IRON DEFICIENCY ANEMIA LABORATORY

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Abstract. *Iron deficiency anemia is one of the most widespread hematological disorders in the world, primarily resulting from insufficient iron levels in the body. This condition impairs hemoglobin synthesis, leading to reduced oxygen transport and various clinical symptoms such as fatigue, pallor, and weakness. Laboratory investigations play a central role in diagnosing this type of anemia, differentiating it from other forms, and guiding appropriate treatment. Key laboratory tests include a complete blood count, serum iron analysis, ferritin level measurement, and evaluation of red blood cell morphology. These tests help detect changes such as low hemoglobin concentration, microcytic and hypochromic red blood cells, and depleted iron stores. Interpretation of these results within the clinical context ensures accurate diagnosis and effective monitoring of therapy.*

Keywords: *Anemia, Iron deficiency, Hemoglobin, Red blood cells, Ferritin, Serum iron, Transferrin.*

ЛАБОРАТОРИЯ ЖЕЛЕЗОДЕФИЦИТНОЙ АНЕМИИ

Аннотация. *Железодефицитная анемия является одним из наиболее распространенных гематологических заболеваний в мире, в первую очередь возникающим из-за недостаточного уровня железа в организме. Это состояние нарушает синтез гемоглобина, что приводит к снижению транспорта кислорода и различным клиническим симптомам, таким как усталость, бледность и слабость. Лабораторные исследования играют центральную роль в диагностике этого типа анемии, дифференциации ее от других форм и определении соответствующего лечения. Основные лабораторные анализы включают общий анализ крови, анализ сывороточного железа, измерение уровня ферритина и оценку морфологии эритроцитов. Эти тесты помогают обнаружить такие изменения, как низкая концентрация гемоглобина, микроцитарные и гипохромные эритроциты и истощенные запасы железа. Интерпретация этих результатов в клиническом контексте обеспечивает точную диагностику и эффективный мониторинг терапии.*

Ключевые слова: *Анемия, Дефицит железа, Гемоглобин, Эритроциты, Ферритин, Сывороточное железо, Трансферрин.*

Introduction

Iron deficiency anemia is the most widespread type of anemia in the world and remains a significant global health challenge. It primarily results from an insufficient amount of iron in the body, which leads to a decrease in the production of hemoglobin, the protein responsible for carrying oxygen in the blood. As a result, the oxygen delivery to the body’s tissues is impaired, leading to symptoms such as fatigue, weakness, dizziness, rapid heartbeat, pale skin, and brittle hair and nails. This form of anemia is especially common among women of reproductive age, pregnant women, and children, due to increased iron requirements. Despite its high prevalence, the condition often goes undiagnosed in its early stages because its symptoms are nonspecific and can easily be attributed to other health issues or general tiredness.

Main part

Iron deficiency anemia is a hematological disorder characterized by a lack of adequate iron in the body, which leads to a decreased production of hemoglobin. This condition limits the blood's ability to carry oxygen efficiently, resulting in systemic symptoms. It is the most common nutritional deficiency anemia worldwide and affects people of all ages and backgrounds. Women of reproductive age and children are particularly vulnerable. According to global health statistics, nearly two billion individuals are affected by this condition. Iron deficiency anemia is not only a medical concern but also a socio-economic issue, as it reduces work capacity and impairs cognitive development. It is a preventable and treatable condition, yet underdiagnosed in many cases. Therefore, public health initiatives aim to improve early detection and management. Understanding its global significance is the first step toward effective control. Proper diagnosis relies heavily on laboratory investigations and biochemical analysis.

The causes of iron deficiency anemia are diverse and can be grouped into three main categories: insufficient dietary intake, impaired absorption, and chronic blood loss. Inadequate dietary iron intake is common in populations relying on plant-based diets with low iron bioavailability. Gastrointestinal disorders such as celiac disease or chronic gastritis can lead to poor absorption of iron. Chronic blood loss due to conditions like peptic ulcers, heavy menstruation, or parasitic infections is a major contributor. Pregnant women often develop anemia due to increased iron demands for fetal development. Infants and adolescents may also face a higher risk due to rapid growth phases. Repeated blood donation or certain medications can also deplete iron stores. Recognizing these risk factors is vital for both prevention and appropriate laboratory testing. The underlying cause must always be identified before initiating treatment. Each patient’s history provides critical information that complements laboratory data.

Iron deficiency anemia often presents with nonspecific clinical symptoms, making it challenging to diagnose without laboratory testing. Common symptoms include fatigue, weakness, dizziness, and shortness of breath. In more severe cases, individuals may experience chest pain, palpitations, and cognitive disturbances. Specific signs such as pale skin, spoon-shaped nails, and dry mouth may also be observed. The pathophysiological basis of the disease involves impaired hemoglobin synthesis due to insufficient iron, which leads to the production of smaller and paler red blood cells. Oxygen delivery to tissues becomes compromised, resulting in tissue hypoxia. Over time, compensatory mechanisms such as increased cardiac output and respiratory rate try to maintain oxygen balance. In children, this can result in developmental delays and behavioral issues. Understanding the pathophysiology aids clinicians in interpreting lab results in context. The duration and severity of iron depletion correlate with the intensity of clinical symptoms.

Laboratory evaluation is essential in confirming the diagnosis of iron deficiency anemia and differentiating it from other types of anemia. A complete blood count is usually the first step, revealing low hemoglobin, low hematocrit, and microcytic, hypochromic red blood cells. Red cell indices such as mean corpuscular volume and mean corpuscular hemoglobin are typically reduced. Serum iron studies are also critical and include measuring serum iron levels, total iron-binding capacity, and transferrin saturation. Ferritin measurement is considered the most sensitive indicator of iron stores and typically appears low in iron deficiency. Inflammatory conditions can mask ferritin levels, which may require additional testing. Reticulocyte hemoglobin content and soluble transferrin receptor levels are newer markers used in advanced settings. Peripheral blood smear analysis can provide morphological evidence of iron-deficient erythropoiesis. These methods together offer a comprehensive diagnostic approach.

Accurate interpretation of laboratory data is crucial to confirm iron deficiency anemia and exclude other causes such as anemia of chronic disease or thalassemia. Low hemoglobin and hematocrit values suggest anemia, but they are not specific. A low mean corpuscular volume and mean corpuscular hemoglobin suggest microcytic hypochromic anemia, which is typical for iron deficiency. Serum iron is often low, while total iron-binding capacity is elevated due to increased production of transferrin. Ferritin levels are typically decreased, confirming depleted iron stores. However, ferritin is an acute phase reactant and may be falsely elevated in inflammatory conditions. Transferrin saturation below 15 percent is highly suggestive of iron deficiency. A careful assessment of all parameters in the clinical context is necessary for accurate diagnosis. Advanced tests like soluble transferrin receptor can help in ambiguous cases. Combining laboratory data with clinical information leads to the best outcomes.

Recent technological advancements have improved the sensitivity, specificity, and speed of laboratory tests for iron deficiency anemia. Automated hematology analyzers now provide detailed red cell indices and reticulocyte parameters, which allow earlier detection of anemia. Modern immunoassay techniques enable precise measurement of serum ferritin and soluble transferrin receptor levels. Flow cytometry and advanced imaging can offer insights into iron status at the cellular level. Point-of-care testing devices are also being developed for rapid screening in community settings. Molecular diagnostics may assist in distinguishing inherited forms of anemia. Standardization of laboratory methods has also improved result comparability between laboratories. These innovations not only help in early diagnosis but also in monitoring treatment response effectively. The integration of artificial intelligence in laboratory data analysis is an emerging field with promising potential. Overall, modern diagnostics contribute significantly to personalized anemia management.

Understanding laboratory findings is essential for guiding the treatment of iron deficiency anemia. Iron supplements, usually administered orally, are the first line of therapy. In cases of malabsorption or intolerance, intravenous iron may be considered. Laboratory monitoring during treatment includes regular checks of hemoglobin, hematocrit, and reticulocyte count. A rise in reticulocytes within one week often indicates a good response to therapy. Hemoglobin levels are expected to increase over a few weeks, and full correction may take several months. Ferritin levels are monitored to assess replenishment of iron stores and prevent relapse. Laboratory testing also helps identify non-responders and adjust the treatment plan accordingly. In certain cases, repeat testing may uncover an underlying issue such as chronic bleeding or coexisting disease. Thus, laboratory follow-up is a vital component of successful anemia management. Regular monitoring helps ensure complete and sustained recovery.

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