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Paediatric Tuberculosis Diagnosis in Resource-Limited Settings: Current Challenges, Available Methods and Emerging Solutions

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Abstract- ***Tuberculosis (TB) remains a major cause of morbidity and mortality among children, particularly in resource-limited settings. Diagnosing paediatric TB is challenging due to non-specific clinical symptoms, low bacterial load, and difficulties in obtaining suitable specimens from children. This review summarizes the major challenges associated with childhood TB diagnosis and evaluates current diagnostic approaches including clinical assessment, tuberculin skin testing, chest radiography, smear microscopy, culture methods, and molecular diagnostics such as Xpert MTB/RIF. Alternative specimen collection methods, including gastric aspirates, induced sputum, stool, and nasopharyngeal samples, are also discussed. Recent innovations, including Xpert MTB/RIF Ultra and urine lipoarabinomannan assays, offer improved diagnostic opportunities but remain limited by cost and infrastructure requirements. Strengthening diagnostic capacity, expanding access to rapid molecular tests, and developing child-friendly point-of-care diagnostics are essential to improving paediatric TB detection and reducing disease burden in low-resource settings.***

Index Terms: ***Childhood tuberculosis, Diagnosis, Resource-limited settings, Xpert MTB/RIF***

I. INTRODUCTION

Tuberculosis remains one of the leading infectious causes of death globally. Although adults account for most TB cases, children represent a significant proportion of the disease burden, particularly in sub-Saharan Africa and Southeast Asia. Childhood TB is frequently underdiagnosed because children usually present with paucibacillary disease, non-specific symptoms, and an inability to produce sputum for laboratory testing. Delayed diagnosis contributes to severe disease outcomes, including TB meningitis, miliary TB, chronic lung disease, growth impairment, and death. Resource-limited settings face additional challenges such as inadequate laboratory infrastructure, shortage of trained personnel, and limited access to advanced diagnostic technologies. Consequently, improving the diagnosis of paediatric TB remains a critical public health priority.

II. CLINICAL DIAGNOSIS OF PAEDIATRIC TUBERCULOSIS

Clinical diagnosis is often the first step in identifying TB in children. Common symptoms include persistent cough, fever, weight loss, failure to thrive, and night sweats. However, these symptoms overlap with many other childhood illnesses, reducing diagnostic accuracy. Several clinical scoring systems and WHO-recommended diagnostic algorithms combine symptoms, history of TB contact, physical examination findings, and radiological evidence to support diagnosis. Although useful, these approaches often lack sensitivity and specificity, especially among children living with HIV.

III. IMMUNODIAGNOSTIC METHODS

A. Tuberculin Skin Test (TST)

The Tuberculin Skin Test remains widely used for identifying TB infection. While relatively inexpensive, its performance is affected by previous BCG vaccination, exposure to non-tuberculous mycobacteria, HIV infection, and malnutrition. The requirement for two clinical visits also limits its effectiveness in resource-constrained settings.

B. Interferon-Gamma Release Assays (IGRAs)

IGRAs offer improved specificity because they are not influenced by BCG vaccination. However, they

are costly, require laboratory infrastructure, and cannot differentiate latent infection from active disease. Their performance is reduced in very young children and immunocompromised patients.

IV. RADIOLOGICAL DIAGNOSIS

Chest radiography is an important component of paediatric TB evaluation. Common findings include hilar lymphadenopathy, pulmonary infiltrates, consolidation, and pleural effusion. However, radiographic abnormalities may resemble other respiratory diseases, and interpretation often varies among clinicians.

Access to quality radiology services remains limited in many resource-poor settings, restricting the usefulness of this diagnostic modality.

V. MICROBIOLOGICAL DIAGNOSIS

A. Smear Microscopy

Sputum smear microscopy is one of the oldest and most widely available TB diagnostic tests. However, its sensitivity in children is low because childhood TB usually contains few bacteria. Consequently, many infected children have negative smear results despite active disease.

B. Mycobacterial Culture

Culture remains the reference standard for microbiological confirmation of TB. It provides higher sensitivity than smear microscopy and allows drug susceptibility testing. Nevertheless, culture requires specialized laboratories and several weeks for result availability, making it impractical for many low-resource settings.

VI. MOLECULAR DIAGNOSTIC METHODS

The introduction of Xpert MTB/RIF significantly improved TB diagnosis by enabling rapid detection of Mycobacterium tuberculosis and rifampicin resistance within hours.

Studies show that Xpert MTB/RIF is substantially more sensitive than smear microscopy and has high specificity. The newer Xpert MTB/RIF Ultra further improves sensitivity, particularly in children with paucibacillary disease.

Despite these advantages, widespread implementation remains limited by equipment costs, cartridge supply requirements, electricity dependence, and maintenance challenges.

VII. SPECIMEN COLLECTION CHALLENGES

Obtaining suitable clinical specimens from children remains one of the greatest challenges in TB diagnosis.

Common specimen collection methods include:

- Induced sputum, which provides good diagnostic yield but requires trained personnel and specialized equipment.
- Gastric aspirates, useful in young children who swallow respiratory secretions during sleep.
- Nasopharyngeal aspirates and swabs, which are less invasive but generally provide lower sensitivity.
- Stool specimens, increasingly recognized as a promising alternative for molecular testing using Xpert MTB/RIF Ultra.

Among these options, stool-based testing offers considerable potential because sample collection is simple, painless, and suitable for community settings.

VIII. EMERGING DIAGNOSTIC APPROACHES

Several new diagnostic technologies are under investigation.

Urine lipoarabinomannan (LAM) testing provides rapid point-of-care results and is particularly useful among HIV-infected children with advanced immunosuppression. Biomarker-based diagnostics, transcriptomic signatures, metabolomics, CRISPR-based assays, and next-generation sequencing have also demonstrated promise in research settings.

Although these innovations may transform paediatric TB diagnosis in the future, additional validation and cost reduction are required before widespread implementation.

IX. CONCLUSION

Paediatric tuberculosis diagnosis remains difficult, particularly in resource-limited settings where the majority of childhood TB cases occur. Conventional diagnostic tools such as clinical assessment, TST, radiography, smear microscopy, and culture remain important, but each has significant limitations. Molecular methods, especially Xpert MTB/RIF and Xpert MTB/RIF Ultra, represent major advances but are not universally accessible.

Improving childhood TB diagnosis requires investment in diagnostic infrastructure, wider deployment of rapid molecular technologies, strengthened healthcare systems, and development of affordable non-sputum-based point-of-care tests. Such interventions are essential to reduce diagnostic delays, improve treatment outcomes, and support global TB elimination efforts.

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