

## The Role of Artificial Intelligence in Improving Diagnostic Accuracy for Paediatric Tuberculosis

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### ABSTRACT

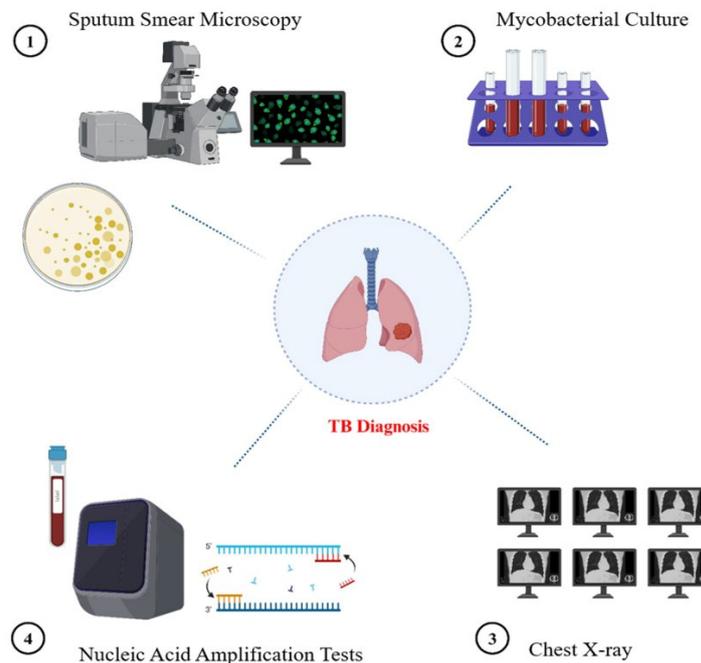
Despite worldwide efforts focused on early diagnosis and treatments to reduce disease transmission, Tuberculosis (TB) remain the leading cause of death for children. Childhood tuberculosis diagnosis is complicated due to the fact that the disease is usually paucibacillary and that it is difficult to collect appropriate clinical samples, leading to the poor sensitivity of the existing tests based on pathogens. Over the last few years, significant technological changes in particular the creation of artificial intelligence (AI) and deep learning have started to transform the field of pediatric TB diagnosis and management. AI-enhance digital chest radiography has demonstrated diagnostic power and sensitivity similar to expert radiologists and at the same time eliminates workload, inter-reader reliability and delays in diagnostics. The CAD systems based on machine learning enhance finding radiographic abnormalities at an early stage and it can be particularly applicable to tuberculosis screening in low-resource or high-burden cases. The review defines the current diagnostic methods like Microscopy, Culture, NAAT like Xpert Mycobacterium tuberculosis/RIF, Interferon-gamma release assays (IGRA) and advanced imaging modalities that emphasize the necessity of having integrated, high-precise and cost-effective diagnostics. Although the potential of AI-based methods is obvious, the issue of data privacy and the absence of standardized validation research, which ensure equal access to AI-based methods, as well as effective systems of governance, are vital measures toward achieving the full potential of artificial intelligence in pediatric TB care. We also the primary challenges to applying AI for paediatric tuberculosis diagnosis and look at current AI application for TB screening in resource-constrained situations. Overall, this review highlights that AI is an effective supplement to current diagnostics, which have promising possibilities of earlier diagnosis, more accurate screening and better management of TB in children worldwide

**Keywords:** *Artificial intelligence (AI), Tuberculosis (TB), Machine learning (ML), Computer aided detection (CAD), Nucleic acid amplification test (NAAT), Interferon-gamma release assays (IGRA), Chest radiograph...*

### 1. INTRODUCTION

Mycobacterium tuberculosis, the airborne infectious disease responsible in the development of tuberculosis remains a primary contributor of illness and death among children under 15 years of age worldwide[1]. The death rate of tuberculosis among children has been approximated to be close to half a million deaths every year and one million children have been reported to have the disease. World Health Organization (WHO) estimates that 1.2million children and young adolescents (2023, under 15 years) fell ill with TB in 2023 with 226,000 deaths worldwide[2]. Tuberculosis (TB) is a major health challenge in the world, particularly among the children, where diagnosis is usually complicated by lack of specific symptoms, and there is problem of acquiring good specimens[3]. All these challenges underscore the necessity to have better diagnostic instruments to improve early and accurate diagnosis. The principal diagnostic approaches currently used for TB including sputum smear microscopy, mycobacterium culture, chest X-ray, and nucleic acid amplification test are illustrated in Fig.1. The adoption of artificial intelligence (AI) can be defined as a type of computer technologies that allow robots to perform tasks that in most cases demand human intelligence, including identification of picture, recognition of patterns, and decision-making. As a result of the existence of sensitive bacteriology tests that screen and diagnose, there have been great achievements in the diagnosis of TB in the past few decades. The Xpert MTB/rifampicin resistance analysis is a quick NAAT test that can detect both Mycobacterium tuberculosis and rifampicin medication resistance[4]. Despite being a reliable test, it is costly and involves the utilisation of human and time resources, particularly in young children when

getting sputum samples is difficult. Because of the confusing clinical symptoms, lower bacillary burden or difficulties obtaining an appropriate specimen, imaging is particularly crucial in the diagnosis of pulmonary TB in children[5]. Nearly a quarter of a million TB related deaths were reported, and 1.3 million cases of TB were detected in children under the age of fifteen, according to the most recent WHO data [WHO 2023 Global TB Report][6]...



**Fig.1: Key Methods used in Tuberculosis Detection.**

### DIGITAL CHEST RADIOGRAPHY WITH AI FOR TB SCREENING

Chest x-ray is affordable equipment which gives a very accurate process of monitoring individuals. Additionally, it is a frequently used diagnostic tool for pulmonary tuberculosis when bacterial confirmation is not attainable and minimum radiation is used. H. Yoon et al study assessed the performance of AI-supported digital casket radiography for TB webbing. AI algorithms achieved perceptivity and particularity similar to mortal radiologists, with the added benefit of reducing workload and individual detainments. The authors stressed the eventuality of AI to enhance mass webbing sweats, particularly in high burden settings. Still, they emphasized the need for nonstop algorithm training and confirmation to insure delicacy across different populations. Ethical considerations, similar as data sequestration and algorithmic bias, were also banded as critical factors for successful perpetration[7].

Chest radiography is recommended in the WHO consolidated recommendation regarding the treatment of TB. Radiography is a sensitive screening method that is crucial for the rapid identification of paediatric tuberculosis, even though it is insufficient to confirm a diagnosis. Moreover, research has indicated that children are more susceptible to tuberculosis (TB) as compared to adults and that in case of early diagnosis, when combined with TB prophylaxis therapy, could mirror less impact of the disease on the general population.

According to the study, adding radiography to child TB contacts may not only enable TB diagnosis earlier than would be possible with symptom screening alone, but it may also identify a subgroup of child contacts who are likely to get TB in the future. Additionally, we demonstrate that nonspecific CXR results in child TB contacts may point to subclinical or incipient TB disease that needs to be treated. However, because tuberculosis preventative medication is still quite successful in asymptomatic contacts including those CXR abnormalities access to it shouldn't be restricted[8].

### CAD WITH MACHINE LEARNING (ML) TECHNOLOGY IN TB DETECTION

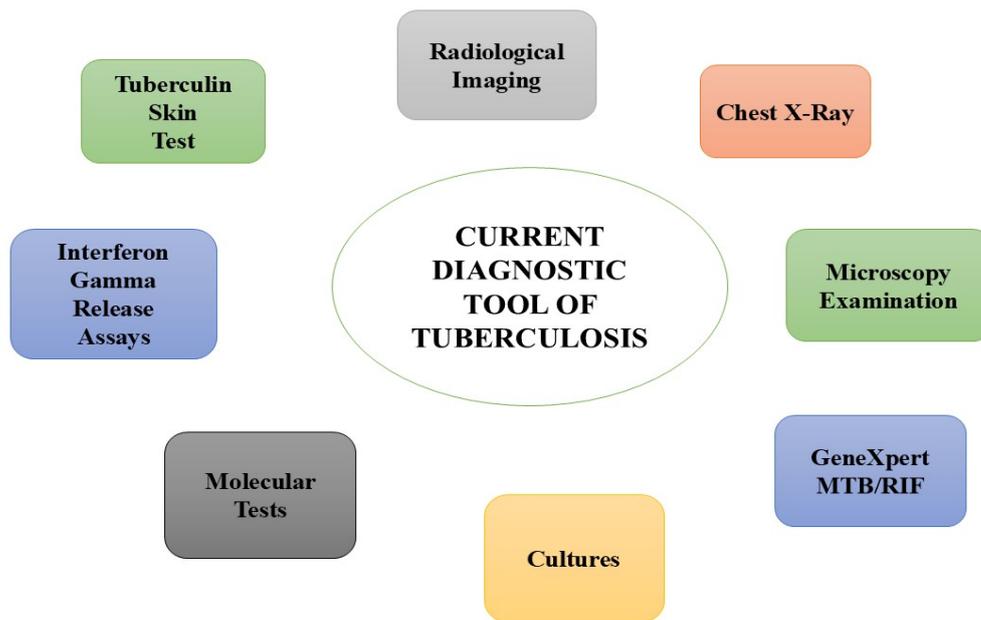
CAD systems driven by AI can be crucial for both mass TB screening and helping radiologists analyse chest X-ray pictures[9]. TB cases can be found via CXR screening. The scientific field of machine learning (ML) depends less on human specification and lets algorithms determine what factors are crucial[10]. Numerous CAD algorithms for CXRs have been developed for common diagnostic procedure. CAD systems in CXRs can assist physicians in identifying suspicious lesions that are easy to interpret, hence boosting the accuracy of detection. Tavaziva G et al analysed each CXR using three commercially available deep learning-based CAD programs. CAD4TB version 6 employed an identical threshold score in all studies, yet sensitivity and specificity showed study to study variation. The perfection of the CAD systems was found to be equal to that of human evaluators. Users must establish threshold scores based on their particular patient population in

order to use CAD, chest x-ray analyses is a very-sensitivity TB ruling-out test[11]. For TB program implementers trying to use CXR screening to enhance TB detection, CAD software for CXR interpretation can solve a number of present issues. CXR examination-based case discovery shown greater accuracy than symptom screening, according to earlier research. Despite its great sensitivity when interpreted by skilled radiologists, CXR has drawbacks, mostly because of its low specificity and considerable variability between readers.

**CURRENT DIAGNOSTICS TOOLS OF TUBERCULOSIS:**

Tuberculosis (TB) is detected using a variety of diagnostic techniques. The microscopic analysis of sputum samples using acid-fast staining to detect Mycobacterium tuberculosis is one of the most widely utilized methods[12]. While cultivating sputum aids in confirming the presence of the bacteria and directs drug susceptibility tests, chest X-rays are crucial in identifying lung patterns associated with tuberculosis. An overall representation of the commonly used TB diagnostic tools is illustrated in Fig.2. Higher sensitivity and the capacity to identify drug resistance are provided by molecular assays, such as Polymerase Chain Reaction (PCR) and Nucleic Acid Amplification. While Tuberculin Skin Tests (TST) can identify TB exposure, Interferon-gamma release assays are an efficient way to differentiate between latent and active TB. GeneXpert new point-of-care assays are designed to provide quick bedside diagnosis, including GeneXpert Mycobacterium tuberculosis/rifampicin resistance (MTB/RIF) offers quick diagnostic results and resistance testing. Computer Tomography (CT) and Magnetic resonance imaging are examples of advanced radiological imaging techniques that are essential for determining the extent of tuberculosis (TB), especially in situation of extrapulmonary involvement[13]. Together these techniques provide a comprehensive diagnostic armament for TB detection and management. The study concentration on the opportunities and difficulties associated with the different TB diagnosis techniques.

The study demonstrates that every diagnostic technique has advantages and disadvantages. The study’s conclusion recommends that efforts should consistently concentrate on enhancing the precision of TB diagnostic techniques, putting cost-effective strategies into practice, putting strong quality control mechanisms in place, adopting a through diagnostic approach, and funding continuing research to address new issues in TB diagnosis[14].



**Fig.2: Current Diagnostic Tool of Tuberculosis**

**2. CHALLENGES**

AI-based tuberculosis diagnoses are very promising, but there are a lot of issues and restrictions on their general acceptance and clinical implementation. Even though AI has a lot of potential, it also poses difficult ethical, privacy, data security, algorithm bias and legal issues. Additional clinical trials are needed to confirm the applicability of AI models. The development of AI algorithms depends on large, well-annotated datasets, which are difficult to get due to the complexity of sensitive personal data[15]. The technological ramifications of data protection, definitions of confidentiality, and other fundamental principles of medical ethics are among the difficulties associated with gaining access to sensitive personal data. Both human biases in decision-making and the biases present in the way healthcare is now provided may be reflected in AI systems[16]. The absence of common definitions and usage guidelines for this technology, as well as conflicting conceptions of liability among many parties, are among the legal challenges associated with its application. It is crucial to make sure that

the business models utilized in the creation, implementation and maintenance of these technologies do not represent conventional political power dynamics that perpetuate historical injustices.

### 3. CONCLUSION

Paediatric tuberculosis is a significant health challenge on the global scale, implying that its clinical manifestation is rather unspecialized, bacillary load is small and sufficient samples cannot be obtained in children, which hinders the efficiency of traditional pathogen-based detection methods. The review highlights the emerging position of Artificial Intelligence particularly the deep learning in improving the accuracy of diagnosis with better interpretation of computer-aided detection systems and chest radiographs. The performance of these AI tools has been seen to be equal to that of trained radiologists and they provide reliable, quick and scalable assistance that is especially useful in high-burden and resource constrained environments. Nonetheless, the challenges that still prevent its widespread adoption include the requirement of large, heterogeneous and quality data, the issue of data privacy, the bias of the algorithms, and the absence of validations on various population. Enhancing the regulatory systems making investments in multicentre clinical validation and making sure that AI is implemented in an ethical and equitable manner will be necessary to exploit the full potential of AI in enhancing early diagnosis and alleviating the burden of childhood tuberculosis.

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