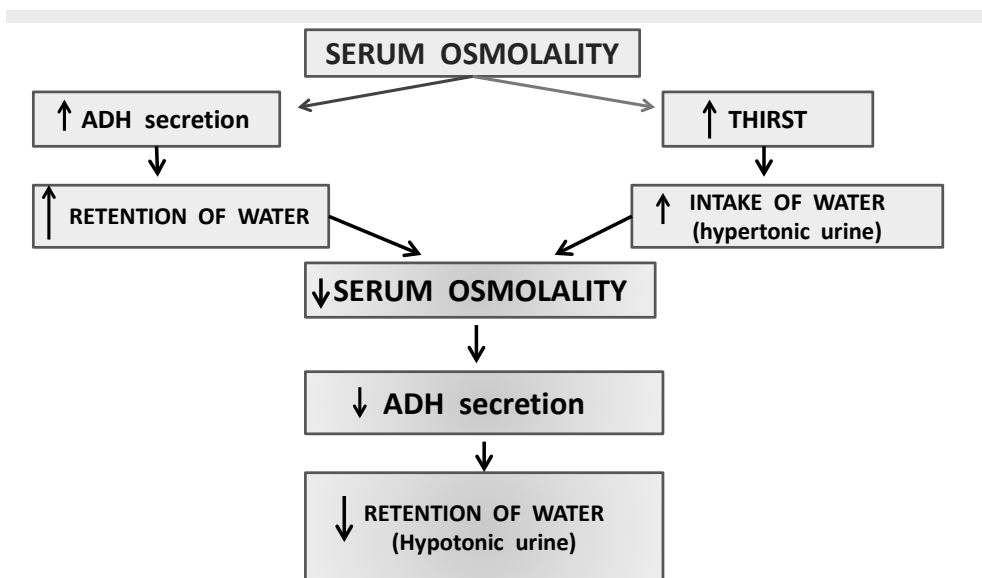


Figure 5. Mechanisms that maintain normal serum osmolality

ADH is synthesized in supraoptic and paraventricular nuclei of pituitary. The secretion of ADH responds to both osmotic and nonosmotic stimuli.

ADH secretion increases by trauma, pain, exercise, nausea, nicotine exposure to heat, and drug such as chloroform and morphine, apparently activating cholinergic neurotransmitters in hypothalamus.

Vasopressin release is stimulated by any of the following:

- Increased plasma osmolality
- Decreased blood volume
- Decreased blood pressure
- Stress

ADH secretion decreases with a decrease in plasma osmolality (decreased concentration of Na, glucose), an increase in intravascular volume, hypertension, alcohol ingestion.

ADH binds to its receptor on epithelial cells of collecting duct, activates G protein, adenilate cyclase, cAMP dependent protein kinase and increases permeability for water of epithelial cell membrane. This increased permeability leads to increase in water reabsorption and production of more concentrated urine.

Water excretion by the kidneys is regulated primarily by vasopressin (ADH). Vasopressin is released by the posterior pituitary and results in increased water reabsorption in the distal nephron.

Vasopressin release may be impaired by certain substances (eg, ethanol, phenytoin), by tumors or infiltrative disorders affecting the posterior pituitary, and by trauma to the brain. In many cases a specific cause cannot be identified.

7. Hypohydration: types, etiology, pathogenesis, clinical manifestation.

The characteristic feature of all kinds of hypohydration is the negative fluid balance: the predominance of water loss over its intake by the organism.

The causes of hypohydration may be either insufficient water supply of the organism or its increased loss. Insufficient water supply of the organism may occur in time of the so-called water “water starvation”, i. e. the deficient intake of liquid with food and drink by the organism (e. g. in time of forced starvation, or when there is no opportunity to secure the regular drinking regime in time of acts of God or hostilities). The other possible causes may be mental disorders or traumas, reducing or eliminating the feeling of thirst (for example, in concussion of the brain; when the neurons of the thirst centre have been damaged due to hemorrhage, ischemia, tumor growth as well as in hysteria and neurosis), somatic diseases,

hampering food and liquid intake (for example, in impaired swallowing, esophageal occlusion, in the trauma of the facial part of the skull).

Increased water loss by the organism may occur in continuous polyuria (for example, in patients with renal failure, diabetes mellitus or when diuretics are not properly administered), gastrointestinal disorders (for example, in continuous profuse salivary discharge, recurrent vomiting, chronic constipation), heavy blood loss (for example, caused by blood vessel and/or heart injury), pathological processes, causing the heavy loss of lymph (for example, in case of extensive burns, lymphatic trunks damaged or injured by a tumor), prolonged or profuse sweating (for example, in the conditions of hot dry climate or industrial processes involving increased air temperature and decreased humidity in the workshop), hyperthermal states of the organism including fever. 1° C body temperature increase results in the discharge of 400-500 ml of liquid daily as a result of sweating.

According to the osmolality of extracellular fluid three types of hypohydration are singled out: hypoosmolar, hyperosmolar and isoosmolar.

In **hypoosmolar hypohydration** the organism's salt losses are predominant as compared to water losses and the decrease in extracellular fluid osmolality.

Causes:

- hypoaldosteronism. It is associated with decreased reabsorption of Na⁺ ions in the kidneys, decreased osmolality of blood plasma and water reabsorption which results in the organism's hypohydration.
- continuous profuse sweating involving the discharge of a great amount of salts.
- recurrent or uncontrollable vomiting (for example, in case of poisoning or pregnancy) causing Na⁺ and K⁺ losses.
- -diabetes mellitus or diabetes insipidus (for example, when ADH is deficient) combined with the excretion of K⁺ salts, Na⁺ glucose, albumins.

- profuse diarrhea (for example, in cholera or malabsorption syndrome) associated with the loss of intestinal juice containing K^+ , Na^+ , Ca^{2+} and other cations.

- improper or unjustified implementation of dialysis procedures (hemodialysis or peritoneal dialysis with low osmolality of dialyzing solution. This results in the diffusion of ions from blood plasma and the fluid for dialysis.

- the correction of isoosmolar hypohydration with the help of solutions with decreased salt concentration.

The extracellular form of hypoosmolar hypohydration is conditioned mainly by the organism's predominant fluid loss. However, its severe and/or continuous varieties are associated with fluid transport into the cell (according to osmolality Gradient). Alongside with that intracellular hyperhydration (cell swelling) determining the extent of extracellular hypohydration may be registered.

Consequences and manifestations include mucous and cutaneous dryness, decreased salivary secretion (hyposalivation), decreased elasticity and tension (turgor) of skin, muscles, recession and softening of eyeballs, reduced amount of daily excreted urine. All these manifestations result from the organism's hypohydration, the reduced volume of intercellular fluid and the volume of circulating blood, decreased perfusion and hemodynamic pressure in arterioles and precapillaries. It should be noted that patients with hypoosmolar hypohydration do not feel thirst due to low blood plasma osmolality and cell hyperhydration.

In **hyperosmolar hypohydration** the organism's water losses are predominant as compared to salt losses. Increased osmolality of intercellular fluid leads to water transport from the cells into extracellular space. Under such conditions general (cellular and intracellular) hypohydration may develop.

Causes:

- Insufficient water intake (for example, in the so called "dry starvation" when a person refuses to drink water; when there is lack of drinking water supply in time of hostilities, acts of God, emergency situations).

- Hyperthermal states (including fever), associated with heavy prolonged sweating.

- Polyuria (for example, in diabetes insipidus (nephritic) involving the loss of a great amount of liquid with low concentration of osmotically active substances: ions, glucose, nitrous compounds by the organism; in diabetes mellitus due to osmotic polyuria in combination with high hyperglycemia). Prolonged artificial lung ventilation (ALV) with insufficiently moistened gaseous mixture.

- Drinking sea water in the conditions of the organism's hypohydration.

- Parenteral infusion of solutions of increased osmolality (for example, in treating disturbances of acid base equilibrium; in artificial feeding of patients with dystrophy).

Consequences and manifestations:

- Decreased volume of circulating blood;
- Increased Ht resulting in blood viscosity;
- Systemic disturbances of blood circulation (central, organ-tissue level, microcirculatory);
- Disturbed acid base equilibrium (mainly acidosis) resulting from impaired hemodynamics, respiration and metabolism;
- Hypoxia.

As it is seen the manifestations of hyperosmolar hypohydration are quite similar (but not identical) to those of hypoosmolar hypohydration. However, considerable cell hypohydration as well as the death of some of the cells in hyperosmolar hypohydration results in a more aggravated course of this pathology. This accounts for the fact that some other signs may occur in hyperosmolar hypohydration.

- Fever due to the release of pyrogen from injured cells.
- Mental disorders (psychomotoric agitation, anxiety, fear of death, and mental confusion and loss of consciousness).
- Excruciating unquenchable thirst due to extra- and intracellular hypohydration. It makes the patient drink any liquid (sea water and

other water unfit for drinking, sewage, etc., which is aggravating his condition even more.)

In children hyperosmolar hypohydration develops at a higher rate and its course is more aggravated. This is conditioned by higher intensity of fluid excretion from the organism by kidneys, lungs, through the skin as compared to that of adults (when calculated per unit of body surface).

Isoosmolar hypohydration involves an approximately equivalent reduction of water and salt concentration in the organism.

Causes:

- Acute severe blood loss at its initial stage (i.e. before the emergency compensatory mechanisms are brought into action).
- Profuse recurrent vomiting. Profuse diarrhea. Extensive burns. Polyuria caused by bigger doses of diuretics.

Consequences and manifestations of isoosmolar hypohydration are conditioned by the reduced volume of extracellular fluid resulting in blood circulation disturbances:

- Reduced volume of circulating blood;
- Increased blood viscosity;
- Disturbances of central, organ-tissular and microhemocirculation;
- Disturbances of acid base equilibrium (for example, acidosis in profuse diarrhea and heavy blood loss, alkalosis in recurrent vomiting);
- Hypoxia (especially after heavy blood loss).

The prompt action of compensatory mechanisms, as a rule, eliminates or considerably decreases the extent of hypohydration and severity of its manifestations.

The mechanisms of hypohydration compensation.

The general mechanisms of dehydration compensation include the activation of the neurons of the hypothalamic thirst centre and the activation of the system “renin - angiotensin – aldosterone”.

In the first case the increased amount of antidiuretic hormone (ADH or vasopressin) is secreted into the blood and diuresis decreases.

In the second case the mineralocorticoid hormone aldosterone increases the renal reabsorption of Na⁺, which results in water staying in the organism.

The feeling of thirst emerges when there is 1-2% deficit of water. It considerably increases in the conditions of excess sodium in the blood plasma – hypernatremia (hyperosmolality). 2,5-4 % water deficit causes a painful, excruciating feeling of thirst. This feeling sometimes makes people take a liquid which is unfit for drinking (for example, sea or dirty water), which aggravates the condition of the organism even more.

Causes of thirst:

- Increased osmolality of extracellular fluid (mainly that of blood plasma being more than 285 mosm/kg H₂O).
- Decreased amount of water in the cells.
- Decreased level of angiotensin II in blood plasma, which immediately stimulates the thirst centre neurons.
- Antidiuretic hormone

The activation of ADH (vasopressin) synthesis in the neurons of supraoptic and paraventricular hypothalamic nuclei and its secretion into blood from the posterior lobe of hypophysis result in decreased diuresis and vasoconstrictive effects.

Compensatory reactions are efficient in the organism's hypohydration of a mild degree, when water deficit does not exceed 5 % as compared to the norm. In hypohydration of more severe degrees special medical aid is necessary.

8. Hyperhydration: types, etiology, pathogenesis, clinical manifestation.

Hyperhydration is characterized by the positive fluid balance: predominant water intake by the organism as compared to water excretion and losses. According to the osmolality of extracellular fluid hypoosmolar, hyperosmolar and isoosmolar hyperhydration are singled out.

Hypoosmolar hyperhydration is characterized by excess extracellular fluid of low osmolality in the organism. Hypoosmolar hyperhydration involves a fluid volume increase both in the extra- and intracellular sector, as excess extracellular fluid according to the gradient of osmotic and oncotic pressure enters the cells.

Causes:

- Excessive infusion of fluids with low concentration of salts or lacking salts into the organism. Most frequently this occurs in the course of repeated enteric infusion of water into the organism. This state is designated as “water poisoning”. Such a situation may arise when patients with mental disorders repeatedly consume a great amount of water or drinks, when water is infused into the gastrointestinal tract through a catheter or a fistula (for example, for gastric or intestinal lavage). The development of “water poisoning” is alleviated with the excretory hypofunction of the kidneys.

- Increased concentration of ADH in blood as a result of its hyperproduction in the hypothalamus (for example, in Parhon’s syndrome).

- Renal failure (with considerable excretory hypofunction of the kidneys).

Marked circulatory insufficiency involving edema development.

Consequences and manifestations:

- Increased volume of circulating blood (hypervolemia) and hemodilution.
- Hypervolemia and hemodilution are conditioned by water transport into the vascular channel due to higher osmotic and oncotic blood pressure as compared to that of intercellular fluid.

- Polyuria is increased urination due to higher filtration pressure in renal corpuscles. Polyuria may not occur at the hypo- or anuria stage of renal failure.

- Erythrocyte hemolysis.

- The emergence of intracellular components in blood plasma (for example, enzymes and other macromolecules) due to the injure or death of cells of different tissues and organs.

- Vomiting and diarrhea due to the organism's intoxication (as a result of the release of excess ions, metabolism products, enzymes and other substances from injured or dead cells.)

- Psychoneurological disorders: flabbiness, apathy, disturbed consciousness, frequent convulsions. The listed disorders result from brain cell injury as a result of their swelling.

Hypoosmolar syndrome. It develops when blood plasma osmolality decreases up to 280 mosm/kg H₂O or even lower, as a rule, as a result of hyponatremia (this syndrome may occur both in hypo- and hyperhydration of the organism). Blood plasma osmolality decrease under 250 mosm/kg H₂O may result in irreversible changes in the organism and its death.

Hyperosmolar hyperhydration is characterized by increased osmolality of extracellular fluid, which is higher than that in the cells.

Causes:

- Forced intake of sea water. It happens when there has not been fresh water for a long time (for example, during sea and ocean catastrophes, when flying vehicles fall down into seas or oceans).

- Infusion of the solutions with increased concentration of salts into the organism without controlling their concentration in blood plasma (for example, in running remedial measures in patients with iso- or hypoosmolar hypohydration, acid base equilibrium disturbances).

- Hyperaldosteronism, causing the excessive reabsorption of Na⁺ in the kidneys.

- Renal failure associated with salt excretion decrease (for example, in "renal tubulo- and/or enzymopathy").

The above-mentioned causes (as well as some others) account for the increase in the volume and the osmolality of extracellular fluid. The latter leads to cell hypohydration (as a result of fluid escape from the cell into extracellular space according to the osmotic pressure gradient). Thus, mixed (associated) dyshydrria develops: extracellular hyperhydration and intracellular hypohydration.

Consequences and manifestations:

- Hypervolemia.
- Increased volume of circulating blood.
- Increased cardiac output, followed by its decrease in case of cardiac insufficiency development.

- Increased arterial blood pressure. Increased central venous blood pressure.

All the above-mentioned signs of hyperosmolar hypohydration result from the blood plasma volume increase.

- Brain edema.

• Pulmonary edema. The last two manifestations develop as a result of intracellular hyperhydration as well as the increased volume of intercellular fluid (edema) due to cardiac insufficiency.

• Hypoxia caused by cardiac insufficiency development, blood circulation disturbances and respiratory disorders.

• Mental disorders, caused by brain injury due to its edema, increasing hypoxia and intoxication of the organism.

• Powerful thirst developing as a result of blood plasma hyperosmolality and cell hypohydration. The additional supply of the organism with water under these conditions aggravates the patient's state.

Hyperosmolar syndrome. It occurs when blood plasma osmolality increases (most often due to excess Na^+ and/or glucose) above 300 mosm/kg H_2O (both in hyper- and hypohydration of the organism). This reveals the signs of cell hypohydration.

Isoosmolar hyperhydration is characterized by the increased volume of extracellular fluid of normal osmolality.

Causes:

• Infusion of a great amount of isotonic solutions (for example, sodium chloride, potassium chloride, sodium hydrocarbonate).

• Insufficient blood circulation, resulting in the increased volume of extracellular fluid due to increased hemodynamic and filtration pressure in

arterioles and precapillaries; decreased efficiency of liquid reabsorption in postcapillaries and venules.

- Increased permeability of microvessel walls which facilitates fluid filtration in precapillary arterioles (for example, in intoxication, some infections, toxemia of pregnancy).

- Hyperproteinemia, in which fluid is transported from the vascular channel into intercellular space according to the oncotic pressure gradient (for example, in general or protein starvation, hepatic insufficiency, nephritic syndrome).

- Chronic lymphostasis, in which the drainage of intercellular fluid into lymph vessels is slowed down.

The listed factors alongside with some others cause the increase of circulating blood volume and intercellular fluid. The developing hyperhydration may be easily eliminated if the system of water metabolism regulation is in optimal condition.

Consequences and manifestations:

- Increased blood volume; its general and circulating fractions (oligocytemic hypervolemia).

- Increased arterial blood pressure, caused by hypervolemia, increased cardiac output and peripheral vascular resistance.

- Cardiac insufficiency development especially in prolonged hypervolemia. The latter causes cardiac overload (both with blood volume and increased vascular resistance).

- Edema development may considerably aggravate the patient's state if edema develops in the lungs or in the brain.

The mechanisms of hyperhydration compensation.

The general mechanism of hyperhydration compensation first of all appears to be diuresis stimulation, which is achieved in various ways including decreasing vasopressin (ADH) synthesis and secretion. Compensatory reactions activated in hyperhydration are efficient in mild and moderate hyperhydration conditions. In its more severe forms drastic remedial measures are required.

9. Edema etiology and pathogenesis in inflammation, starvation, diseases of heart and kidney.

Edemas are classified according to their localization, the extent of their spread, the rate of their development and the basic pathogenetic factor of edema development.

According to the origin, edema can be classified into congestive (due to cardiac insufficiency), renal, inflammatory, liver, endocrine, toxic, neurogenic.

According to edema localization general edema (anasarca) and dropsy are singled out. Anasarca is the edema of subcutaneous cellular tissue.

Dropsy is the edema of a body cavity (accumulation of transudate in it).

Ascites is the accumulation of excess transudate in the abdominal cavity.

Hydrothorax is the accumulation of transudate in the chest.

Hydropericardium is excess fluid in the pericardium cavity.

Hydrocele is the accumulation of transudate between the folia of the testicular serous membrane.

Hydrocephaly is excess fluid in the brain ventricles (inner dropsy of the brain) and/or between the brain and the skull - in subarachnoid or subdural space (outer dropsy of the brain).

According to the extent of their spread local and general edemas are singled out.

Local edema (for example, in the tissue or organ at the point of inflammation or allergic reaction development).

General edema is the accumulation of excess fluid in all organs or tissues (for example, hypoproteinemic edemas in hepatic insufficiency or nephritic syndrome).

According to the rate of edema development instantaneous and acute development or chronic development are singled out.

Instantaneous edema develops within a few seconds after being affected (for example, after being bitten by insects or snakes).

Acute edema normally develops within an hour after the causal factor action (for example, pulmonary edema in acute myocardial infarction).

Chronic edema develops within several days or weeks (for example, nephrotic edema in time of starvation).

According to the basic pathogenic factor hydrodynamic, lymphogenic, oncotic, osmotic and membranogenic edemas are singled out.

Pathogenic factors of development.

Hydrodynamic factor.

Hydrodynamic (hemodynamic, hydrostatic, mechanical) factor is characterized by increased efficient hydrostatic pressure.

1. Increased venous blood pressure.

General venous blood pressure increases in cardiac insufficiency due to its decreased contractile and pumping functions. Local venous blood pressure increases when there is obturation of venous vessels (for example, with a thrombus or embolus) or when veins or venules are squeezed (for example, by a tumour, a scar, edematous tissue).

2. Increased volume of circulating blood (for example, in hypervolemia, polycythemia, water poisoning).

3. Tissue turgor decreases. Turgor decrease is an important factor, potentiating the mechanism of fluid filtration from the vessel into the tissue.

Lymphogenous (lymphatic) pathogenetic factor.

Mechanisms of action of lymphogenous (lymphatic) pathogenetic factor of edematization are different in dynamic and mechanical lymph insufficiency.

Dynamic lymph insufficiency. This mechanism of lymphatic edematization is caused by a considerable increase of lymphization. In this case lymph vessels seem to be unable to transport considerably increased volume of lymph into general blood supply. The same features can be observed in hyperproteinemia in patients with nephrosis or hepatic insufficiency.

Mechanical lymph insufficiency. It is the so-called mechanical protection against the drainage of lymph through the vessels caused by their squeeze or

obturation. In such cases one can observe considerable tissue edematization accompanied by an increase in size and mass. Edematization in the lower extremities is usually referred to as elephantiasis. In elephantiasis a leg can increase in size and mass considerably (up to 40-50 kg). The same process can occur in the upper extremities, genital organs and some other, quite often large parts of the human body. It is necessary to note that lymphogenous (lymphatic) edemas can cause accumulation of fluid rich in proteins (up to 3-4 g). One can also observe excessive formation of collagenous fibers and other elements of connective tissue that can cause deformation of organs and tissues.

Oncotic factor.

The main peculiarities of the oncotic factor (hyperalbuminemic, hyperproteïnemic) are a reduction of oncotic blood pressure or/and an increase of oncotic pressure in the intercellular fluid.

Hyperproteinemia (mainly due to hyperalbuminosis as albumins are 2.5 times more hydrophilic than globulins) is often caused by:

- 1) Insufficient intake of proteins during starvation or protein deprivation;
- 2) Disorders related to cavity or/and membrane digestion (e.g. in cases of resection of intestinal fragments, dysbacteriosis, malabsorption);
- 3) Reduced synthesis of albumins in the liver (e.g. under the influence of hepatotropic poison, advanced cirrhosis);
- 4) Excessive loss of proteins in the body (e.g. in case of nephrosis excreted with urine, in extensive burns with plasma, in intestinal and stomach disorders with feces);

The factors which can cause increased oncotic interstitial fluid pressure are regional and they usually produce or potentiate local edematization. Hyperoncemia of interstitial fluid can be caused by:

1. Excessive transport of blood proteins into intercellular space. It can be associated with increased permeability of the walls of small vessels

2. Escape of proteins of the cells into intercellular fluid in case of cell damage or destruction (e.g. in the focus of inflammation, ischemia, allergic reactions);

3. Increased hydrophility of protein micella in interstitial fluid.

- accumulation of excessive amounts of some ions in interstice (e.g. H^+ , K^+ , Na^+);
- insufficient amounts of the ions of Ca^{2+} ;
- excessive amounts of such as histamine, serotonin;
- deficient amounts of thyroid hormones containing iodine.

Mechanism of action of the oncotic factor consists in reducing efficient oncotic absorptive force (as a consequence of hyperproteinemia or/and hyperoncemia of the tissues). As a result, the volume of filtrated water from small vessels into interstitial fluid according to the gradient of oncotic pressure increases, whereas resorption of fluid from intercellular space into postcapillaries and venules decreases.

Osmotic factor.

The osmotic factor of edema consists either in increasing osmolality of interstitial fluid or in decreasing osmolality of the plasma, or in combining both processes.

Mechanism of action of the osmotic factor consists in excessive transportation of water from the cells and vessels of the microcirculatory channel into intercellular fluid according to the gradient of osmotic pressure (higher in interstice). This mechanism is considered a component of pathogenesis in cardiac, nephritic, hepatic and other edemas. In the above-mentioned edemas the volume of extracellular fluid increases.

The membranogenic factor is characterized by a considerable increase in the permeability of the vessel walls in the microcirculatory channel for water, fine-molecular and macromolecular substances (proteins are most significant).

Membranogenic factor.

Mechanisms of membranogenic factor action:

1) Facilitation of water filtration. In this relation the drainage of fluid from the blood and lymph into interstitial space increases. On the other hand, this mechanism is balanced with increased water reabsorption in the venous part of capillaries related to thinning of their walls.

2) Increased amounts of protein molecules from small capillaries into interstitial fluid. On the one hand, it can lead to decreased oncotic pressure of the plasma and lymph but, on the other hand, it leads to the development of hyperoncemia of intercellular fluid. Due to the increased permeability of the walls of small capillaries the fluid passes into intercellular space according to the gradient of oncotic pressure. It is this process that underlies edema development of the tissues in case of inflammation, local allergies, stings, poisonings, effect of pure oxygen, and especially when atmospheric pressure is high.

In practice, edema which developed under the influence of one of the mentioned pathogenetic factors is not very common. In other words, there are no monopathogenetic edemas. Thus, in each case of edema one can distinguish:

- initial (primary) pathogenetic factor in the patient;
- secondary pathogenetic factors.

Edemas due to cardiac insufficiency

Systemic edema occurs in congestive heart failure (cardiac insufficiency) affecting right ventricular cardiac function or both ventricular. Pulmonary edema result from cardiac insufficiency both left ventricular and general (right and left). Cardiac insufficiency, i.e. state in which a person's heart does not supply organs and tissues with the amount of blood necessary for their functioning and maintaining plastic processes, is characterized by lower (compared with normal) of cardiac output and primary circulatory hypoxia.

This type resulting from increased capillary pressure. The hydrostatic capillary pressure depends on the arterial blood pressure, the arteriolar resistance, the state of the precapillary sphincters, and, most importantly, the venous pressure.

An increase in the venous pressure within the microvessels results in increased filtration of fluid from the capillaries and an accumulation of fluid in the tissues. Although increased venous hydrostatic pressure is important, the pathogenesis of cardiac edema is more complex.

Thus, initial pathogenetic factor is a hydrodynamic factor.

Sequence and significance of pathogenetic factors of edematization are different depending on the dynamics of blood circulation disorders and their complications. Pathogenesis of a cardiac edema includes all of the mentioned factors:

- Decreased cardiac output.
- Reduced volume of circulating blood
- Activation of baroreceptors in the walls of blood vessels.
- Narrowing of the arterioles of the cortical substance of kidneys.
- Increased blood supply in the medullary substance of kidneys.
- Increased reabsorption of Na⁺ in venal tubules of kidneys which can lead to hyperosmia of the blood.

- Activation of osmoreceptors.
- Increased synthesis and release of antidiuretic hormone in the blood.
- Increased water reabsorption in kidneys.
- Increased efficient hydrodynamic pressure. Activation of water filtration in the arterial part of the capillaries is accompanied by inhibition of water reabsorption in the venous part of small capillaries. Reduced flow of blood in the vessels of kidneys. The main cause is decreased cardiac output.

- Activation of the system renin-angiotensin-aldosteron.
- Increased reabsorption of Na⁺ in the venal tubules of kidneys.
- Systemic increase of the venous blood pressure both in great and peripheral venous blood vessels.

- Slackened drainage of lymph from tissues which results in developing mechanical lymph insufficiency.

- Increased volume of interstitial fluid, i.e. rate of edematization.
- Disorders related to the drainage of osmotically active substances (e.g. ions, inorganic and organic compounds) caused by venous hemostasia (i.e. venous hyperemia) and lymph insufficiency.
 - Increased amounts of metabolites (e.g. lactic acid, pyruvic acid, peptides, amino acids) caused by metabolism disorders in case of hypoxia.
 - Activation of non-enzymic hydrolysis of the components of basement membrane in the walls of the vessels. It can also lead to an increase of their permeability.
 - Increased formation and activation of which provide the increase of permeability in the walls of small vessels (e.g. histamine, serotonin, kinin, separate factors of the complement).
 - Increased escape of proteins from the blood into interstitial space.
 - Disorders related to synthesis of protein function of the liver which can lead to hyperalbuminosis.
 - Reduced efficient oncotic absorptive force.
 - Increased outflow of water from small capillaries into intercellular space according to the increased gradient of oncotic pressure.

Hence, edema occurring in case of cardiac insufficiency is the result of a combination of all pathogenetic factors such as hydrodynamic, osmotic, oncotic, membranogenic and lymphatic ones.

Kidney edemas.

Various forms of kidney pathology are usually accompanied by more or less marked edematization. Initial pathogenetic factors are different in patients with nephrotic and nephritic syndrom.

Edemas in nephrotic syndrome .

The causes of nephrotic syndrome can be related to primary disorders of kidneys (e.g. focal glomerulosclerosis, lipid nephrosis) and secondary modification of renal tissue (e.g. tuberculosis, allergic reactions). Nephrotic syndrome is

characterized by diffuse destruction of the parenchyma of kidneys and severe proteinuria (> 3.5 g/day)

The initial pathogenetic factor of edema is oncotic factor, which result from:

1) Increased permeability of the membranes of nephritic glomerules for the proteins. In this case, the blood loses not only albumins but also globulins, transferrin, haptoglobin, peruloplasmin and some other proteins.

2) Disorders related to reabsorption of proteins in venal tubules of kidneys.

All of the above mentioned blood disorders lead to considerable changes in the content of proteins in the body.

Main links of pathogenesis

Protein losses with urine (i.e. proteinuria)→ Daily protein losses in patients with nephrosis can reach 35-55 g/l (normally, utilization is no more than 50 mg).
→Reduced concentration of proteins in the plasma (i.e. hypoproteinemia)
→Decrease of efficient oncotic absorptive force→Increase of water filtration in small vessels and accumulation of excessive water in intercellular space and body cavities (i.e. edema)→Squeeze of lymph vessels by edematous tissues caused by the development of mechanical lymph insufficiency and increase of edematization.
→Reduced volume of circulating blood (i.e. hypovolemia)→Activation of vascular baroreceptors which provide increased Na⁺ reabsorption in venal tubules of kidneys→Reduced flow of blood in kidneys caused by hypovolemia which activates the system “renin-angiotensin-aldosteron”. It potentiates reabsorption of Na⁺ in kidneys→Increase of Na⁺ in the plasma (i.e. hypernatremia). It activates osmoreceptors→Stimulation of synthesis in neurons of hypothalamus and excretion of antidiuretic hormone into the blood→Activation of water reabsorption in renal tubules→Increase of efficient hydrostatic pressure in small vessels of tissues which potentiates accumulation of transudate in interstitial space. Besides, transportation of water from the vessels of the microcirculatory system into interstice provides intensive hypovolemia and lymph insufficiency.

Thus, during nephrotic edematization pathogenetic factors potentiating edematization are combined. In nephrotic edematization oncotic, hydrostatic and lymphatic pathogenetic factors usually participate.

Edemas developing in patients with nephritis.

Nephritic syndrome can be caused by: disorders of blood circulation in kidneys (more often ischemia) in patients with inflammatory or immunoinflammatory diseases such as chronic diffuse glomerulonephritis. In this case, nephritic tissues (including vessels of kidneys) can be squeezed by inflammatory exudate. The rigid capsule of the kidney is. Therefore, even small amounts of exudate can cause the squeeze of its parenchyma. It can result in the disorders of blood supply of kidneys including the cells of juxtaglomerular apparatus.

The initial pathogenetic factor is a hydrostatic factor (due to reduced blood supply of the cells of juxtaglomerular apparatus) and formation of ducts between rounded impaired cells of endothelium.

Links of pathogenesis

Stimulation of synthesis and excretion of renin into the blood by the cells of juxtaglomerular apparatus. → Production of angiotensin in the blood under the influence of renin which is converted into angiotensin II with the help of angiotensin-converting enzymes. This process usually takes place in the lungs and walls of the vessels. A small portion of angiotensin II converts into angiotensin III. → Stimulation of angiotensin II and, to some extent, angiotensin III provides excretion of aldosterone by the cells of glomerular zone of the adrenal cortex → Increased reabsorption of Na⁺ in venal tubules of kidneys is associated with the development of hypernatremia → Activation of osmoreceptors is usually accompanied by excretion of antidiuretic hormone into the blood → Increased water reabsorption in renal tubules is associated with the development of hypervolemia → Increased efficient hydrostatic pressure which can cause increased fluid filtration in the arterial part of capillaries and inhibition of water reabsorption in the venous part of capillaries → Edema develops → Edema is an accumulation of excessive

interstitial fluid → Reduced volume of glomerular filtration accompanied by potentiating hypervolemia can result in a decrease in the number of functioning nephrons damaged during glomerulonephritis.

The most common increased permeability of the walls of vessels is usually referred to as generalized capillaritis. It makes the process of transportation of proteins and water into interstice as well as reabsorption of fluid in kidneys much easier.

Increased permeability of glomerular filter for proteins (i.e. proteinuria). Development of hyperproteinemia. Reduced efficient oncotic absorptive force which can provide the enlargement of edema. Thus, in nephritic edematization one should take into consideration the following factors: hydrodynamic, oncotic, membranogenic ones.

Pulmonary edema

Pulmonary edema refers to excess accumulation of fluid in the extravascular spaces of the lung. Pulmonary edema can be classified based on the etiology into cardiogenic pulmonary edema and noncardiogenic pulmonary edema. Microscopically, pulmonary edema reveals the alveoli to be filled with pale pink fluid.

Cardiogenic pulmonary edema results from abnormalities of hemodynamic (Starling) forces.

Initial and basic pathogenetic factors are hemodynamic factors. They are characterized by:

- Reduced contractility of the myocardium of the left ventricle.
- Increased systolic residual volume of the blood in the left ventricle.
- Increased end-diastolic volume and pressure in the left ventricle of the heart.
- Increased blood pressure in the vessels of the pulmonary circulation (higher than 25-30 mm Hg).

- Increased efficient hydrodynamic pressure. If it exceeds efficient oncotic absorptive force, transudate passes into intercellular space of the lungs (interstitial edematization may develop).

Noncardiogenic pulmonary edema results from cellular injury. Edema may be the result of either endothelial injury (infections, disseminated intravascular coagulopathy, or trauma) or alveolar injury (from inhaled toxins, aspiration, drowning, or near drowning).

Pulmonary edemas developing under the influence of toxic substances.

The causes can be such toxic substances as poisonous substances like phosgene, high concentration oxygen.

Membranogenic factors which can be associated with increased permeability of the walls of small vessels are regarded as the initial and basic pathogenic factors

Factors which can lead to the increase of permeability of the walls of the vessels under the influence of toxic substances are as follows:

- Acidosis which can cause non-enzymatic hydrolysis of the ground substance in the basement membrane of small vessels;
- Increased activity of hydrolytic enzymes.

10. Alterations in Na blood plasma content: etiology and consequences.

Sodium is the major cation of the extracellular space. It is a primary determinant of serum osmolarity, though not the only one. The normal range of serum sodium in children is 135 - 145 mEq/L as it is in adults. A serum sodium concentration of > 145 mEq/L is considered hypernatremia, whereas hyponatremia is regarded as a serum sodium < 135 mEq/L.

Hypernatremia

Though hypernatremia often occurs in the context of dehydration, the latter implies hypovolemia, and hypovolemia need not be present for hypernatremia to be a significant clinical concern. Symptoms may include muscle weakness, irritability and agitation, high-pitched cry, insomnia, and lethargy.

A rise in serum sodium concentration draws water out of cells. Thus, despite dehydration, tachycardia and other clinical symptoms of hypovolemia may be minimal and develop ominously late because intravascular volume is "protected." Subcutaneous tissue is classically described as "doughy" and skin is "like velvet." Serious CNS manifestations can be observed, especially when the patient is hypovolemic. Neural cell dehydration and subsequent brain shrinkage can lead to tearing of bridging veins with subdural or subarachnoid hemorrhages. Increased blood viscosity can cause capillary and venous congestion and possibly sinus venous thrombosis. Encephalopathy and seizures have been reported.

Hypernatremia is most often due to free water loss in excess of sodium and potassium. People normally compensate by drinking more water, but impaired thirst and inability to access water are not uncommon in hospitalized children. Less frequently, intake of excess sodium - or this combined with free water loss - is to blame. Common etiologies in hospitalized children are accompanied by brief explanations below.

Gastrointestinal losses: Both gastric and intestinal fluid losses can result in hypernatremia because in each instance, the fluid lost has sodium + potassium concentrations far lower than serum (Secretory diarrheas are notable exceptions, in which fluid losses are usually equivalent to serum in sodium + potassium concentrations). Examples include acquired viral enteritides, iatrogenic diarrhea (lactulose, charcoal, antibiotic-induced), and chronic nasogastric suctioning. Isotonic fluid replacement does not provide sufficient solute-free water, potentiating the issue.

Renal losses: Loop diuretics such as furosemide impair tubular concentrating ability by disrupting the countercurrent gradient, resulting in water loss in excess of electrolytes. This is also true in osmotic diuresis resulting from mannitol, hyperglycemia which exceeds the kidneys' reabsorptive capacity (usually 240 mg/dL), or urea from high-protein tube feedings.

Skin loss: Sweat represents a route for excess free water loss. For instance, pre-term or term infants who breastfeed inadequately, and/or who are kept under

radiant warmers or "bili-lights," may be prone to developing hypernatremic dehydration due to unreplaced, insensible loss.

Other losses: Other sources of chronic fluid loss which should be considered in hospitalized pediatric patients include externalized ventricular drains, thoracostomy tubes, peritoneal drains, ostomy output, and externalized oral secretions ("drool").

Inadequate free water provision: Replacement of gastrointestinal output with isotonic fluid does not provide sufficient solute-free water, which potentiates hypernatremia. Tube feeds may require the addition of scheduled water administration to prevent development of a free water deficit during periods of increased free-water loss. Urea-induced (osmotic) diuresis from protein-rich feeds has also been described.

Excess sodium provision: Hypertonic saline (typically 3%) is given intermittently or as an infusion to induce hypernatremia and control intracranial hypertension in the setting of brain injury. Frequent sodium bicarbonate administration to treat ongoing metabolic acidosis can present a significant sodium load. Use of normal saline for volume resuscitation followed by excess free-water loss induced by loop diuretics is another example of hypernatremia caused by sodium loading.

Hyponatremia

Hyponatremia may occur in the context of hypovolemia, euvoolemia, or hypervolemia. Serum Na < 120 mEq/L may manifest acutely as seizures, or with altered mental status ranging from disorientation to lethargy to coma. At < 115 mEq/L, hyperreflexia, pseudobulbar palsy, and Cheyne-Stokes respiration may be observed.

Normally, a reduction in serum sodium is paralleled by a reduction in serum osmolarity (SOsm), which suppresses ADH secretion. Hyponatremia develops most often as a result of an impaired ability to suppress ADH despite a SOsm fall. Rarely, the cause is water intake which is so massive that it exceeds the kidneys'

ability to excrete it. A convenient way to classify hyponatremia is by volume status.

Hypovolemic hyponatremia can result from GI or renal losses of fluid. It was previously noted that vomiting and diarrhea typically involves fluid loss which has sodium + potassium concentration less than that of plasma and may result in hypernatremia. However, in the setting of severe intravascular depletion, baroreceptors respond by overcoming ADH suppression and instead causing its release in an attempt to recover intravascular volume. The contribution of renal fluid loss can be magnified by thiazide diuretics, which allow sodium and chloride to be secreted, but in contrast to loop diuretics, do not disrupt the countercurrent gradient; thus, ADH is still able to mediate urine concentration.

Euvolemic hyponatremia is exemplified by the syndrome of inappropriate ADH secretion, which can also be hypervolemic in the extreme. Commonly encountered causes unrelated to osmotic and hemodynamic stimuli (which would be "appropriate") include bronchiolitis, asthma, pneumonia, positive-pressure ventilation, CNS insults and trauma. Hospitalized pediatric patients also have several reasons for physiologically elevated ADH levels such as nausea, vomiting, pain, stress, and hypoxia. Given that iatrogenic hyponatremia has been associated with the routine administration of hypotonic fluids to hospitalized pediatric patients, some authors advocate for the predominant use of isotonic fluids in this setting.

Hypervolemic hyponatremia is seen with heart failure, cirrhosis, advanced renal failure, and water intoxication. Diminished cardiac output in heart failure and arteriolar dilation in cirrhosis can inappropriately signal 'volume depletion' to baroreceptors despite volume retention, once again triggering ADH release. Meanwhile, atrial stretch-induced natriuretic peptide release causes sodium secretion. Severe renal failure results in impaired renal free water excretion. Hyponatremia is often a late finding in these conditions and reflects severity of disease. In pediatrics, water intoxication is encountered most frequently in infants

who are given large amounts of water, overwhelming the kidney's ability to excrete free water.

Hyperosmolar states can fall in any volemic category. Profound hyperglycemia, or alternate osmole accumulation such as mannitol in the setting of renal failure, will draw water out of cells and cause a dilutional hyponatremia (If the osmotic diuresis is profound, however, electrolyte-free water loss will cause SNa to rise as noted previously). Significant hyperlipidemia or hyperproteinemia reduces the proportion of plasma that is free water; while sodium concentration in the free water fraction remains the same, it is reduced relative to total plasma volume because the free water fraction is reduced; this has earned it the name 'factitious.'

11. Alterations in K blood plasma content: etiology and consequences.

Potassium is the predominant intracellular cation. Normal serum potassium levels are between 3.5 and 5.5 mEq/L. This is much less than intracellular levels that range between 140 and 150 mEq/L. The distribution of potassium levels across cellular membranes helps determine the resting membrane potential as well as the timing of membrane depolarization. Therefore, organ systems largely dependent on membrane depolarization for function are most affected by changes in serum potassium levels.

In **hypokalemia**, the resting membrane potential is increased. Both action potentials and refractory periods are prolonged. Symptoms do not generally develop unless potassium levels are less than 3.0 mEq/L. The following signs and symptoms should raise the concern for hypokalemia:

Cardiac manifestations:

- -T wave flattening
- -ST depression
- -Appearance of U wave
- -Arrhythmias

Skeletal and smooth muscle manifestations:

- -Hypotonia and muscle weakness
- -Respiratory depression
- -Muscle cramps
- -Constipation and/or ileus
- -Rhabdomyolysis and myoglobinuria

In hyperkalemia, the resting membrane potential is decreased, and the membrane becomes partially depolarized. Initially, this increases membrane excitability. However, with prolonged depolarization, the cell membrane will become more refractory and less likely to fully depolarize. The following signs and symptoms should raise the concern for hyperkalemia:

Cardiac manifestations:

- -Peaked T waves
- -Shortened QT interval
- -Prolonged PR interval
- -Flattening of P wave
- -Widened QRS interval
- -Bundle branch and atrioventricular conduction blocks
- -Arrhythmias

Skeletal muscle manifestations:

- -Ascending muscle weakness
- -Flaccid paralysis

The causes of both hypokalemia and hyperkalemia can be classified into causes related to changes in intake, changes in excretion, and shifts between the intracellular and extracellular spaces.

Causes of Hypokalemia:

Decreased Intake: Daily potassium intake is 2 to 4 mEq/Kg/day up to 40-120 mEq/day in adults. Because the kidneys are able to significantly limit the excretion of potassium, hypokalemia rarely develops exclusively from decreased potassium intake.

Increased Urinary Excretion:

Increased mineralocorticoid activity: Aldosterone increases urinary sodium reabsorption, thereby promoting passive excretion of potassium into the urine.

Polyuria: While the kidneys are generally able to reduce potassium concentrations to 5 to 10 mEq/L, high urine output may still lead to excessive potassium losses.

Diuretics: Loop diuretics, thiazides, and carbonic anhydrase inhibitors can all cause urinary potassium loss.

Metabolic alkalosis: States that lead to increased bicarbonate and therefore increased delivery of bicarbonate to the distal tubules can lead to passive excretion of potassium.

Renal Tubular Acidosis leads to shifting of potassium from the intracellular to the extracellular space and resultant total body depletion of potassium even when serum potassium levels may remain normal. Once treatment is begun with bicarbonate replacement, the true hypokalemic state may be realized as increased bicarbonate delivery to the distal tubules will lead to increased excretion of potassium.

Hypomagnesemia: While mechanisms are unclear, hypomagnesemia alone can cause increased potassium loss in the urine.

Increased Losses other than urinary:

Gastrointestinal: Potassium levels in stool can range between 10 and 80 mEq/L. Prolonged or severe diarrhea can lead to clinically significant potassium losses and hypokalemia.

Sweat: Potassium levels are 5 to 10 mEq/L in sweat. Circumstances that can lead to clinically significant potassium losses from sweat include very hot environments, strenuous exercise, and cystic fibrosis.

Shifting of potassium into the intracellular space:

Alkalosis: With the rise in serum pH, intracellular hydrogen ions will pass into the extracellular fluid in order to minimize the extracellular increase in pH. To

maintain electroneutrality, potassium ions will enter the intracellular space to replace the exiting hydrogen ions.

Insulin: Insulin increases the transport of potassium into skeletal muscle and hepatocytes.

Beta-adrenergic activity: Both endogenous and exogenous catecholamines can increase the transport of potassium into cells. Aerosolized albuterol therapy for asthma exacerbations is a common cause of mild hypokalemia in children, although this rarely leads to clinical significance.

Hypokalemic periodic paralysis: A rare genetic disorder that is characterized by sudden and rapid shifts of potassium into cells, leading to very low serum potassium levels. Attacks are manifested by muscular weakness or generalized paralysis that lasts less than 24hrs.

Causes of Hyperkalemia:

Decreased Urinary Excretion:

Renal Failure: Impaired potassium regulation and excretion most often arises in oliguric states and when distal renal tubular flow is compromised.

Hypoaldosteronism: Low levels of aldosterone will result in increased sodium excretion and potassium retention.

Distal renal tubular acidosis: In type I RTA, impaired reabsorption of sodium will lead to decreased potassium excretion.

Other drugs: Spironolactone and ACE inhibitors both can decrease the renal excretion of potassium.

Shifting of potassium into the extracellular compartment:

Metabolic Acidosis: With the decrease in serum pH, extracellular hydrogen ions will pass into the intracellular fluid in order to minimize the extracellular decrease in pH. To maintain electroneutrality, potassium ions will leave the intracellular space to replace the entering hydrogen ions.

Beta-adrenergic Blockade: Nonselective beta-blockers can decrease the transport of potassium into cells.

Insulin: In diabetes, decreased insulin will lead to reduced transport of potassium into cells.

Increased Tissue Breakdown: Injuries and conditions that lead to cellular breakdown can increase serum potassium levels. Such conditions include crush injuries, rhabdomyolysis, and tumor lysis syndrome.

12. Alterations in Ca blood plasma content: etiology and consequences.

Calcium is an important divalent cation required for many enzymatic and cellular functions. It is a critical component of bone ossification, and as one would expect, about 99% of total body calcium resides in skeletal tissue. Of the fraction found in plasma, about 40% of it is bound to protein, and 10% is complexed with anions. The remaining serum calcium is ionized and unbound. While serum ionized calcium represents only a very small fraction of total body calcium, it is also the most physiologically important form of calcium circulating in the body. Depending on age, normal serum ionized calcium levels range between 0.95 and 1.5 mmol/L (3.7 and 6mg/dL).

Several organ systems can be impacted by derangements of calcium homeostasis. Among its many functions, calcium plays a key role in cardiac pacemaking, muscle contraction, neuronal function, vascular tone, and hemostasis. Derangements in calcium homeostasis can cause both acute findings related to changes in serum ionized calcium levels as well as chronic findings related to prolonged calcium imbalances.

Evaluation of abnormal calcium levels may take into consideration the age of the patient as well as how the homeostatic processes of the body regulating calcium may be affected. There are two general categories of processes that can lead to imbalances in calcium homeostasis.

First, extracellular calcium is very tightly regulated by a complex series of hormonal actions through Vitamin D and parathyroid hormone (PTH). Therefore, a failure in any component of this system can lead to derangements in calcium levels. Chronic or subacute calcium derangements are often caused by this process.

Secondly, since a large amount of extracellular calcium is complexed with proteins or anions, conditions that affect protein binding and chelation can also affect unbound calcium levels. Acute hypocalcemia is more likely to be caused by this type of process.

Causes of Hypocalcemia can be divided into four categories:

- impaired ability to mobilize calcium bone stores,
- abnormal losses of calcium from the kidney,
- increased protein binding or chelation such that greater proportions of calcium are in the nonionized form
- soft tissue sequestration

Plasma calcium exists in a dynamic equilibrium with calcium in bone. The ability to mobilize calcium from bone depends on adequate levels of PTH. Decreased levels of PTH may result from primary or secondary forms of hypoparathyroidism. Suppression of PTH release may also occur when vitamin D levels are elevated. The activated form of vitamin D (calcitriol) can be used to suppress the secondary hyperparathyroidism that occurs in persons with kidney failure. Magnesium deficiency inhibits PTH release and impairs the action of PTH on bone resorption. This form of hypocalcemia is difficult to treat with calcium supplementation alone and requires correction of the magnesium deficiency.

There is an inverse relation between calcium and phosphate excretion by the kidneys. Phosphate elimination is impaired in renal failure, causing plasma calcium levels to decrease. Hypocalcemia and hyperphosphatemia occur when the glomerular filtration rate falls below 25 to 30 mL/ minute (normal is 100 to 120 mL/minute). Only the ionized form of calcium is able to leave the capillary and participate in body functions. A change in pH alters the proportion of calcium that is in the bound and ionized forms. An acid pH decreases binding of calcium to protein, causing a proportionate increase in ionized calcium, whereas total plasma calcium remains unchanged.

An alkaline pH has the opposite effect. As an example, hyperventilation sufficient to cause respiratory alkalosis can produce tetany because of increased

protein binding of calcium. Free fatty acids increase binding of calcium to albumin, causing a reduction in ionized calcium. Elevations in free fatty acids sufficient to alter calcium binding may occur during stressful situations that cause elevations of epinephrine, glucagon, growth hormone, and adrenocorticotrophic hormone levels.

Hypocalcemia is a common finding in a patient with acute pancreatitis. Inflammation of the pancreas causes release of proteolytic and lipolytic enzymes. It is thought that the Ca^{2+} combines with free fatty acids released by lipolysis in the pancreas, forming soaps and removing calcium from the circulation.

Calcium deficit due to dietary deficiency exerts its effects on bone stores rather than extracellular calcium levels. A dietary deficiency of vitamin D is seldom seen today because many foods are fortified with vitamin D. Vitamin D deficiency is more likely to occur in malabsorption states, such as biliary obstruction, pancreatic insufficiency, and celiac disease, in which the ability to absorb fat and fat-soluble vitamins is impaired. Failure to activate vitamin D is another cause of hypocalcemia.

Manifestations. Hypocalcemia can manifest as an acute or chronic condition. The manifestations of acute hypocalcemia reflect the increased neuromuscular excitability and cardiovascular effects of a decrease in ionized calcium. Ionized calcium stabilizes neuromuscular excitability, thereby making nerve cells less sensitive to stimuli. Nerves exposed to low ionized calcium levels show decreased thresholds for excitation, repetitive responses to a single stimulus, and, in extreme cases, continuous activity. The severity of the manifestations depends on the underlying cause, rapidity of onset, accompanying electrolyte disorders, and extracellular pH. Increased neuromuscular excitability can manifest as paresthesias (i.e., tingling around the mouth and in the hands and feet) and tetany (i.e., muscle spasms of the muscles of the face, hands, and feet). Severe hypocalcemia can lead to laryngeal spasm, seizures, and even death.

Cardiovascular effects of acute hypocalcemia include hypotension, cardiac insufficiency, cardiac dysrhythmias (particularly heart block and ventricular

fibrillation), and failure to respond to drugs such as digitalis, norepinephrine, and dopamine that act through calcium-mediated mechanisms.

Chronic hypocalcemia is often accompanied by skeletal manifestations and skin changes. There may be bone pain, fragility, deformities, and fractures. The skin may be dry and scaling, the nails brittle, and the hair dry. Development of cataracts is common. A person with chronic hypocalcemia may also present with mild diffuse brain disease mimicking depression, dementia, or psychoses.

Hypercalcemia represents a total plasma calcium concentration of greater than 10.5 mg/dL. Falsely elevated levels of calcium can result from prolonged drawing of blood with an excessively tight tourniquet. Increased plasma proteins (e.g., hyperalbuminemia, hyperglobulinemia) may elevate the total plasma calcium but not affect the ionized calcium concentration.

Causes. A plasma calcium excess (i.e., hypercalcemia) results when calcium movement into the circulation overwhelms the calcium regulatory hormones or the ability of the kidney to remove excess calcium ions.

The two most common causes of hypercalcemia are increased bone resorption due to neoplasms and hyperparathyroidism. These two etiologies account for more than 90% of all patients with hypercalcemia. Hypercalcemia is a common complication of malignancy, occurring in approximately 10% to 20% of persons with advanced disease. A number of malignant tumors, including carcinoma of the lungs, have been associated with hypercalcemia.

Some tumors destroy the bone, but others produce humoral agents that stimulate osteoclastic activity, increase bone resorption, or inhibit bone formation.

Less frequent causes of hypercalcemia are prolonged immobilization, increased intestinal absorption of calcium, excessive doses of vitamin D, and the effects of drugs such as lithium and thiazide diuretics. Prolonged immobilization and lack of weight bearing cause demineralization of bone and release of calcium into the bloodstream. Intestinal absorption of calcium can be increased by excessive doses of vitamin D.

A variety of drugs elevate calcium levels. The use of lithium to treat bipolar disorders has caused hypercalcemia and hyperparathyroidism. The thiazide diuretics increase calcium reabsorption in the distal convoluted tubule of the kidney. Although the thiazide diuretics seldom cause hypercalcemia, they can unmask hypercalcemia from other causes such as underlying bone disorders and conditions that increase bone resorption.

Manifestations. The signs and symptoms associated with calcium excess originate from three sources: changes in neural excitability, alterations in smooth and cardiac muscle function, and exposure of the kidneys to high concentrations of calcium.

Neural excitability is decreased in patients with hypercalcemia. There may be a dulling of consciousness, stupor, weakness, and muscle flaccidity. Behavioral changes may range from subtle alterations in personality to acute psychoses.

The heart responds to elevated levels of calcium with increased contractility and ventricular dysrhythmias. Digitalis accentuates these responses. Gastrointestinal symptoms reflect a decrease in smooth muscle activity and include constipation, anorexia, nausea, and vomiting. Pancreatitis is another potential complication of hypercalcemia and is probably related to stones in the pancreatic ducts.

High calcium concentrations in the urine impair the ability of the kidneys to concentrate urine by interfering with the action of ADH (an example of nephrogenic diabetes insipidus). This causes salt and water diuresis and an increased sensation of thirst. Hypercalciuria also predisposes to the development of renal calculi.

Hypercalcemic crisis describes an acute increase in the plasma calcium level. Malignant disease and hyperparathyroidism are the major causes of hypercalcemic crisis. In hypercalcemic crisis, polyuria, excessive thirst, volume depletion, fever, altered levels of consciousness, azotemia (i.e., nitrogenous wastes in the blood), and a disturbed mental state accompany other signs of calcium

excess. Symptomatic hypercalcemia is associated with a high mortality rate; death often is caused by cardiac arrest.

Examples of KROK tests and situational tasks on acid-base balance disorders

1. Trauma of the head brain a patient is accompanied by repeated vomiting and shortness of breathing. At an inspection it is marked: $\text{pH} = 7,62$; $\text{pCO}_2 = 40$ mm of Hg. What is violation of the acid-basic state at a patient?

- A Ungas alkalosis
- B Gas alkalosis
- C Ungas acidosis
- D Gas acidosis
- E -

2. Hypoxemia and hypercapnia are educed at the research of blood gas composition at the patient with the chronic disease of respiratory system on a background of the shortness of breathing, tachicardia and cyanosys. Because of what violations of the external breathing these changes were arise up?

- A Hypoventilation
- B Hyperventilation
- C Hyperperfusion
- D Hypoperfusion
- E Hyperdiffusion

3. A newborn child with pylorostenosis has often repeating vomiting accompanied by apathy, weakness, hypertonicity, sometimes convulsions. What disorder form of acid-base balance is it?

- A Nongaseous alkalosis
- B Gaseous alkalosis
- C Gaseous acidosis
- D Metabolic acidosis
- E Excretory acidosis

4. After taking poor-quality food a patient developed repeated episodes of diarrhea. On the next day he presented with decreased arterial pressure, tachycardia, extrasystole. Blood pH is 7,18. These abnormalities were caused by the development of:

- A Nongaseous acidosis
- B Gaseous acidosis
- C Nongaseous alkalosis
- D Gaseous alkalosis
- E Metabolic alkalosis

5. Disorder of the airways passage in small and middle bronchi was revealed in the patient. What disorder of the acid-base equilibrium can be detected in the blood?

- A Respiratory acidosis
- B Metabolic acidosis

- C Respiratory alkalosis
- D Metabolic alkalosis
- E --

6. 48 y.o. patient with diabetes mellitus was admitted to the hospital in severe pre-coma state. When examining of acid-base balance metabolic acidosis was revealed. What is the main possible mechanism of found changes development?
- A. Disorders of O_2 using in cells
 - B. Disorders of buffer systems of blood
 - C. Decrease of CO_2 removing
 - D. Excretion of alkali elements with urine
 - E. Formation of products of incomplete oxydation
7. A group of mountain climbers went through the blood analysis at the height of 3000 m. It revealed decrease of HCO_3^- to 15 micromole/l (standard is 22-26 micromole/l). What is the mechanism of HCO_3^- decrease?
- A Hyperventilation
 - B Intensification of acidogenesis
 - C Hypoventilation
 - D Decrease of ammoniogenesis
 - E Decrease of bicarbonate reabsorption in kidneys
8. For a patient with respiratory insufficiency pH of blood is 7,35. Determination of pCO_2 showed the presence of hypercapnia. At research of pH of urine the increase of her acidity is marked. What form of violation of the acid-basic state in this case?
- A Compensated gas acidosis
 - B Compensated metabolic acidosis
 - C Decompensated metabolic acidosis
 - D Compensated gas alkalosis
 - E Decompensated gas alkalosis
9. Toxicosis with the heavy repeated vomiting for a day long developed at a pregnant woman. After twenty-four hours tetaniform convulsions and dehydration of organism began to show up. What change of pH caused the described changes?
- A Excretory alkalosis
 - B Gas alkalosis
 - C Gas acidosis
 - D Metabolic acidosis
 - E Secretory acidosis
10. In a patient with diabetes mellitus metabolic acidosis developed as a result of accumulation of keton bodies. Arterial blood pH is:
- A. 7,40
 - B. 7,32
 - C. 7,48
 - D. 7,56
 - E. 7,66

11. Patient of D., 48 y.o., which suffers from obesity, conducted the course of medical starvation in home terms. The deep, noisy breathing appeared on 10 day,

arterial pressure went down to 90/60 mm Hg, a selection of urine diminished, urine with the smell of acetone. What is conditioned described?

- A. Non gas alkalosis
- B. Hyperglycemia
- C. Ketosis
- D. Hypoglycemia
- E. Gas acidosis

12. A 65-years-old patient with multiple fractures of ribs was admitted to the hospital. What type of acid-base balance disorder may develop in him?

- A. Gas acidosis
- B. Gas alkalosis
- C. Non-gas acidosis
- D. Non-gas alkalosis
- E. There are no disorders of acid-base balance

13. A pregnant woman has toxicosis, which accompanied by prolonged vomiting. Data of her biochemical analyses show: pH of blood – 7.38, pCO₂ of arterial blood – 46 mmHg, SB – 17 mmol/L, BE – (+ 6 mmol/L). What type of acid-base balance disorder takes place in this case?

- A. Compensated non-gas alkalosis
- B. Decompensated non-gas alkalosis
- C. Compensated non-gas acidosis
- D. Decompensated non-gas acidosis
- E. Compensated gas alkalosis

14. A 58-years-old female patient was admitted to the hospital in severe state. Data of her biochemical analyses show: pH of blood – 7.33, pCO₂ of arterial blood – 36 mmHg, SB – 17 mmol/L, BE – (- 6 mmol/L). What type of acid-base balance disorder takes place in this case?

- A. Compensated non-gas alkalosis
- B. Decompensated non-gas alkalosis
- C. Compensated non-gas acidosis
- D. Decompensated non-gas acidosis
- E. Compensated gas alkalosis

15. What is the reason for gas alkalosis?

- A. Pulmonary hyperventilation
- B. Loss of gastric juice
- C. Loss of intestine juice
- D. Pulmonary hypoventilation
- E. Hyperaldosteronism

16. What kind of acid-base balance disturbances may be observed in case of diabetes mellitus?

- A. Non-gas acidosis
- B. Gas acidosis
- C. Gas alkalosis
- D. Non-gas alkalosis
- E. Excretory acidosis

17. At examination of patient following were found: hyperglycemia, ketonuria, polyuria, hyperstenuria, and glucosuria. What kind of acid-base balance disturbances occurs in this case?
- A. Gas alkalosis
 - B. Non-gas alkalosis
 - C. Metabolic alkalosis
 - D. Metabolic acidosis
 - E. Gas alkalosis
18. At getting up in mountains euphoria, head pain, dizziness, heart beating, dyspnoe, which was alternated from apnoe, developed for an alpinist. What did violation of the acid-basic state develop for an alpinist?
- A. Metabolic alkalosis
 - B. Gas alkalosis
 - C. Non gas alkalosis
 - D. Gas acidosis
 - E. Non gas acidosis
19. Respiratory alkalosis developed in group of alpinists during ascending to on Everest. Thus pressure of CO₂ in arterial blood:
- A. 40 mm Hg
 - B. 50 mm Hg
 - C. 60 mm Hg
 - D. 70 mm Hg
 - E. 30 mm Hg
20. A patient suffered from diabetes mellitus was admitted to the hospital because of worsening of his condition. He has general malaise, polyuria, lethargy, and sleepiness. Kussmaul respiration, heart arrhythmia, and acetone scent in expired air are noticed in this patient. What kind of shift of acid-base balance contributes these symptoms?
- A. Gas alkalosis
 - B. Gas acidosis
 - C. Non-gas metabolic alkalosis
 - D. Non-gas metabolic acidosis
 - E. Non-gas excretory alkalosis
21. What violation of the acid-basic state does take place at blood pH 7,48?
- A. Alkalosis decompensate
 - B. Alkalosis compensated
 - C. Metabolic decompensated acidosis
 - D. Acidosis compensated
 - E. Acidosis excretory decompensated
22. What acid –basic balance disorder can develop in 2 hours after repeated vomiting?
- A. Excretory acidosis
 - B. Excretory alkalosis
 - C. Eczogenic alkalosis
 - D. Metabolic acidosis

- E. Eczogenic acidosis
23. Patient, who suffers from severe diarrhea, was admitted to the hospital with consequences disorder, Kussmaul respiration. Blood pH 7,30, deficiency of base. Acidic reaction of urine, contain many phosphates and ammonium salts. What is acid-basic balance disorder develop in this case?
- A. Non-gas alkalosis
 - B. Non-gas acidosis
 - C. Excretory alkalosis
 - D. Gas alkalosis
 - E. Gas acidosis
24. Repeated vomiting occurs in patient suffered from pylorostenosis which is bring to severe state. Appeared appation, weakness, increased muscular tonus, cramps. What is acid-basic balance disorder develop in this case?
- A. Non-gas alkalosis
 - B. Non-gas acidosis
 - C. Excretory alkalosis
 - D. Gas alkalosis
 - E. Gas
25. In the case of development of mountain disease compensatory lung hyperventilation is developed. What is acid-basic balance disorder develop in this case?
- A. Non-gas alkalosis
 - B. Non-gas acidosis
 - C. Excretory alkalosis
 - D. Gas alkalosis
 - E. Gas acidosis
26. During bronchial asthma attack patient developed gas acidosis (hypercapnia). What type of acid-base balance disorder takes place in this case?
- A. Gas alkalosis
 - B. Gas acidosis
 - C. Non-gas metabolic alkalosis
 - D. Non-gas metabolic acidosis
 - E. Non-gas excretory alkalosis
27. Patient was appointed solution of glucose intravenously with potassium bicarbonat. Such indexes are determined: pH- 7,43; pCO₂ - 61 mm Hg; SB - 31,5 mecv/l; BB - 59 mecv/l; BE +8,5 mecv/l . What ABB violation does take place in this case?
- A. Non gas alkalosis
 - B. Non gas acidosis
 - C. Excretory alkalosis
 - D. Gas acidosis
 - E. Gas alkalosis
28. Patient had such laboratory parameters – pH-7,32, pCO₂ 35 mm Hg, SB- 16,5 mecv/l, BB – 35,0 mecv/l, BE – 9,0 mecv/l, TK day urine - 8,0 mecv/day. What is acid-basic balance disorder develop in this case?

- A. Non-gas alkalosis
- B. Non-gas acidosis
- C. Excretory alkalosis
- D. Gas alkalosis
- E. Gas acidosis

29. Patient get head trauma, which accompanied with repeated vomiting and dyspnoe. Laboratory tests: pH -7,48, pCO₂ – 30 mm Hg, SB – 27 mecv/l, BB- 50,0 mecv/l., BE -+ 3,0 mecv/l. What is acid-basic balance disorder develop in this case?

- A. Non-gas alkalosis
- B. Non-gas acidosis
- C. Excretory alkalosis
- D. Gas alkalosis
- E. Gas acidosis

30. For a patient with nephrotic syndrome polyuria observed, hyponatremia (patient gets diacarb). Patient had such laboratory parameters: pH - 7,30; pCO₂ - 36 mm Hg; SB- 17,0 mecv/l; BB - 42 mecv/l; BE - 8,0 mecv/l. What ABB violation does take place in this case?

- A. Non gas alkalosis
- B. Non gas acidosis
- C. Excretory alkalosis
- D. Gas acidosis
- E Gas alkalosis

31. Patient in comatose state. Laboratory tests: keton bodies – 58 mg%, TK day urine- 40 mecv/day, pH – 7,30, p CO₂ – 50 mmHg, SB – 15,5 mecv/l, BB – 38,0 mecv/l, BE – 13,0 mecv/l. What is acid-basic balance disorder developing in this case?

- A. Non-gas alkalosis
- B. Non-gas acidosis
- C. Excretory alkalosis
- D. Gas alkalosis
- E. Gas acidosis

32. Patient suffers from severe toxic damage of kidney with anuria. Laboratory tests: lactic acid – 20 mg%, pH -7,25, p CO₂ - 47 mecv/l, SB -18,5 mecv/l, BB – 40,5 mecv/l, BE -70 mecv/l. What is acid-basic balance disorder develop in this case?

- A. Non-gas alkalosis
- B. Non-gas acidosis
- C. Excretory alkalosis
- D. Gas alkalosis
- E. Gas acidosis

33. An operation is conducted with artificial ventilation of lungs. Patient had such laboratory parameters: pH -7,47; pCO₂-75 mm Hg; SB-27,0 mecv/l; BB-49,0 mecv/l; BE+3,5 mecv/l. What ABB violation does take place in this case?

- A. Non-gas alkalosis

- B. Non-gas acidosis
- C. Excretory alkalosis
- D. Gas alkalosis
- E. Gas acidosis

34. An operation is conducted with artificial ventilation of lungs. Patient had such laboratory parameters: pH -7,32; pCO₂-25 mm Hg; SB-20 mecv/l; BB-40 mecv/l; BE+3,0 mecv/l. What ABB violation does take place in this case?

- A. Non-gas alkalosis
- B. Non-gas acidosis
- C. Excretory alkalosis
- D. Gas alkalosis
- E. Gas acidosis

35. Patient suffers from sharp insufficiency of left ventricle of heart. Edema of lung developed. Patient had such laboratory parameters: pH - 7,32; pCO₂ - 51 mm Hg; SB - 18,0 mecv/l; BB - 45 mecv/l; BE +8.0 mecv/l. What ABB violation does take place in this case?

- A. Non-gas alkalosis
- B. Non-gas acidosis
- C. Excretory alkalosis
- D. Gas alkalosis
- E. Gas acidosis

36. For a patient with diabetes mellitus hyperglycemia, ketonuria, glycosuria is marked, hyperstenuria and polyuria. What form of ABB violation does take place in this situation?

- A. Gas acidotic
- B. Metabolic acidosis
- C. Gas alkalosis
- D. Non gas alkalosis
- E. Excretory alkalosis

Correct answers								
1-A	2-A	3-A	4-A	5-A	6-E	7-A	8-A	9-A
10-B	11-C	12-A	13-A	14-D	15-A	16-A	17-D	18-B
19-E	20-D	21-A	22-B	23-B	24-C	25-D	26-B	27-A
28-B	29-C	30-B	31-B	32-B	33-E	34-D	35-B	36-B

Situational tasks:

1. An alpinist frequency and breathing depth was sharply increased. After some time breathing depressed and loss of consciousness came suddenly.

- 1) What type of ABB violation take place in this patient?
- 2) What are possible reasons for it origin?
- 3) Explain the mechanism of frequent and deeply breathing at getting up on a height.
- 4) Why did breathing stimulation change its depression?

- 5) What does a patient need to appoint - the breathing by clear oxygen or carbogen?
2. Patient get head trauma, which accompanied with repeated vomiting and frequent breathing. During inspection found out the followings indexes of ABB: pH - 7,56; pCO₂ = 30mm Hg; SB = 28 mmol/L; BB = 50 mmol/L; BE = +5 mmol/L.
- 1) What type of ABB violation takes place in this patient?
 - 2) What are possible reasons of origin?
 - 3) What are the mechanisms of functions compensation in this case?
 - 4) What possible violations can arise up?
 - 5) How to correct ABB violation in a patient?
3. A pregnant woman has toxicosis, which accompanied by prolonged vomiting. Data of her biochemical analyses show: pH of blood – 7.38, pCO₂ of arterial blood – 46 mmHg, SB – 38 mmol/L, BE – (+ 6 mmol/L).
- 1) What type of ABB violation takes place in this patient?
 - 2) What are the mechanisms of functions compensation in this case?
 - 3) What possible violations can arise up?
 - 4) How to correct ABB violation in a patient?
4. Patient with diabetes mellitus has violation of acid-basic state, which developed as a result of keton bodies accumulation. Blood pH 7,32.
- 1) What type of ABB violation takes place in this patient?
 - 2) What possible violations can arise up from the side of different organs and systems?
 - 3) How to correct ABB violation in a patient?
5. A 58-years-old patient was admitted to the hospital in severe state. Data of her biochemical analyses show: pH of blood – 7.33, pCO₂ of arterial blood – 36 mmHg, SB – 17 mmol/L, BE – (- 6 mmol/L).
- 1) What type of ABB violation takes place in this patient?
 - 2) What are the mechanisms of functions compensation in this case?
 - 3) What possible violations can arise up from the side of different organs and systems?
 - 4) How does to correct ABB violation in a patient?
6. Patient with bronchial asthma has disturbances of airways passage at the level of small and medium bronchi.
- 1) What type of ABB violation takes place in this patient?
 - 2) What possible violations can arise up from the side of different organs and systems?
 - 3) How to correct ABB violation in a patient?
7. Patient suffers from bronchial asthma.

pH 7,35
pCO₂, mm Hg 52
SB, mmol/l 22
BB, mmol/l 45
BE, mmol/l +2

1. Name the type of ABB violation at the patient.
2. Explain the reasons of described violation origin.
3. How to correct the described violation?

8. An operation with using of artificial blood circulation is performed to the patient.

pH 7,34
pCO₂, mm Hg 37
SB, mmol/l 14
BB, mmol/l 29
BE, mmol/l -12

1. Name the type of ABB violation at the patient.
2. Explain the reasons of described violation origin.
3. How to correct the described violation?

9. Primary diagnosis of the patient is “diabetes mellitus”.

pH 7,36
pCO₂ mm Hg 36
SB, mmol/l 19,5
BB, mmol/l 39
BE, mmol/l -5
TA, mmol/l 37
NH₄⁺, mmol/l -17

1. Name the type of ABB violation at the patient.
2. Explain the reasons of described violation origin.
3. How to correct the described violation?

10. Primary diagnosis of the patient is “chronic glomerulonephritis, acute phase”.

pH 7,28
pCO₂ mm Hg 35
SB, mmol/l 16,5
BB, mmol/l 135
BE, mmol/l 9
TA, mmol/l 8
NH₄⁺, mmol/l -

1. Name the type of ABB violation at the patient.
2. Explain the reasons of described violation origin.
3. How to correct the described violation?

Examples of KROK tests and situational tasks on water and electrolyte metabolism disorders

1. A 56 year old patient suffering from cardiac insufficiency has edema of feet and shins, edematous skin is pale and cold. What is the leading mechanism of edema pathogenesis?
 - A Rise of hydrostatic pressure in venules
 - B Drop of oncotic pressure in capillaries
 - C Increase of capillary permeability
 - D Disorder of lymph outflow
 - E Positive water balance
2. A patient with nephrotic syndrome has massive edemata of his face and limbs. What is the leading pathogenetic mechanism of edemata development?
 - A Drop of oncotic blood pressure
 - B Increase of vascular permeability
 - C Rise of hydrodynamic blood pressure
 - D Lymphostasis
 - E Increase of lymph outflow
3. A patient was stung by a bee. Examination revealed that his left hand was hot, pink, edematous, there was a big red blister on the site of sting. What is the leading mechanism of edema development?
 - A Increased vessel permeability
 - B Reduced vessel filling
 - C Injury of vessels caused by the sting
 - D Drop of oncotic pressure in tissue
 - E Drop of osmotic pressure in tissue
4. A patient ill with enteritis accompanied by massive diarrhea has low water rate in the extracellular space, high water rate inside the cells and low blood osmolarity. What is such disturbance of water-electrolytic metabolism called?
 - A Hypo-osmolar hypohydration
 - B Hyperosmolar hypohydration
 - C Osmolar hypohydration
 - D Hypo-osmolar hyperhydration
 - E Hyperosmolar hyperhydration
5. A patient was admitted to the infectious department. His symptoms: dry skin, decreased skin turgor, rice-water stool. The patient was diagnosed with cholera. What disorder of water-electrolytic balance is most often observed in this disease?
 - A Isoosmotic hypohydration
 - B Hyperosmotic hyperhydration
 - C Hypoosmotic hypohydration
 - D Hyperosmotic hypohydration
 - E Hypoosmotic hyperhydration
6. Edema was modeled in the white rat by the injection of adrenalin. What pathogenetic mechanism of edema development?

- A. Oncotic
- B. Hydrodynamic
- C. Membranogenic
- D. Lymphogenic
- E. Colloid-osmotic

7. Patient of D., 35 years, complains about permanent thirst, decrease of appetite, headache and convulsion. He drinks 9 l during a day. Day's diuresis is increased, urine without pathological changes, specific gravity - 1005. The reason of development such pathology is the damage of:

- A. The epithelium of kidney tubule
- B. Adenohypophis
- C. Epyphis
- D. Hypothalamic nucleus
- E. Basal membrane of glomerulus capillaries

8. Inflammation is characterised by increasing penetration of vessels of microcirculation stream, increasing of their fluid dynamic blood pressure. Increasing of the osmotic concentration and dispersity of protein structures present in the intercellular fluid. What kind of edema will appear in this case?

- A Mixed
- B Hydrodynamic
- C Colloid-osmotic
- D Lymphogenic
- E Membranogenic

9. Inflammation of a patient's eye was accompanied by accumulation of turbid liquid with high protein at the bottom of anterior chamber that was called hypopyon. What process underlies the changes under observation?

- A Disturbance of microcirculation
- B Primary alteration
- C Secondary alteration
- D Proliferation
- E -

10. A patient who suffers from severe disorder of water-salt metabolism experienced cardiac arrest in diastole. What is the most probable mechanism of cardiac arrest in diastole?

- A Hyperkaliemia
- B Hyponatremia
- C Organism dehydration
- D Hypokaliemia
- E Hyponatremia

11. An animal with aortic valve insufficiency got hypertrophy of its left heart ventricle. Some of its parts have local contractures. What substance accumulated in the myocardiocytes caused these contractures?

- A Calcium
- B Potassium
- C Lactic acid

D Carbon dioxide

E Sodium

12. A patient who suffers from heart failure has enlarged liver, edemata of lower extremities, ascites. What is the leading mechanism in the development of this edema?

A Hydrodynamic

B Colloid osmotic

C Lymphogenous

D Membranogenic

E -

13. Periodic renal colics attacks are observed in the woman with primery hyperparathyroidizm. Ultrasonic examination revealed small stones in the kidneys. What is the cause of the formation of the stones?

A Hypercalcemia

B Hyperphosphatemia

C Hypercholesterinemia

D Hyperuricemia

E Hyperkalemia

14. Transmural myocardial infarction in the patient was complicated with progressive acute left ventricle insufficiency. What is the most typical for this state?

A Edema of the lungs

B Edema of the extremities

C Cyanosis

D Ascites

E Arterial hypertension

15. Patient suffered from cirrhosis of liver was intravenous injected 500 ml of 5% glucose solution. What disturbances of water-salt balance may appear in this patient?

A. Hypoosmolar hyperhydration

B. Hyperosmolar hyperhydration

C. Isoosmolar hyperhydration

D. Hypoosmolar hypohydration

E. There is no dyshydration

16. A person, who has been on vegetable diet for along time, has edemas. What is the main mechanism of edema development in this case?

A. Hypoaminoacidemia

B. Hypoproteinemia

C. Decrease of quantity of microelements in blood

D. Hypoglycemia

E. Anemia

17. Patient, 32, during 4 years suffers on chronic glomerulonephritis. Edemas are marked on face, lately edemas appeared in trunk, that glomerulonephritis with a nephrotic syndrome. What pathogenetic factor of edemas development for this patient?

- A. Increase of tissue liquid oncotic pressure
 - B. Difficulty of lymph outflow
 - C. Decrease of oncotic blood pressure
 - D. Increase of hydrodynamic blood pressure in capillaries
 - E. Increase of capillaries permeability
18. As a result of continuous starvation the glomerular filtration rate has increased by 20%. The most probable cause of the glomerular filtration alteration under the mentioned conditions is:
- A. Increase in the systemic arterial pressure
 - B. Increase in the permeability of the renal filter
 - C. Increase of the renal blood flow
 - D. Decrease in the oncotic pressure of blood plasma
 - E. Increase of the filtration quotient
19. After a surgery a 36-year-old woman was given an intravenous injection of concentrated albumin solution. This has induced intensified water movement in the following direction:
- A. From the intercellular fluid to the cells
 - B. From the intercellular fluid to the capillaries
 - C. No changes of water movement will be observed
 - D. From the cells to the intercellular fluid
 - E. From the capillaries to the intercellular fluid
20. A patient has osmotic pressure of blood plasma at the rate of 350 mOsmol/l (norm is 300 mOsmol/l). This will cause hypersecretion of the following hormone:
- A. Cortisol
 - B. Adrenocorticotropin
 - C. Vasopressin
 - D. Natriuretic
 - E. Aldosterone
21. Patient, 62 years, during 15 years suffers on insufficiency of mitral valve. Last month the edema of lower extremities began to arise up. What is the mechanism of edema development?
- A. Increase of permeability of capillaries
 - B. Decrease of oncotic blood pressure
 - C. Increase of oncotic pressure of tissue liquid
 - D. Violation of lymphatic vessels
 - E. Increase of hydrostatical blood pressure
22. A patient with chronic cardiac insufficiency have edema of lower extremities. What is the leading link of their pathogenesis?
- A. Hypothalamo-hypophysar system
 - B. Renin-angiotensin-aldosterone system
 - C. Sympato-adrenal system
 - D. Parasympathetic system
 - E. Kalikrein-kinin system
23. A person, after the long period of starvation has edema. What is the main mechanism of edema development in this case?

- A. Decrease of oncotic pressure in the blood
 - B. Increase of oncotic pressure in tissues
 - C. Increase of hydrostatic pressure of venous blood
 - D. Decrease of hydrostatic pressure of tissues
 - E. Decrease of blood circulating volume
24. Pulmonary hypertension and right-ventricle heart insufficiency with ascites and edemas develop in a patient suffered from pneumosclerosis. What is the main mechanism of edema development in this case?
- A. Increase of hydrostatic pressure in veins
 - B. Increase of oncotic pressure of tissues
 - C. Decrease of oncotic pressure of blood
 - D. Reduction of heart stroke volume
 - E. Increase of vascular permeability
25. Which of followings may cause the isoosmolar hypohydration?
- A. Acute blood loss
 - B. Diarrhea
 - C. Vomiting
 - D. Perspiration
 - E. Hyperventilation
26. A patient has uneasiness in the chest and difficult breathing after physical exertion. Some time later cough with foamy liquid phlegm appears. Significant cyanosis develops in the patient. What is the leading mechanism for edema development in this case?
- A. Hydrodynamic
 - B. Colloid
 - C. Membranogenous
 - D. Lymphogenic
 - E. Osmotic
27. Development of toxic edemat is predefined:
- A. Hypoproteinemia
 - B. By the promoted permeability of vessels
 - C. Hypernatremia
 - D. Acidosis
 - E. By the promoted hydrostatic pressure
28. Patient had trauma, hyperemia of skin is appeared in place of damage, she became hot. Pain, limitation extremity motions, edema appeared. Name the initiating pathogenetic factor of inflammatory edema?
- A. Increase of microvessels permeability
 - B. Decrease of oncotic blood pressure
 - C. An increase of blood pressure in capillaries
 - D. Violation of lymph outflow
 - E. An increase of osmotic pressure in the region of inflammation
29. A patient with severe nephropathy accompanied by severe oedema syndrome that develops as complication of bronchiectasis. Laboratory examination of this patient displays abundant proteinuria, cylinderuria, distinct decrease of protein

content in blood serum, hyperlipidemia, hypokalemia, and other pathological changes. What is the most important link in development of edemas in this patient?

- A. Decrease of oncotic pressure of blood
- B. Increase of osmotic pressure of interstitial fluid
- C. Increase of hydrostatic pressure of blood
- D. Blockade of lymphatic drainage
- E. Increase of microvessel permeability

30. At complete starvation (with taking water) generalized edemas develop. What is the leading pathogenic factor in this case?

- A. Increase of oncotic pressure of interstitial fluid
- B. Decrease of osmotic pressure of blood plasma
- C. Decrease of oncotic pressure of blood plasma
- D. Increase of osmotic pressure of interstitial fluid
- E. Decrease of hydrostatic pressure of interstitial fluid

31. What is the leading factor of edema development in case of nephrotic syndrome?

- A. Increase of hydrostatic pressure in capillaries
- B. Increase of vascular permeability
- C. Hypoalbuminemia
- D. Dynamic lymphatic insufficiency
- E. Increase of blood volume

32. A patient complain about a muscular weakness, feeling of weight in the epigastral area. At an inspection found out taxicardia, arterial hypotension, on ECG - lengthening the interval of PQ, decrease of T voltage. What violation of mineral metabolism causes development of these disorders?

- A. Hypernatremia.
- B. Hypokaliemia
- C. Hyperkaliemia.
- D. Hyponatremia.
- E. Deficit of iron.

33. A patient was admitted to the infectious hospital with complaints about unrestrained vomit. What violations of water-salt metabolism are there?

- A. Isoosmolar dehydration
- B. Hyperosmolar dehydration
- C. Hypoosmolar hyperhydration
- D. Hyperosmolar hyperhydration
- E. Hypoosmolar dehydration

34. People found themselves on the island after a catastrophe in the ocean, without fresh water. What form of water-salt metabolism violations will develop?

- A. Hyperosmolar hyperhydration
- B. Isoosmolar hypergidration
- C. Hypoosmolar hyperhydration
- D. Hyperosmolar dehydration
- E. Hypoosmolar dehydration

35. Osmotic diuresis develops at diabetes mellitus. What violations of water-electrolyte balance are observed?
- Isotonic dehydration
 - Hypoosmolar dehydration
 - Hyperosmolar hyperhydration
 - Hyperosmolar dehydration
 - Isoosmolar hyperhydration
36. Patient carried heavy infectious disease, after that appeared the signs of diabetes insipidus. Day's diuresis was increased to 10l. Afterwards dehydration of organism purchased threatening character. What mechanism of development?
- Increase of ultrafiltrate osmolarity
 - Braking of water suction in the intestine
 - Decrease of reabsorbtion of water in kidney
 - Decrease of reabsorbtion of sodium in kidney
 - Decrease of plasma oncotic pressure
37. Patient 43 years, appeared the signs of cardiac activity decompensation with the origin of edema and ascyt after the sharpening of rheumatic heart disease. The increase of production of what matter may cause those violation
- Aldosteron
 - Insulin
 - Cortisol
 - Vasopresin
 - Corticothropin
38. At a examination the edema is discovered in the area of left forearm, which arose up after the bite of bee. Name the leading pathogenetic mechanism of this edema:
- Hydrodynamic
 - Oncotic
 - Osmotic
 - Lymphogenic
 - Membranogenous
39. When treating for dehydration by means of salt-poor fluids at the background of sharply reduced excretory renal function resulted from tubular necrosis the worsening of general condition, confused consciousness, convulsive readiness, and brain edema with vomiting develop. What kind of water-salt metabolism disturbances takes place in this case?
- Hypoosmolar hyperhydration
 - Isoosmolar hyperhydration
 - Hyperosmolar hyperohydration
 - Hypoosmolar hypohydration
 - Hyperosmolar hypohydration
40. Edemas are developed in a patient with renal disease. High quantity of albumen in the analyses of urine. What mechanism is it possible to explain the origin of edemas for such patient?
- By the decrease of lymph oncotic pressure

- B. By the decrease of filtration pressure in buds
 - C. By the decrease of blood plasma oncotic pressure
 - D. By the decrease of interstitial oncotic pressure
 - E. By the increase of blood plasma osmotic pressure
41. Person, 64years, complain about the dysphnoe, frequent heart beating, rapid fatigueability. In the evening edemas appear on legs. What main pathogenetic factor in the development of edemas?
- A. Increase of tissue liquid oncotic pressure
 - B. Violation of lymph outflow
 - C. Decrease of oncotic blood pressure
 - D. Increase of hydrodynamic pressure
 - E. Increase of capillaries permeability
42. Edema of Quinke (common edema of tissues) developed in the patient with allergy. What pathogenetic factor is starting in this case?
- A. Decrease of hydrostatical pressure in tissues
 - B. Decrease blood plasma oncotic pressure
 - C. Increase of permeability of capillaries walls
 - D. An increase of hydrodynamic blood pressure
 - E. An increase of osmotic pressure in tissues
43. Considerable part of alimantar starvation cases are accompanied with edema. What is the main pathogenetic factor of edema in this case?
- A. Decrease of tissues hydrostatical pressure
 - B. Decrease of blood plasma oncotic pressure
 - C. Increase of blood osmotic pressure
 - D. Increase of intercellular liquid oncotic pressure
 - E. Increase of blood hydrodynamic pressure
44. Patient with burn shock next to anaesthetic drugs it is vitally necessary to enter antishock solutions in connection with water-electrolyte metabolism violations. What water-electrolyte metabolism violation most probably arise up at burn illness?
- A. Hypoosmolar of hypohydria
 - B. Hypoosmolar hyperhydration
 - C. Isoosmolar dehydration
 - D. Hyperosmolar dehydration
 - E. Hyperosmolar hyperhydria
45. Patient, 35 years, carried hepatitis and continued to adopt an alcohol, the signs of liver cirrhosis developed with ascyt and edemata of lower extremities. What blood composition changes did become deciding in development of edema?
- A. Hypokaliemia
 - B. Hypoglobulinemia
 - C. Hypoalbuminemia
 - D. Hypocholesterinemia
 - E. Hypoglycemia

46. Patient carried operative interference concerning intestinal impassability, after the signs of considerable dehydration appeared. What blood ions must be appointed in the first turn for water-salt balance correction?
- Chlor
 - Cuprum
 - Sodium
 - Calcium
 - Magnesium
47. A woman ate orange, after she has edema of palpebra, lips, neck, and tongue. Before on oranges there were pouring out on a skin, itch. What pathogenetic mechanism lies in development of edema?
- An increase of hydrodynamic blood pressure in capillaries
 - Violation of lymph outflow
 - Increase of capillaries permeability
 - Decrease of oncotic blood pressure
 - Increase of tissue fluid oncotic pressure
48. Patient, 35 years, who drinks alcohol often, has strong muscular and cardiac weakness, vomit, diarrhea, AP-100/60 mm Hg. All those symptoms developed during diuretics treatment. Reason of such state is the increased selection with urine:
- Phosphates
 - Na
 - K
 - Cl
 - Ca
49. Hypertensive solution of glucose was intravenously entered a patient. It will increased motion of water:
- From intercellular liquid to the capillaries
 - There were no changes
 - From capillaries to the intercellular liquid
 - From cell to the intercellular liquid
 - From intercellular liquid to the cell
50. Patient has reduced synthesis of vasopresin, that why he has polyuria and dehydration of organism. In what does consist mechanism of polyuria development of polyuria?
- Increase of glomerular filtration speed
 - Decrease of water reabsorbtion in tubuls
 - Decrease of Na⁺ reabsorbtion in tubuls
 - Decrease glucose of reabsorbtion
 - Decrease of protein reabsorbtion in tubuls

Correct answers									
1-A	2-A	3-A	4-A	5-A	6-B	7-D	8-A	9-A	10-A
11-A	12-A	13-A	14-A	15-A	16-A	17-C	18-D	19-B	20-C
21-E	22-B	23-A	24-A	25-A	26-A	27-B	28-E	29-A	30-C
31-C	32-B	33-E	34-A	35-D	36-C	37-A	38-E	39-A	40-C

41-D	42-C	43-B	44-C	45-C	46-C	47-C	48-C	49-D	50-B
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Situational tasks:

1. The worker of hot workshop had the unendurable feeling of thirst, increase of body temperature and brief loss of consciousness.

- 1) Type of water-electrolyte metabolism violation.
- 2) What measures of prophylaxis need to be taken, to prevent this violation?
- 3) What water-electrolyte metabolism violation will develop if patient will drink water without the salt?

2. Patient suffers from insufficiency of the mitral valve, patient marks the presence of edemas on lower extremities in the evening after work.

- 1) What is the mechanism of this edema development?
- 2) Explain their localisation?

3. A child had dehydration of organism in the result of diarrhea. Isotonic solution of sodium chloride and desoxycortikosteron (mineralocortikoid) were appointed intravenous. Muscular weakness developed after some time. The level of Na in plasma is - 180 mmol/L (in a norm - 135-155 mmol/L), to potassium - 3,4 mmol/L (in a norm - 3,5-5,5 mmol/L).

- 1) What is the mechanism of complication?
- 2) Is the medical tactic correct? Explain.

4. A 0,1% solution of adrenalin was injected to the white rat intraabdominal in dose - 1 mg/100g of body mass. In 30 minutes, breathing became frequent and superficial, then sharp and convulsive, than foamy liquid appeared from the nose cavity, there was acrocyanosis. At appearance of sharp edema of lungs an animal die. What pathogenetic mechanism of edema development?

- 1) What mechanism of edema development takes place in this case? Explain.

5. Patient D. 35 years, complain about permanent thirst, decrease of appetite, headache, convulsions. He drinks 9 l during a day. Diuresis is increased, urine without pathological changes, specific gravity - 1005.

- 1) What is the disease at the patient?
- 2) Reasons for its origin.
- 3) Explain the mechanisms of its development.
- 4) What forms of this disease do you know?
- 5) What is the treatment of the disease?

6. Patient D., 82, delivered in a hospital with chronic cardiac insufficiency in the decompensate state. Tachycardia, arterial pressure is decreased. There is edema of lower extremities.

- 1) What are the main pathogenetic factors in development of edemas at cardiac insufficiency.

RECOMMENDED LITERATURE

Basical:

1. General and clinical pathophysiology : textbook for students of higher educational institutions, of IV th level of accreditation / A. V. Kubyshkin [et al.] ; ed. by.: A. V. Kubyshkin, A. I. Gozhenko. - 2nd ed. - Vinnytsya : Nova Knyha Publishers, 2016. - 656 p.
2. Simeonova, N. K. Pathophysiology : textbook for students of higher medical educational institutions of the III-IV accreditation levels / N. K. Simeonova ; ed. by.: V. A. Mikhnev. - 2nd ed. - Kyiv : AUS Medicine Publishing, 2015. - 544 p.

Additional:

1. Damjianov, Ivan. Pathophysiology / I. Damjianov ; ill. M. Chansky. - Philadelphia : Saunders, 2009. - 464 p.
2. General and Clinical Pathophysiology : Workbook for medical students and practitioners. - Odessa : The Odessa State Medical University, 2002. - 243 p.
3. Gozhenko, A. I. Pathophysiology / A.I. Gozhenko, I.P. Gurkalova. - Odessa : The Odessa State Medical University, 2005. - 325 p.
4. Kumar V. Robbins and Cotran Pathologic Basis of Disease. V. II / V. Kumar, A. K. Abbas, J. C. Aster. - South Asia ed. - India : Elsevier, 2015. - 1391 p.
5. Kumar V. Robbins and Cotran Pathologic Basis of Disease. Vol. I / V. Kumar, A. K. Abbas, J. C. Aster. - South Asia ed. - India : Elsevier, 2015. - 1391 p.
6. McPhee, Stephen J. Pathophysiology of Disease An Introduction to Clinical Medicine [Electronic resource] : учебник / Stephen J. McPhee. - 2nd ed. - 107 МБ. - NY : Appleton & Lange, 2000.
7. Mufson, Maurice A. Pathophysiology : PreTest Self-Assessment & Review / M.A. Mufson, C. A. Heck, S. M. Nesler. - 3th ed. - Chicago : Medical Publishing Division, 2002. - 268 p.
8. Pathophysiology: textbook for students / P.F. Litvitsky, S.V. Pirozhkov, E.B. Tezikov). - Moscow:Geotar-Media, 2016. – 432 p.