OPTIMIZATION OF TUBERCULOSIS DIAGNOSIS THROUGH THE COMBINATION OF LABORATORY AND INSTRUMENTAL METHODS

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Abstract. *Tuberculosis remains a major medical and social problem due to its high incidence and mortality. According to WHO, around 11.2 million new cases and 1.21 million deaths were reported globally in 2024. This review summarizes laboratory and instrumental diagnostic methods, highlighting their sensitivity, specificity, and clinical applicability. Integration of these approaches enhances the accuracy of detecting active and latent tuberculosis, supports optimal treatment decisions, and improves patient monitoring. Modern diagnostic strategies play a crucial role in controlling disease spread and reducing its global impact.*

Keywords: *tuberculosis, Mycobacterium tuberculosis, laboratory methods, instrumental methods.*

Tuberculosis remains a significant global health problem due to its high incidence, mortality, and social impact. Tuberculosis is an infectious disease caused by Mycobacterium tuberculosis, predominantly affecting the lungs but

also capable of involving various other organs. The disease is characterized by high contagiousness and a potential for severe complications, including fatal outcomes, which underscores the necessity for early and accurate diagnosis [3].

The causative agent of tuberculosis is Mycobacterium tuberculosis, a Gram-positive mycobacterium with high resistance to adverse environmental conditions. The primary source of infection is a person with an active form of the disease who releases the pathogen via the airborne route. Mycobacteria are capable of persisting in the body in a latent form and becoming activated when the immune response is weakened, which determines the risk of disease development even long after the initial infection [4,6].

The clinical course of tuberculosis is variable and is determined by the stage, form, and severity of the disease. The most common manifestations include a persistent cough lasting more than three weeks, usually productive with sputum and sometimes with blood admixture, shortness of breath, chest pain, general weakness and fatigue, loss of appetite and body weight, night sweats, as well as subfebrile or moderate fever predominantly in the second half of the day. These symptoms reflect both localized involvement of the respiratory system and the systemic impact of the infection on the body.

Instrumental methods make it possible to assess the localization, extent, and severity of lesions in the lungs and extrapulmonary organs, to identify associated pathological changes, and to monitor disease dynamics. Chest radiography is an accessible screening method that allows the detection of focal and infiltrative changes, cavities, and calcifications [5].

Computed tomography provides high resolution and precise visualization of lesions, the extent of fibrotic changes, and the condition of lymph nodes. Magnetic resonance imaging is primarily used for lesions of the spine, joints, soft tissues, and central nervous system, enabling the detection of inflammatory processes, abscesses, and structural changes without the use of ionizing radiation. Ultrasonography is used to assess pleural effusion, the

condition of lymph nodes and abdominal organs, as well as to monitor puncture and diagnostic procedures [1].

Bronchoscopy provides the opportunity to visually examine the bronchial tree, detect inflammatory and obstructive changes, and obtain tissue and sputum samples for microbiological and histological analysis. The combined use of instrumental methods alongside laboratory diagnostics allows for more accurate detection of active and latent forms of tuberculosis and helps determine the optimal strategy for patient treatment and monitoring [2].

Laboratory diagnostics aim to confirm the presence of the pathogen, determine its susceptibility to anti-tuberculosis drugs, and monitor the effectiveness of therapy. Microscopic examination of sputum smears allows for the rapid detection of acid-fast mycobacteria using the Ziehl–Neelsen staining method. This method is used as a screening test; however, its sensitivity is limited in cases of low bacterial load. Culture-based methods, such as inoculation on Lowenstein–Jensen and similar media, represent the "gold standard" of diagnosis, allowing for the isolation of viable mycobacteria and determination of the pathogen's drug susceptibility. The main limitation of these methods is the long time required to obtain results [4].

Molecular genetic methods, including PCR and nucleic acid-based tests, enable the rapid detection of mycobacterial DNA in clinical samples with high sensitivity and specificity, allow the identification of genes associated with drug resistance, and reduce diagnostic time from several weeks to a few hours [2,3].

Immunological methods, such as enzyme-linked immunosorbent assay (ELISA) enables the detection of antibodies or antigens of Mycobacterium tuberculosis in biological fluids, providing high diagnostic sensitivity and specificity. The method is effective for the early identification of infected individuals, screening for latent infection, and monitoring therapy effectiveness. ELISA is conveniently used in combination with microscopy,

culture-based, and molecular genetic methods, enhancing diagnostic accuracy and allowing for the monitoring of disease progression [6].

Conclusions. The effective diagnosis of tuberculosis relies on the combined application of laboratory and instrumental techniques. Instrumental examinations allow precise assessment of the location, extent, and severity of pulmonary and extrapulmonary lesions. Laboratory methods provide confirmation of the pathogen, evaluation of its drug susceptibility, and monitoring of treatment outcomes. The integration of these approaches enhances diagnostic accuracy, facilitates the timely identification of both active and latent forms of the disease, and supports the development of optimized strategies for patient management, therapy, and preventive interventions.

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