CLINICAL BLOOD ANALYSIS

Methodical instructions
for English medium students
the 3rd–6ht year of medical university
(level III–IV of accreditation)

МІНІСТЕРСТВО ОХОРОНИ ЗДОРОВ'Я УКРАЇНИ
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Compilers T. V. Ashcheulova
N. N. Gerasimchuk

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Упорядники Т. В. Ащеулова
Н. М. Герасимчук

Blood is a specialized bodily fluid that delivers necessary substances to the body's cells – such as nutrients and oxygen – and transports waste products away from those same cells.

Constituents of human blood

- Blood accounts for 7 % of the human body weight, with an average density of approximately 1060 kg/m^3, very close to pure water's density of 1000 kg/m^3.
- The average adult has a blood volume of roughly 5 litres, composed of plasma and several kinds of cells (occasionally called corpuscles); these formed elements of the blood are erythrocytes (red blood cells), leukocytes (white blood cells) and thrombocytes (platelets).
- By volume the red blood cells constitute about 45 % of whole blood, the plasma constitutes about 55 %, and white cells constitute a minute volume.

Blood functions

Blood performs many important functions within the body including:

- Supply of oxygen to tissues (bound to hemoglobin which is carried in red cells)
- Supply of nutrients such as glucose, amino acids and fatty acids (dissolved in the blood or bound to plasma proteins (eg blood lipids)
- Removal of waste such as carbon dioxide, urea and lactic acid
- Immunological functions, including circulation of white cells, and detection of foreign material by antibodies
- Coagulation, which is one part of the body's self-repair mechanism
- Messenger functions, including the transport of hormones and the signaling of tissue damage
- Regulation of body pH (the normal pH of blood is in the range of 7,35–7,45) (covering only 0.1 pH unit)
- Regulation of core body temperature Hydraulic functions

Blood cells

A blood cell (also called blood corpuscle) is any cell of any type normally found in blood. In mammals, these fall into three general categories with life time:

- Red blood cells – 120 day
- White blood cells – days to years
- Platelets 28 days.

Determination of the number of erythrocytes, leukocytes and platelet in the blood has long been fundamental procedure in hematology. Manual methods provide satisfactory measurement of the leukocytes and platelet counts, but the erythrocytes count is quite inaccurate when performed manually. Electronic automatically cell counting methods by electrical impedance and optical devices are now widely used and permit accurate enumeration of all there formed elements.

The International Committee for Standardization in Hematology has recommended that the following units be used (SI units): white cell count, "number 10^9/l", red cell count, "number 10^{12}/l" and platelet as "number 10^9/l". Primary function: red blood cells - transport of oxygen; white blood cells – produces antibodies to fight infection; platelets – blood clotting.

Red blood cells (erythrocytes) (RBC)

All erythrocytes undergo the stage of reticulocytes. Coming from the bone marrow into the peripheral blood, reticulocytes within about a day and a half lose basophilic substance and turn into mature erythrocytes.

In an adult in the peripheral blood 2–10 reticulocytes per 1000 erythrocytes (0.7 %), the limit of normal – 0,2–1,2 %.

The value of reticulocytes. The number of reticulocytes is judged by: the effectiveness of erythropoiesis; about the effectiveness of treatment with iron, vitamin B_{12}, folic acid. Clinical significance of reticulocyte changes.

Increase:

– acute bleeding (more than 6–10 % of blood loss for 3–4 days after hemorrhage);

– acute hemolysis (up to 20–25 % and above);

– hemolytic anemia (in response to the need for erythrocytes);

– treatment with hematopoietic drugs (iron, vitamins, folic acid).

Reduction:

– chronic iron deficiency anemia (untreated);

– megaloblastic anemias;

– hypo- and aplastic anemias.

The number of reticulocytes begins to increase from day 4, maximum – for 8–9 days and returns to normal at the end of the second week.

Mature human red blood cell is shaped like flattened, bilaterally indented sphere. Normal sign – diameter 7–7,5 μm.

A normal mature red blood cell has a surface membrane and cytoplasm, which is further subdivided into hemoglobin and troma.

Normal values of erythrocytes count	
Men	4,0–5,0 ×· 10^{12}/L
Women	3,7–4,7 × 10^{12L}
Infants, full-term, cord blood	5,0±1.0 × 10^{12}/L
Children, 1 year	4,4±0.8 × 10^{12}/L
Children, 10–12 years	4,7±0.7 × 10^{12}/L

The level of erythrocytes is influenced by the following physiological factors:

1. Age. There is erythrocytosis in newborns. On the first day after birth, the level of Er – 6.0×10^{12}; HB 210–220 g/l. (Associated with the phenomena of intrauterine hypoxia).

2. Gender. In women, the number of erythrocytes in the blood is lower than in men (inhibitory effect of estrogen on erythropoiesis).

3. Exercise increases the number of erythrocytes.

4. Climbing to a height is accompanied by the development of erythrocytosis.

5. Emotional, stressful situations increase the number of erythrocytes.

Qualitative RBCs changes

- Size changes – anisocytosis
- Shape changes – poikilocytosis
- Color changes – anisochromia
- Degenerate forms – Howell-jolly bodies and Cabot rings

Shape changes – poikilocytosis:

- Spherocyte – spherical shape, no central pallor
- Elliptocyte – elliptical in shape, not hypochromic
- Target cell – hypochromic, with central pigment; thin cell; surface/ volume ratio increased
- Schisocytes – helmet or triangular shaped, fragmented or greatly distorted RBC; smaller than normal
- Stomatocyte – Uniconcave, as contrasted with normal biconcave RBC; slit-like instead of circular area of central pallor in RBC.

Howell-Jolly bodies. These are small, well-defined, round, densely staining basophilic inclusion bodies about 1 μm in diameter, which usually occur singly but sometimes in multiples. They appear after splenectomy and are also seen in cases of severe anemia from a variety of causes. They contain DNA and may be chromosomal remnants or nuclear fragments.

Cabot rings. These are blue-staining, threadlike inclusions in the red cells in severe anemia. They may appear as rings, figures-of-eight, or twisted and convoluted in a variety of shapes. They may occupy the entire periphery of the cell but frequently are much smaller. They are not often seen. It has been postulated that they are remnants of the mitotic spindle, but others have found that they contain histone and iron.

Howell-jolly bodies and Cabot rings occur mostly in vitamin B_{12} deficiency anemia.

Pathological changes

- microcytes < 6.5 μm
- macrocytes – 8 μm
- megaloblasts, megalocytes > 12 μm

Hemoglobin (Hgb) – 28 % of the red blood cells mass is composed by hemoglobin. The hemoglobin molecule is roughly spherical with a maximum molecular diameter of about 6,4 μm. It is a tetramer, consisting of

two pairs of polypeptide chains. To each of the four chains is attached a highly coloured prosthetic group – heme, a complex of iron and protoporphyrin The protein portion of the molecule is called globin.

An adult mature red cell has:

- hemoglobin A_1 (α_2 & β_2 chains) – 97 %;
- hemoglobin A_2 (α_2 & δ_2 chains) – 2,5 %;
- hemoglobin F (α_2 & γ_2 chains) – < 1 %.

Normal ranges for

Male 130–160 g/l

Female 120–140 g/l

The International Committal for Standardization in Hematology has recommended that the following units be used (SI units): hemoglobin, "g/dl" (dl-deciliters).

Normal values of hemoglobin	
Men	15,5±2,5 g/dl
Women	14,0±2,5 g/dl
Infants, full-term, cord blood	16,5±3,0 g/dl
Children, 1 year	12,0±1,0 g/dl
Children, 10–12 years	13,0±1,5 g/dl

Hemoglobin is a constituent of erythrocytes and ensures respiratory function of the blood (respiratory pigment). It is located inside the erythrocytes and not in the plasma owing to which:

1) blood viscosity is reduced; the content of the same quantity of hemoglobin in the plasma would increase several times blood viscosity sharply interfering with heart performance and circulation;

2) the oncotic pressure of plasma is decreased, which prevents tissue dehydration;

3) loss of hemoglobin by the body is prevented due to its filtration in the renal tubules and excretion in the urine.

White blood cells (leukocytes)

Leukocytes or white blood cells (WBCs) play an important role in body defence against micro-organisms, viruses, pathogenic protozoa, and foreign substances, i.e. they ensure immunity. In adults blood contains $4–9 \times 10^9$/L leukocytes, i.e. their number is 500–1000 times less than that of erythrocytes.

Leukocytes are classified as:

- granular (neutrophils, eosinophils, and basophils) and
- agranular (lymphocytes and monocytes).

To assess changes in the leukocyte count, the decisive importance is attached to changes in the interrelation of leukocytes rather than in their quantity. In healthy persons it is rather constant and any changes indicate various abnormalities.

*Neutrophilic granulocytes (*neutrophils) are the most numerous group of white corpuscles making up 50–75 per cent of all blood leukocytes. They are called so because their granular structure enables them to be stained readily with neutral dyes. Depending on the shape of their nucleus, the neutrophils are classified into juvenile (metamyelocytes), stab or band and segmented or polychronuclear. In the leukogram the juvenile forms constitute not more than 1 per cent, stab 1–5 per cent and segmented forms 45–70 per cent. The content of juvenile neutrophils rises in a number of diseases. Shift to the left (or regeneration index) indicates the proportion of the juvenile to mature forms of neutrophils. This name implies that the neutrophils in the leukogram are arranged from left to right by the degree of their maturity. This shift is calculated by the proportion of myelocytes, juvenile and stab forms to the number of segmented forms. Normally, it is 0,05–0,1 and can reach 1–2 in severe infections and inflammatory diseases.

The degree of the shift shows the disease gravity and the body reaction to it. Not more than 1 per cent of the total number of neutrophils circulates in the blood. Their main portion is accumulated in the tissues. At the same time, the marrow has a reserve of neutrophils that exceeds the amount of circulating neutrophils by 50 times.

▪ *Eosinophils.* Changes in the inflammatory focus are decreased under the action of histamine assimilation and neutralization caused by eosinophils. In allergic reactions, helminth invasion, and in antibacterial therapy the eosinophil number is increased because a large number of mast cells and basophils are destroyed (degranulated), and large quantities of histamine whose neutralization requires eosinophils are released. Among the functions of eosinophils is production of plasminogen, which determines their participation in the process of fibrinolysis.

▪ *Basophils.* Basophils constitute only 1 per cent of blood leukocytes. Functions of basophils are determined by biologically active substances they contain. Like the connective-tissue mast cells, they produce histamine and heparin and are united in the group of heparinocytes. The number of basophils is increased in the regeneration (final) phase of acute inflammation, while in chronic inflammation this increase is not significant. Heparin of basophils interferes with blood clotting at the site of the inflammation focus, and histamine causes vasodilatation to promote resorption and healing of a lesion.

▪ *Monocytes* make up 0–10 per cent of blood leukocytes, are capable of amoeboid movement, manifest the appreciable phagocytic and bactericidal activity. Monocytes phagocytize up to 100 bacteria, while neutrophils only 20–30. They appear in the inflammatory lesion after neutrophils and display the highest activity in an acid medium in which neutrophils lose their activity. At the inflammatory lesion monocytes phagocytize bacteria and dead leukocytes, the abnormal cells of the inflammed tissue, clear the lesion and prepare it for regeneration. For that

function monocytes were called “body scavengers”. Macrophages take part in processes of inflammation and regeneration, in lipid and iron metabolism. They possess the antitumour and antiviral effect; this is assosiated with the fact that secrete lysozyme, complement, interferon, elastase, collagenase, plasminogen activator, and the fibrinogenic factor that activates the synthesis of collagen and accelerates formation of fibrous tissue. Monocytes are the central link in the mononuclear phagocyte system (MPS). Elements of this system are characterized by the capacity to phagocytosis and pinocytosis; they have antibody receptors and complement and common origin and morphology. After emigration into the tissues monocytes are converted into macrophages. The latter participate in formation of a specific immunity along with phagocytosis. Macrophages engulf foreign substances, digest and turn them into a specific compound immunogen which, together with lymphocytes, forms a specific immune response.

▪ *Lymphocyte* make up 20–40 per cent of white blood corpuscles. In adults lymphocytes number 1000–3600 cells per mkm. As distinct from all other leukocytes, they not only penetrate through the tissues but can also return into the blood. Their lifespan is 20 and more years (some of them survive during the whole life), unlike that of other leukocytes. Lymphocytes are a central link of the body's immunity system. They are responsible for the formation of specific immunity, ensure immune control and defence against all foreign substances, and maintain the genetic, constancy of the internal environment. Lymphocytes possess a peculiar capacity to distinguish foreign material from self in the body since their membranes contain specific molecules-receptors that become activated upon the contact with foreign proteins. They accomplish the synthesis of defence antibodies lysis of foreign cells, are involved in the rejection of a foreign transplant, ensure immunological memory (hyper-reaction in response to repeated contact with foreign antigen), and destruction of self-mutant cells, etc. Each of these functions is realized by the specific types of lymphocytes which comprise three groups: T lymphocytes (thymus-dependent), B lymphocytes (bursa “equivalent” or dependent), and null lymphocytes.

Platelets (Thrombocytes)

Blood Platelets are granular non-nucleated fragments of cytoplasm in the form of oval discs. A platelet consists of two parts, a clear outer ground susbstance occupying the greater part of the platelet and a central part that contains granules. They secrete a hormone called serotonin which constricts torn blood vessels. They also have a major role in accumulating at sites of injury sticking together to plug gaps in broken blood vessels. Their normal number is 180,0–320,0 $\times 10^9$/1 (180 000–320 000 per 1 μl) of blood.

The Platelets result from fragmentation of large cells called megakaryocytes in the red bone marrow.

- 200 billion platelets are produced per day.
- Blood contains 150,000–300,000 platelets per 3 mm.
- Platelets are involved in the process of blood clotting or coagulation.

Plasma

About 55 % of whole blood is blood plasma, a fluid that is the blood's liquid medium, which by itself is straw-yellow in color. The blood plasma volume totals of 2,7–3,0 litres in an average human. It is essentially an aqueous solution containing 92 % water, 8 % blood plasma proteins, and trace amounts of other materials. Plasma circulates dissolved nutrients, such as, glucose, amino acids and fatty acids (dissolved in the blood or bound to plasma proteins), and removes waste products, such as, carbon dioxide, urea and lactic acid. Other important components include: serum albumin, blood clotting factors (to facilitate coagulation), immunoglobulins (antibodies), lipoprotein particles, various other proteins, various electrolytes (mainly sodium and chloride). The term serum refers to plasma from which the clotting proteins have been removed. Most of the proteins remaining are albumin and immunoglobulins.

Complete Blood Count

A complete blood count (CBC), also known as full blood count (FBC) or full blood exam (FBE) or blood panel is one of the most common blood test being done by practitioners worldwide. As its name suggests, the test calculates the number of each type of cell/matter you have within the bloodstream per unit volume.

There are in all 7 main tests that make up the CBC:

– Red Blood Cell Count;
– Hemoglobin Count;
– Color index;
– White Blood Cell Count;
– Platelet Count;
– Erythrosytes sedimentation rate.

The changes of erythrocytes are corresponded to the quantitative (increasing or decreasing of erythrocytes number) and qualitative (morphology cells).

Increasing of erythrocytes number is classified as erythrocytosis, decreasing – as erythrocytopenia.

Erythrocytosis

Physiological condition: newborn, excessive perspiration.

Pathological condition:

Primary: Polycythemia Vera

Secondary:

1. Associated with hypoxia

– cardiovascular disease, usually congenital resulting in significant venous admixture;

– pulmonary disease resulting in impaired gas perfusion, perfusion of poorly lung, pulmonary arteriovenous fistulas;

– high attitude residence;

– hypoventilation associated with obesity (Pickwickian syndrome);

– hemoglobin variant with increased affinity for oxygen;

– heavy smoking;

– methemoglobinemia (rarely).

2. Due to inappropriate erythropoietin increase in

– benign and malignant tumors of kidney, liver, central nervous system, uterus, ovary;

– renal disease hydronephrosis, Vascular impairment, cysts.

3. Associated with Adrenocortical steroids or Androgens

– adrenal hypercorticism;

– virilizing tumors;

– androgens used therapeutically.

4. Associated with chronic chemical exposure

– nitrites, sulfonamides, other substances producing methemoglobin and sulphaemoglobin;

– cobalt, shellac components, various alcohols.

5. Relative

– "stress" or "spurious" polycythemia;

– dehydration: water deprivation, vomiting;

– plasma loss: burns, enteropathy.

Erythrocytopenia

1. Depression of bone narrow: leukemia, aplastic anemia, metastases in bone marrow.

2. Hemorrhage.

3. Hemolysis of erythrocytes.

4. Deficiency of iron.

5. Deficiency of vitamins B_{12}.

6. Hemoglobinopathy.

Clinical significance of hemoglobin changes

Decreased concentration of the hemoglobin in the blood (oligochromemia) observes in anemia of different etiology (as a result of hemorrhage, deficiency of iron, vitamin B_{12}, and folate, increase hemolysis of erythrocytes, etc.).

Increased concentration of hemoglobin in the blood (hyperchromemia) occurs in erythremia, cardio-pulmonary failure, some congenital heart defects, and usually accompanied by increased erythrocytes number.

In blood clotting relative increasing of hemoglobin concentration can be found.

Color index

Once the quantity of erythrocytes and hemoglobin in a given blood specimen is known, it is possible to calculate the hemoglobin content of each erythrocyte. There are many methods by which hemoglobin saturation can be determined. One of them is the calculation of the color index. This is a conventional value derived from the ratio of hemoglobin to the number of erythrocytes. This value is found by dividing a triplet quantity of hemoglobin in grams by the first three figures expressing the quantity of erythrocytes. Normally this value is 0,85–1,1 (normochromia).

Clinical significance of color index changes

Hyperchromia, that is increased hemoglobin content in separate erythrocyte resulted in color index more than 1.1, depend only on increased volume of erythrocytes (macrocytosis), but not on increased saturation of hemoglobin.

Hyperchromia (color index 1,2–1,5) is characteristic of vitamin B12 deficiency anemia. Hyperchromia can observe in some chronic hemolytic and myelotoxic anemia.

Hypochromia – color index decreasing (less than 0,8) can be result of decreased erythrocytes volume (microcytosis) or insufficient hemoglobin saturation of normal volume erythrocytes.

Hypochromia can be caused by lack of iron, defective globin synthesis, defective porphyrin synthesis, and is found in the patients with iron deficiency anemia, anemia of chronic diseases, thalassemia, hemoglobinopathies (C, E), and sideroblastic anemia.

Normochromia, usually observed in healthy individuals, can also be found in some anemia (acute posthemorrhagic, acute hemolytic, hypo- and aplastic).

Clinical significance of leukocytes changes

The changes of leukocytes are corresponded to the quantitative (increasing or decreasing of leukocytes number) and qualitative (morphology cells).

Increasing of leukocytes number is classified as *leukocytosis*, decreasing – as *leukocytopenia*.

Leukocytosis

Physiological condition: new born, digestive process (after taking food, rich of protein), physical exercise, pregnancy, and taking some medicine (hormones).

Pathological condition: leukemia, infectious process, inflammatory, purulent process, myocardial infarction, malignant tumor, uremia, loss of blood, shock.

Leukopenia

Physiological condition: deep sleep, starvation.

Pathological condition; bacterial, virus infectious, autoimmune disease, hypoaplastic condition (administration X-ray, chemical substances, radiation), agranulocytosis (after administration some medicine – for treatment malignant process).

The percentage of separate forms of leukocyte in peripheral smear is considered *as leukocyte formula* – it is the percentage of separate forms of blood leukocytes.

The normal value of leukocyte formula	
Leukogramma:	
Bands or stabs neutrophils	0,04–0,3 × 10^9/L (1–6 %)
Polymorphonuclear neutrophils	2,0–5,5 × 10^9/L (47–72 %)
Basophils	0–0,065 × 10^9/L(0–1 %)
Eosinophils	0,02–0,3 × 10^9/L (0,5×5 %)
Lymphocytes	1,2–3,0 × 10^9/L(19–37 %)
Monocytes	0,09–0,60 × 10^9/L (3–11 %)

Clinical significance of leukocyte formula changes

The leukocyte formula is counted in stained smears.

The changes of different forms of leukocytes have clinical significance. Increasing of neutrophils number is classified as neutrophilia, decreasing – as neutropenia.

Neutrophilia

Infections:

– pyogenic bacterial: staphylococcal, streptococcal, pneumococcal, meningococcal, gonococcal;

– non pyogenic: acute rheumatic fever, diphtheria, scarlet fever, acute poliomyelitis, cholera, herpes zoster, mycobacterial, fungal, spirochaetal, parasitic.

Metabolic disorders, due to varied causes leading to liver insufficiency, uremia, diabetes, acidosis, gout, eclampsia.

Neoplasms:

– myeloproliferative disorder: myeloid leukemia, lymphomas, polycythemia vera, myelosclerosis;

– other malignancies: carcinomas (metastatic or otherwise), sarcomas

Conditions causing cell necrosis or destruction:

– acute hemolysis;

– infarctions;

– drug intoxication: nephrotoxins, hepatotoxins;

– various drugs/chemicals implicated are phenacetin, digitalis, quinine, adrenaline, organic arsenicals, lead, mercury, carbon monoxide.

Trauma and hemorrhage:

– hemorrhage: acute hemorrhage (especially internal hemorrhage);

– trauma: operative, fractures, crush injuries, burns.

Cardiac disorders:

– paroxysmal tachycardia.

Collagen disease:

– polyarteritis nodosa;

– acute phase of rheumatoid arthritis;

– dermatomyositis.

It is necessary to account the degree of lobation of the neutrophile nuclei.

After the degree of nuclear shift in the leukocytic formula the following kinds of neutrophilic leukocytosis are distinguished:

1) with any nuclear shift – an increased number of mature segmented neutrophils on the background of leukocytosis as a whole;

2) with a hyporegenerative nuclear shift to the left – an increased number of band forms of neutrophils (above 5 %), it is characteristic of a slight course of several infections and inflammation;

3) with the regenerative nuclear shift to the left which indicates the reactive activation of granulocytopoiesis. On the background of neutrophilia and increased number of band forms metamyelocytes and sometimes individual myelocytes occur. It is characteristic of the purulent septic processes;

4) with the hyperregenerative nuclear shift to the left which reflects the excessive hyperplasia of leukopoietic tissue with disturbance of maturation of the cells and expressed rejuvenation of the blood. The quantity of band neutrophils and metamyelocytes is strongly increased, the younger forms occur (myelocytes and even a few promyelocytes and myeloblasts). The total number of leukocytes can be increased, nonchanged or even decreased because of exhausted myelopoiesis. The absence of eosinophils (aneosinophilia) is often observed. This shift is met in adversely proceeding infectious and purulent septic processes;

5) with the degenerative nuclear shift which testifies to an inhibition of the bone marrow. On the background of leukopenia the number of band neutrophils is increased; there are a lot of destructed segmented forms, metamyelocytes are absent. It is characteristic of severe infections, endogenic intoxications, etc. In hyperproduction of pathologically changed leukocytes and disturbance of their maturation the regenerative-degenerative shift is observed. Thus leukocytosis is marked, and the number of band neutrophils, metamyelocytes and myelocytes with the attributes of degeneration is increased;

6) with the nuclear shift to the right which is characterized by occurrence of hypersegmented (5 segments) neutrophils and testifies to an

inhibition of granulocytopoiesis. It is found out in radiation sickness, pernitious anemia, however can be observed in a healthy man.

In various diseases the change in the total number of leukocytes is accompanied by the occurrence in the blood of the pathologic leukocytes, which are classified into regenerative (they are found out in norm only in the bone marrow) and degenerative (destructed) forms. The attributes of degeneration are: toxicogenic granularity, vacuolisation, hypochromatosis, anisocytosis, fragmentation, picnosis and rexis of the nucleus, hypersegmentation, etc.

Leukemoid reactions – the pathologic reactions of the blood system with high leukocytosis and occurrence of immature leukocytes in the blood, which are similar to those in leukemias, but are temporary and convertible. They occur in infections, inflammatory diseases, intoxications, lymphogranulomatosis, parasitic, allergic diseases, collagenoses, infections mononucleosis, etc.

Neutropenia.

The kinds of leukopenia (neutropenia):

– distributive neutropenia is observed in shock, neuroses, inflammatory diseases, malaria. The ratio between the circulating and marginal pools of leukocytes is changed as a result of congestion of leukocytes in dilated cappilaries of the blood depots (lung, liver, intestine).

This leukopenia is temporary and is usually replaced by leukocytosis.

Neutropenia owing to intensive destruction of neutrophils. It is observed:

a) under influence of antibodies leukoagglutinins, which are formed in blood transfusions, under influence of some drugs, which are allergens-haptens (sulpha drugs, amidopyrin, etc.);

b) in diseases accompanied by increased number of the circulating inmmune complexes (autoimmune diseases, tumors, leukemias);

c) in action of toxins (the toxic forms of typhoid fever, influenza, dysentery, the extensive inflammatory processes, the poisoning with benzene, arsenic, sulphonamides);

d) in the enlarged spleen (collagenoses, liver cirrhosis, hemolytic anemia, etc.).

Neutropenia owing to disturbed or inhibited leukopoiesis. It is observed in action of various toxic substances and drugs, ionising radiation, in replacement of the bone marrow by leukemic or tumor tissue, in protein and vitamin starvation, etc.

Sometimes leukopenia is manifested in the form of agranulocytosis which is characterized by a strong decrease or even absence of neutrophils and other granulocytes in the blood, when the number of granulocytes is below 0.75×10^9/l or the total number of leukocytes is below 1.0×10^9/l.

Eosinophilia.

Allergic slates: asthma, fever, exfoliative dermatitis, erythema multiforme, urticaria, food sensitivity, angioneurotic edema, serum sickness, drug allergy.

Parasitic disease: intestinal forms, tissue forms.

Skin disorders: pemphigus, dermatitis herpetiformis, psoriasis, scabies, prurigo.

Drug administration: liver extracts, penicillin, streptomycin, chlorpromazine.

Neoplasms: myeloproliferative (eosinophilic leukemia, chronic myeloid leukemia, polycythemia), others (Hodgkin's disease, multiple myeloma, metastatic and necrotic, occult tumor).

Miscellaneous: familial eosinophilia, eosinophilic syndrome, eosinophilic granulomatosis (visceral larva migrans), scarlet fever, polyarteritis nodosa, tropical eosinophilia, pernicious anemia, post splenectomy, idiopathic neutropenia, post transfusion mononucleosis.

Eosinopenia.

Drug/hormone therapy: adrenocortical steroids, adrenaline, ephedrine, insulin. Response to stress: acute infections, traumatic shock, surgical operations, severe exercise, burns, acute emotional stress, exposure to cold.

Endocrine diseases: Cushing's disease, acromegaly. Miscellaneous: aplastic anemia.

Basophilia: chronic myeloid leukemia, myelosclerosis, polycythemia vera, hypersensitivity states, myxoedema, iron deficiency anemia (some cases), hemolytic and toxic anemia of long standing, pre-leukemia (some cases).

Basophilopenia: neutrophil leukocytosis or leukemoid reaction associated with infection, neoplasma, tissue necrosis, acute anemia; allergic conditions; hyperthyroidism; myocardial infarction; Cushing's syndrome; following prolonged corticosteroid therapy.

Monocytosis. Infections:

– bacterial: brucellosis, sub-acute bacterial endocarditis, tuberculosis, typhoid fever, recovery stage of an acute infection;

– rickettsial: rocky mountain spotted fever, typhus;

– protozoan: malaria, kala-azar, trypanosomiasis, oriental sore;

– viral: infections mononucleosis.

Neoplasms: monocytic leukemia, carcinomatosis, Hodgkin's and other lymphomas, myeloproliferative disorders, multiple myeloma. Collagen diseases; rheumatoid arthritis, SLE.

Miscellaneous: chronic ulcerative colitis, regional enteritis, sarcoidosis, lipid storage diseases, hemolytic anemia, hypochromic anemia, recovery from agranulocylosis.

Lymphocytosis:

– acme infections: infectious mononucleosis, pertussis lymphocytosis, mumps, chickenpox, rubella, infective hepatitis, convalescent stage of many acute infections, toxoplasmosis, influenza;

– chronic infections; brucellosis, tuberculosis, syphilis (secondary);

– endocrine disorders: thyrotoxicosis, adrenal cortical insufficiency, hypopituitarism, myasthenia gravis;

– neoplasms: non Hodgkin's lymphomas, chronic lymphatic leukemia, lymphosarcoma, multiple myeloma.

Lymphopenia: severe pancytopenia; congestive heart failure; adrenocorticosteroid therapy (transient).

Clinical significance of thrombocytes changes

If the number of thrombocytes decreases significantly (throtnhocytopenia), a tendency to haemorrhages develops. The critical figure at which hemorrhage occurs is believed to be $30–10^9$/l (30 000 per 1 μm). Thrombocytopenia occurs in affection of the bone marrow by infectious causative agents, some medicinal preparations, ionizing radiation, and in autoimmune processes. Thrombocytosis occurs after hemorrhage, in polycythemia, and malignant tumors.

Thrombocytopenias:

– intensified destruction of thrombocytes (immune – in measles, German measles, action of sulpha drugs, chronic lymphoid leukemia, diffusive diseases of the connective tissue, etc.; in scarlet-fiver, sepsis, increased function of the mononuclear phagocytic system);

– insufficient production of thrombocytes (irradiation, poisoning by the chemical substances, metaplasia of the bone marrow, deficit of vitamin B_{12} and folic acid, hereditary disturbances);

– increased expenditure of thrombocytes (in local and generalized intravascular blood clotting);

– redistribution of thrombocytes (in trauma, epylepsia, anaphylactic shock, etc.).

Erythrocyte sedimentation rate (ESR)

The normal rate of erythrocyte sedimentation from 1 to 10 mm/h in adult males, 2 to 15 mm/hr in no pregnant females, and only 0.5 mm/h in newborns.

Clinical significance of the Erythrocyte Sedimentation Rate

The Erythrocyte Sedimentation Rate (ESR) (normally 1–10 mm/h in man and 2–15 mm/h in women) depends on the various factors.

– On the changes ratio between proteins of the blood. The increased content of the high dispersed proteins (globulins, fibrinogen) in inflammation and certain infections leads to acceleration of ESR, as far as these proteins absorbed on the negative charged erythrocytes reduce their surface charge and thus promote their agglutination and sedimentation.

– On the number of erythrocytes. The increased their number (polycythemia, shock) reduces ESR, and the decreased number (anemia) accelerates ESR.

– On the content of cholesterol and lecithin in the blood. Cholesterol absorbed on erythrocytes accelerates and lecithin, on the contrary, decreases ESR.

– On the changed relative density of erythrocytes. In hypercapnia (asphyxia, cardiac insufficiency) ESR decreases owing to increased diameter of erythrocytes and reduced their relative density.

– On viscosity of the blood. Hydremia accelerates ESR and the increased viscosity (anhydremia) reduces ESR.

ESR also can be accelerated in intensive physical work.

PRACTICAL TRAINING

1. Which of the following is an increase in the number of RBCs?

A. Erythrocytosis *C. Eritropeniya* *E. Anizohromiya*
B. Erythremia *D. Poliglobuliya*

2. Which of the following is an increase in diameter of RBCs more than 12 μm?

A. Shizotsitami *C. Macrocytes* *E. Microcytes*
B. Megalocytes *D. Poikilocytes*

3. Which of the following is a change the size of RBCs ?

A. Poikilocytosis *C. Anizohromiya* *E. Microcytosis*
B. Anisocytosis *D. Shizotsitoz*

4. Which of the following is an increased blood hemoglobin?

A. Heart defect *D. Hepatitis*
B. Chronic lung disease *E. Gastrointestinal disease*
C. Allergies

5. Which of the following is a critical decrease of the number of platelets?

A. 150 thousand *C. 50 thousand* *E. 200 thousand*
B. 100 thousand *D. 180 thousand*

6. Which of the following disease observed in eosinophilia?

A. Pyelonephritis *C. Hepatitis* *E. Tuberculosis*
B. Helminthiasis *D. Pneumonia*

7. Which of the following in women is normal?

A 5–15 mm *C. 12–18 mm* *E. 20–28 mm*
B. 2–10 mm *D. 10–25 mm*

8. Which of the following is a decrease in color index?

A. Normohromiya *C. Hyperchromic* *E. Poliglobuliya*
B. Hypochromia *D. Erythremia*

9. Which of the following diseases are not accompanied by lymphocytosis?

A. Influenza *D. Typhoid*
B. Myocardial infarction *E. Radiation sickness*
C. Mononucleosis

10. Which of the following is the normal RBCs number in men?

A. 3.0–6.4 × 10^{12}L *C. 2.0–5.4 × 10^{12}/L* *E. 4.0–5.1 × 10^{12}/L*
B. 3.9–4.7 × 10^{12}/L *D. 4.5–6.1 × 10^{12}/L*

Keys: 1A, 2B, 3B, 4B, 5C, 6B, 7A, 8B, 9E, 10E.

Blood test No 1

Patient	a 42 – year old male patient
Erythrocytes	4.7×10^{12}/L
Hb	130 g/L
The color index	0.85
Reticulocytes	2%
Thrombocytes	250×10^{9}/L
Leukocytes	16×10^{9}/L
Basophiles	– %
Eosinophils	4 %
Neutrophils	73 %
– myelocytes	– %
– juvenile neutrophils	7 %
– stab neutrophils	20 %
– segmentonuclear neutrophils	46 %
Lymphocytes	15 %
Monocytes	8 %
Anisocytosis	–
Poikilocytosis	–
ESR	22 mm

Blood test No 2

Patient	a 27 – year old male patient
Erythrocytes	4.5×10^{12}L
Hb	130 g/L
The color index	1.0
Reticulocytes	– %
Thrombocytes	300×10^{9}/l
Leukocytes	4.0×10^{9}/l
Basophiles	– %
Eosinophils	2 %
Neutrophils	76 %
– myelocytes	– %
– juvenile neutrophils	12 %
– stab neutrophils	18 %
-segmentonuclear neutrophils	46 %
Lymphocytes	18 %
Monocytes	4 %
Anisocytosis	–
Poikilocytosis	–
ESR	25 mm

Blood test No 3

Patient	a 30 – year old male patient
Erythrocytes	4.6×1012/L
Hb	120 g/L
The color index	0.88
Reticulocytes	1 %
Thrombocytes	230×109/L
Leukocytes	15×109/L
Basophiles	– %
Eosinophils	1 %
Neutrophils	86%
– myelocytes	– %
– juvenile neutrophils	2 %
– stab neutrophils	17 %
– segmentonuclear neutrophils	67 %
Lymphocytes	10 %
Monocytes	3 %
Anisocytosis	–
Poikilocytosis	–
ESR	46 mm

Blood test No 4

Patient	a 43 – year old male patient
Erythrocytes	4.3×1012/L
Hb	145 g/L
The color index	1.0
Reticulocytes	2 %
Thrombocytes	270×109/L
Leukocytes	5.2×109/L
Basophiles	– %
Eosinophils	3 %
Neutrophils	46 %
– myelocytes	– %
– juvenile neutrophils	2 %
– stab neutrophils	2 %
– segmentonuclear neutrophils	42 %
Lymphocytes	42 %
Monocytes	10 %
Anisocytosis	–
Poikilocytosis	–
ESR	26 mm

Blood test No 5

Patient	a 45 – year old male patient
Erythrocytes	4.5×1012/L
Hb	160 g/L
The color index	1.0
Reticulocytes	1 %
Thrombocytes	305×109/L
Leukocytes	7.5×109/L
Basophiles	– %
Eosinophils	8 %
Neutrophils	57 %
– myelocytes	– %
– juvenile neutrophils	– %
– stab neutrophils	2 %
– segmentonuclear neutrophils	55 %
Lymphocytes	32 %
Monocytes	8 %
Anisocytosis	–
Poikilocytosis	–
ESR	12 mm

Blood test No 1

Standards of answers: Inflammatory process in the organism with sufficient reactivity and favorable prognosis (neutrophilic leukocytosis, shift of leukocytic formula to the left, accelerated ESR).

Blood test No 2

Standards of answers: Inflammatory process in the organism with insufficient reactivity and doubtful prognosis (neutrophilesis against a background of leukopenia, shift of leukocytic formula to the left, accelerated ESR).

Blood test No 3

Standards of answers: Infection-inflammatory process in the organism with high reactivity and favorable prognosis (neutrophilic leukocytosis, shift of leukocytic formula to the left, accelerated ESR).

Blood test No 4

Standards of answers: Relative lymphocytosis against a background of accelerated ESR may be evidence of recovery process.

Blood test No 5

Standards of answers: Organism allergization caused by infection or helminthic invasion (eosinophilia)

Навчальне видання

Клінічний аналіз крові

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для англомовних студентів 3–6-х курсів
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III–IV рівнів акредитації

Упорядники Ащеулова Тетяна Вадимівна
Герасимчук Ніна Миколаївна

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Редакційно-видавничий відділ
ХНМУ, пр. Науки, 4, м. Харків, 61022
izdatknmurio@gmail.com

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