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PEDIATRIC TUBERCULOSIS: DIAGNOSTIC CHALLENGES AND FUTURE STRATEGIES

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Abstract: This comprehensive review delves into the persistent diagnostic barriers inherent in pediatric tuberculosis (TB), especially in high-burden, resource-limited countries such as Uzbekistan. Highlighting the clinical ambiguity caused by paucibacillary disease and the difficulty in specimen collection, the review covers conventional methods—including clinical scoring, chest radiography, tuberculin skin test (TST), interferon-gamma release assays (IGRAs), GeneXpert MTB/RIF and Ultra—as well as innovative advances like stool-based assays, blood-based host-response tests (e.g., Xpert MTB-HR), and AI-enhanced chest X-ray interpretation. We also discuss digital decision-support systems, active case-finding, and contact-tracing strategies. Country-specific data underscore significant underdiagnosis, with up to 58% of cases missed in children aged 0–4 . The review advocates for integrated diagnostic algorithms supported by modern tools and stronger health systems, with research priorities focused on cost-effectiveness, technology adaptation, and tailored pediatric solutions.

Keywords: pediatric tuberculosis, paucibacillary, GeneXpert MTB/RIF Ultra,Xpert MTB-HR host-response, stool-based Xpert, AI-based chest X-ray, clinical scoring algorithms ,active case finding.,digital decision support, Uzbekistan burden

Introduction: Tuberculosis in children remains a leading cause of mortality, with approximately 1.2 million pediatric cases and 226,000 deaths globally in 2023 . Paucibacillary infection, non-specific symptoms like fever and cough, and limited laboratory capacity make diagnosis challenging . In Uzbekistan (~57/100 000 incidence; ~3,200 pediatric cases in 2020), high MDR-TB prevalence exacerbates detection issues . Underdetection is especially acute in children under 5, accounting for ~58% of missed cases .

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2. Methods

Literature search: PubMed, WHO, MDPI, Scopus, Google Scholar, ResearchGate; English-language studies from the past decade, focusing on pediatric TB diagnosis in resource-limited settings.

Inclusion criteria: Diagnostic performance, field implementation, technological innovations, modeling of missed cases.

Data triangulation: Supplemented by WHO reports and country-specific program data.

Results

3.1 Core Diagnostic Challenges

Low bacillary burden & sample issues: Microbiological confirmation in children <30%, even with induced sputum .Symptom overlap: Fever, weight loss, cough often mirror other pediatric illnesses .

Limited infrastructure: Centralized labs/platforms (GeneXpert, culture) inaccessible in many rural areas .

3.2 Traditional Diagnostics Revisited

Clinical algorithms: Provide structured guidance but vary widely in sensitivity and specificity; risk of both under- and over-diagnosis .TST and IGRA: Helpful for LTBI detection; insufficient to confirm active disease .Chest X-ray: Readings subjective and require radiologist training; implementation aided by CAD/Ai tools .

Xpert MTB/RIF Ultra & Urine LAM: Ultra improves sensitivity (~80–89%) in children; LAM suitable for HIV-positive children but variable sensitivity (13–93%) .

3.3 Emerging Technologies

Stool-based Xpert: Easier to collect; implemented in Vietnam/Tanzania, accounting for ~37% of pediatric TB testing .

Host-response cartridge (Xpert MTB-HR): Detects 3-gene blood signature; AUC 0.85–0.89, sensitivity ~60–90%; performs better in confirmed vs unconfirmed cases .AI-enhanced CXR: Self-supervised ViT models achieved AUC ~0.70 in pediatric TB detection . Commercial CAD tools (e.g., qXR) outperform human radiologists in adults, likely adaptable for children with further training .

Decision-support systems (CDSS): Pilot systems in Philippines use block-chain and rule-based algorithms to assist frontline health workers .

3.4 Uzbekistan-Specific Data

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MDR-TB burden ranks Uzbekistan high in region; national survey launched mid-2023 .

Contact tracing remains low (<5 contacts/case), delaying pediatric detection .Digital learning and AI-supported CXR initiatives piloted in Tashkent provinces—evaluation ongoing.

Discussion:Diagnostic gap: Globally <50% pediatric TB cases detected; in Uzbekistan lower still, especially among <5 age group .Multimodal strategy: Combining stool-Xpert, blood host-assays, AI-supported CXR reading, and decision-support can triangulate results and compensate for individual limitations.

Implementation barriers: Infrastructure deficits, cost constraints, lab referral complexities, training needs, and data-sharing hurdles.Health system interventions: Scale up GeneXpert Ultra and MTB-HR tools; train community workers in sample collection (stool, capillary blood); expand contact tracing via mobile-health platforms.Research agenda: Validate cost-effectiveness and diagnostic value of integrated algorithms, specifically for Uzbekistan's epidemiology and health systems.

Conclusion: Pediatric TB diagnosis in Uzbekistan needs urgent prioritization. Multi-biological, multi-tech diagnostic cascades—a combination of stool Ultra, blood host-response assays, AI-based CXR, and CDSS—should be piloted. Health system strengthening in lab access, training, and digital infrastructure is equally vital. Future studies should focus on algorithm performance, economic viability, and adaptation to local workflows.

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