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MODERN APPROACHES TO LABORATORY EVALUATION OF ANEMIAS OF VARIOUS ETIOLOGIES

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Abstract. Anemias of various etiologies represent one of the most common hematological problems in clinical practice and are associated with a significant reduction in patients' quality of life. The diversity of etiological factors and pathogenetic mechanisms underlying anemia necessitates the use of a comprehensive and differentiated laboratory approach to diagnosis. This article reviews modern laboratory methods for the diagnosis of anemia based on the assessment of complete blood count parameters, erythrocyte morphology, indicators of iron metabolism, vitamin B_{12} and folic acid levels, as well as markers of hemolysis and inflammation. Particular attention is paid to the differential diagnosis of iron deficiency anemia, megaloblastic anemia, hemolytic anemia, and anemia of chronic disease. The application of modern laboratory technologies improves diagnostic accuracy, enables timely determination of anemia etiology, and optimizes therapeutic strategies.

Keywords: anemia, laboratory diagnosis, complete blood count, erythrocyte indices, iron metabolism, iron deficiency anemia, vitamin B_{12} deficiency, folate deficiency, hemolytic anemia, anemia of chronic disease, differential diagnosis

Relevance. Anemias of various etiologies are among the most common pathologies in clinical practice and occur in patients of all age groups. The high prevalence of anemia, its multifactorial etiology, and the diversity of clinical manifestations determine the significant medical and social importance of this problem. Anemic syndrome often accompanies chronic inflammatory diseases, oncological conditions, and disorders of the gastrointestinal and endocrine systems, which significantly complicates the diagnosis and treatment of the underlying disease. Clinical manifestations of anemia are frequently nonspecific and may be mild, especially in the early stages. In this context, laboratory diagnostics plays a decisive role in detecting anemic syndrome, determining its etiology, and assessing its severity. Modern laboratory methods allow not only the evaluation of quantitative parameters of erythrocytes and hemoglobin but also a deeper understanding of the pathogenetic mechanisms of anemia development [3,8,11].

The use of extended laboratory panels, including indicators of iron metabolism, vitamin B_{12} and folate levels, markers of hemolysis and inflammation, as well as morphological examination of erythrocytes, significantly increases the accuracy of differential diagnosis of anemias of various etiologies. Thus, improvement of modern approaches to laboratory diagnosis of anemia is an актуальной task of clinical laboratory diagnostics, aimed at timely disease detection, optimization of therapeutic strategies, and improvement of patient prognosis [6,7,10].

The clinical manifestations of anemias of various etiologies are characterized by pronounced polymorphism and depend on the degree of hemoglobin reduction, the rate of development of anemic syndrome, the patient’s age, and the presence of comorbidities. The most common general symptoms include weakness, increased fatigue, reduced work capacity, dizziness, dyspnea on exertion, palpitations, and pallor

of the skin and mucous membranes. In severe anemia, syncopal episodes, decreased arterial blood pressure, and signs of tissue hypoxia may be observed [1,4,6].

Iron deficiency anemia is typically associated with manifestations of sideropenic syndrome, including dry and scaling skin, brittle hair and nails, pica, altered taste and smell, as well as glossitis and angular stomatitis. Megaloblastic anemias related to vitamin B_{12} or folate deficiency are characterized by involvement of the gastrointestinal tract and nervous system, manifesting as atrophic glossitis, diarrhea, paresthesias, sensory disturbances, and cognitive impairment. Hemolytic anemias are accompanied by jaundice, splenomegaly, dark-colored urine, and signs of intoxication resulting from increased erythrocyte destruction. In anemia of chronic disease, the clinical picture is often masked by symptoms of the underlying pathology, and the anemic syndrome develops gradually and may remain unnoticed for a long time. Thus, the clinical presentation of anemia is nonspecific and requires mandatory confirmation and clarification of etiology using laboratory diagnostic methods [3,12,15].

The pathogenesis of anemias of various etiologies is multifactorial and is обусловлен by impaired processes of erythrocyte production, maturation, or increased destruction, as well as a decrease in hemoglobin concentration. Depending on the leading mechanism of anemia development, anemias are classified into those associated with deficiency of substrates necessary for erythropoiesis, suppression of hematopoiesis, and increased hemolysis [3,7,15].

Iron deficiency anemia develops as a result of insufficient dietary iron intake, impaired absorption in the gastrointestinal tract, or chronic blood loss. Iron deficiency leads to decreased hemoglobin synthesis and the formation of microcytic hypochromic erythrocytes, accompanied by tissue hypoxia. In the pathogenesis of anemia of chronic disease, the inflammatory process plays an important role, with increased synthesis of hepcidin, which disrupts iron mobilization from stores and its utilization in the bone marrow [1,7,15].

Megaloblastic anemias are caused by deficiency of vitamin B_{12} or folic acid, which are essential for DNA synthesis. Impaired cell division leads to the formation of

megaloblasts and reduced efficiency of erythropoiesis. Hemolytic anemias develop as a result of increased erythrocyte destruction due to congenital membrane defects, enzymopathies, hemoglobinopathies, or immune mechanisms, accompanied by elevated bilirubin levels and activation of the reticuloendothelial system [9,14,15].

Laboratory diagnosis of anemias of various etiologies occupies a key position in the detection of anemic syndrome, determination of its type, and assessment of severity. The primary stage of evaluation is the complete blood count, which allows assessment of hemoglobin level, erythrocyte count, hematocrit, as well as erythrocyte indices—mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC). Changes in these parameters make it possible to suggest a microcytic, normocytic, or macrocytic pattern of anemia [3,13].

Examination of erythrocyte morphology in a peripheral blood smear has important diagnostic value, enabling detection of anisocytosis, poikilocytosis, hypochromia, and the presence of megalocytes or spherocytes. Determination of reticulocyte count is used to assess erythropoietic activity and to differentiate anemias associated with bone marrow suppression from those due to increased erythrocyte destruction. For the diagnosis of iron deficiency states, parameters of iron metabolism are evaluated, including serum iron, ferritin, total iron-binding capacity, and transferrin saturation. Diagnosis of megaloblastic anemia is based on measurement of serum vitamin B_{12} and folic acid levels. In suspected hemolytic anemia, markers of hemolysis play a crucial role, such as elevated indirect bilirubin and lactate dehydrogenase levels, and decreased haptoglobin concentration [6,10].

In some cases, additional methods are used to уточнение the diagnosis, including bone marrow examination, immunological tests, and molecular genetic techniques. Comprehensive use of modern laboratory parameters ensures accurate differential diagnosis of anemias of various etiologies and helps determine optimal patient management strategies [7,15].

Anemias of various etiologies, in the absence of timely diagnosis and adequate treatment, may lead to the development of severe complications affecting multiple organs and systems. The main pathophysiological consequence of anemic syndrome is chronic tissue hypoxia, which contributes to dysfunction of vital organs, primarily the cardiovascular and nervous systems. From the cardiovascular perspective, anemia may cause tachycardia, arterial hypotension, development of heart failure, and ischemic myocardial changes, especially in elderly patients and individuals with underlying cardiac pathology. Long-standing anemia leads to compensatory myocardial hypertrophy and increases the risk of arrhythmias [6,11].

Disorders of the central nervous system manifest as decreased concentration, cognitive impairment, dizziness, and syncopal episodes. In megaloblastic anemias caused by vitamin B_{12} deficiency, irreversible neurological complications, including polyneuropathy and myelopathy, may develop. In patients with hemolytic anemias, complications may include biliary disorders, splenomegaly, and chronic intoxication with erythrocyte breakdown products [7,14,15].

Anemia is of particular clinical significance in pregnant women, as it increases the risk of fetal hypoxia, preterm birth, and postpartum complications. Thus, the complications of anemias of various etiologies underscore the need for early detection of the disease and the application of comprehensive modern laboratory diagnostic methods [5].

Conclusion. Anemias of various etiologies remain a relevant problem in modern clinical medicine due to their high prevalence, diversity of etiological factors, and nonspecific clinical manifestations. Effective diagnosis of anemic syndrome is impossible without a comprehensive laboratory evaluation, which allows not only confirmation of the presence of anemia but also identification of its pathogenetic type. Modern approaches to the laboratory diagnosis of anemia are based on the combined use of complete blood count parameters, morphological examination of erythrocytes, assessment of erythropoietic activity, indicators of iron metabolism, vitamin B_{12} and folic acid levels, as well as markers of hemolysis and inflammation.

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