

## ASSESSMENT OF BIOCHEMICAL BLOOD MARKERS REFLECTING BONE TISSUE METABOLISM

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**Abstract.** Biochemical blood analysis plays an important role in assessing the functional state of bone tissue. This article reviews the main biochemical parameters reflecting bone metabolism, as well as the processes of bone formation and resorption. Special attention is given to indicators such as calcium, phosphorus, alkaline phosphatase, vitamin D, parathyroid hormone, and markers of bone remodeling. Analysis of these parameters enables the timely detection of mineral metabolism disorders, the diagnosis of osteoporosis, osteomalacia, and other diseases of the skeletal system, as well as the evaluation of the effectiveness of ongoing therapy. Biochemical markers represent an accessible and informative tool for comprehensive diagnosis and monitoring of bone tissue status.

**Keywords:** bone tissue metabolism, biochemical blood markers, calcium–phosphorus metabolism, alkaline phosphatase, vitamin D, parathyroid hormone, bone

remodeling, bone formation markers, bone resorption markers, osteoporosis, mineral metabolism

**Relevance.** Bone tissue pathology represents one of the most significant medical and social problems in modern medicine. The prevalence of diseases associated with impaired bone structure and function is steadily increasing, which is related to population aging, lifestyle changes, vitamin D deficiency, hormonal disorders, chronic somatic diseases, and long-term use of medications. Osteoporosis, osteopenia, osteomalacia, and other metabolic bone diseases are characterized by a latent course in the early stages and are often diagnosed only after the development of complications such as pathological fractures and bone deformities [7,15].

In modern clinical practice, early diagnosis of disorders of bone metabolism is of particular importance, as it allows timely implementation of preventive and therapeutic measures. In this context, biochemical blood analysis is one of the most accessible, informative, and cost-effective laboratory diagnostic methods. Biochemical parameters reflect the dynamic processes of bone formation and resorption, as well as the state of calcium–phosphorus metabolism, which plays a key role in maintaining skeletal strength and functional integrity [6,7,10].

Determination of serum levels of calcium, phosphorus, alkaline phosphatase, vitamin D, parathyroid hormone, as well as specific markers of bone remodeling such as osteocalcin and markers of bone resorption, makes it possible to objectively assess the functional state of bone tissue. Changes in these parameters often precede structural alterations detected by instrumental diagnostic methods, which emphasizes their high diagnostic value. In addition, biochemical markers are widely used to monitor the effectiveness of ongoing therapy and to assess disease prognosis. Thus, a comprehensive analysis of parameters reflecting bone tissue function in biochemical blood tests is a relevant and promising area of modern clinical laboratory diagnostics. Its application contributes to improving the quality of early diagnosis, optimizing

therapeutic strategies, and reducing the incidence of complications of bone system diseases, which is of great importance for practical healthcare [3,8,11].

Bone tissue is a dynamically renewing system in which processes of formation and resorption continuously occur. Balanced interaction between osteoblasts and osteoclasts ensures the maintenance of normal skeletal structure and strength. Disruption of these processes leads to the development of metabolic bone diseases, which highlights the importance of laboratory assessment of bone metabolism [1,4,6].

Biochemical blood analysis makes it possible to detect changes reflecting the functional state of bone tissue and the intensity of metabolic processes. One of the key indicators is calcium, which plays a leading role in bone mineralization and neuromuscular signal transmission. Deviations in serum calcium levels may indicate disorders of bone metabolism, diseases of the parathyroid glands, vitamin D deficiency, and other pathological conditions. Phosphorus is an essential component of the bone matrix and participates in energy metabolism. Combined assessment of calcium and phosphorus levels allows for more accurate diagnosis of mineral metabolism disorders. Alkaline phosphatase is of significant diagnostic value, as its bone-specific fraction reflects osteoblastic activity and bone formation processes. An increase in its activity is observed in conditions associated with enhanced bone remodeling, osteomalacia, and fracture healing [3,12,15].

Vitamin D plays a key role in the regulation of calcium–phosphorus metabolism and intestinal absorption of minerals. Its deficiency leads to impaired bone mineralization and an increased risk of osteoporosis. Parathyroid hormone (PTH) has a direct effect on bone resorption, maintaining calcium homeostasis in the blood. Changes in its level make it possible to assess endocrine mechanisms involved in the regulation of bone metabolism. In recent years, increasing importance has been attributed to specific markers of bone remodeling. Osteocalcin is an indicator of osteoblastic activity and is used to assess bone formation processes. Markers of bone resorption, such as type I collagen telopeptides, reflect osteoclast activity and the degree of bone tissue degradation. Their determination allows early detection of

disorders of bone metabolism, even before the appearance of clinical manifestations [3,15].

Comprehensive interpretation of biochemical blood parameters makes it possible not only to diagnose diseases of the skeletal system but also to assess their dynamics, the effectiveness of ongoing treatment, and the risk of complications. Thus, biochemical blood analysis is an important tool in modern laboratory diagnostics, ensuring timely detection and monitoring of disorders of bone tissue function. Clinical manifestations of bone tissue diseases are diverse and largely depend on the nature and stage of the pathological process and the severity of disturbances in bone metabolism. In the early stages, these diseases are often asymptomatic or accompanied by nonspecific complaints, which complicates timely clinical diagnosis [1,7,15].

One of the most common clinical symptoms is pain syndrome, which may vary in localization and intensity. Bone and joint pain is usually dull in nature, increases with physical activity, and often worsens at night. In pronounced mineral metabolism disorders, decreased muscle strength, rapid fatigue, and limited mobility are observed. In osteoporosis and osteomalacia, the clinical picture often includes increased bone fragility and a tendency to pathological fractures occurring after minimal trauma. Typical fractures involve the vertebral bodies, the femoral neck, and the distal radius. Patients may experience loss of height, spinal deformities, kyphosis, and postural abnormalities.

Disorders of calcium–phosphorus metabolism may also be accompanied by neuromuscular manifestations. Hypocalcemia is associated with muscle cramps, paresthesias, and increased neuromuscular excitability. Hypercalcemia, in contrast, may present with weakness, loss of appetite, nausea, constipation, and cardiac rhythm disturbances. In endocrine disorders, particularly those involving parathyroid gland dysfunction, clinical manifestations include a combination of skeletal, muscular, and visceral symptoms. Such patients often present with bone pain, frequent fractures, urolithiasis, and gastrointestinal disturbances [9,14,15].

The diagnosis of bone tissue diseases is based on a comprehensive assessment of clinical data, laboratory findings, and instrumental studies. A central role in early detection and monitoring of pathological changes in bone metabolism is played by biochemical blood analysis, which allows objective evaluation of bone tissue function. The main biochemical parameters include levels of total and ionized calcium, phosphorus, alkaline phosphatase, vitamin D, and parathyroid hormone. Measurement of calcium and phosphorus concentrations helps identify disorders of calcium–phosphorus metabolism and suggests the presence of metabolic bone diseases. Changes in alkaline phosphatase activity, particularly its bone-specific fraction, reflect the intensity of bone formation processes and are used to assess osteoblastic activity [3,13].

Vitamin D is a crucial regulator of mineral metabolism, and its deficiency is widespread across different age groups. Determination of serum 25-hydroxyvitamin D [25(OH)D] levels allows assessment of vitamin D status and the risk of osteoporosis and osteomalacia. Evaluation of parathyroid hormone levels is necessary to assess endocrine regulation of bone metabolism and to differentiate between primary and secondary hyperparathyroidism. Of particular diagnostic importance are bone remodeling markers, which are divided into markers of bone formation and bone resorption. Bone formation markers include osteocalcin, reflecting osteoblastic activity. Bone resorption markers, such as C- and N-terminal telopeptides of type I collagen, allow assessment of the degree of bone degradation and are used for early diagnosis of metabolic disorders [6,10].

For comprehensive evaluation of the skeletal system, laboratory methods are complemented by instrumental studies, including radiography, ultrasound densitometry, and dual-energy X-ray absorptiometry (DXA). However, biochemical blood parameters enable the detection of functional disturbances at early stages, before the appearance of pronounced structural changes. Thus, biochemical diagnostics is an integral Meyer part of the comprehensive examination of patients with bone tissue diseases, ensuring early detection of pathological processes, assessment of their activity, and monitoring of treatment effectiveness [7,14,15].

**Conclusion.** Biochemical blood analysis is an important and informative method for assessing the functional state of bone tissue. Determination of calcium–phosphorus metabolism parameters, alkaline phosphatase activity, levels of vitamin D and parathyroid hormone, as well as specific markers of bone remodeling, allows objective evaluation of bone formation and resorption processes. Changes in these parameters are often detected at early stages of skeletal system diseases, even before the appearance of pronounced clinical and instrumental signs. The use of laboratory markers in clinical practice helps reduce the risk of complications, including pathological fractures, and improves the quality of medical care provided to patients.

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