# ARTIFICIAL INTELLIGENCE IN TB CONTROL

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Traditional methods of diagnosing tuberculosis require significant time and resources, particularly in countries where the disease is prevalent and healthcare systems are less developed. Additionally, more and more tuberculosis cases are becoming resistant to drugs, posing a significant hazard to public health. Culture-based TB diagnosis, which has long been considered the most reliable method, faces challenges due to its long testing times. To address this issue, MTB/RIFassays such as GeneXpert and Truenat were developed. These are rapid molecular tests that detect Mycobacterium tuberculosis DNA and rifampicin resistance [1]. However, as of 2022, their use remains limited, with only 33% of people globally using them as initial diagnostic tests [2].

In recent decades, the rapid advancement of computer technology has led to an increased interest in artificial intelligence (AI) across various industries, particularly in the realm of image recognition. The term "Artificial Intelligence" was coined by John McCarthy [3]. AI involves creating computer systems capable of studying and developing theories, methods, and technologies, as well as performing tasks that simulate and extend human intelligence. Researchers and innovators are utilizing AI to supplement and enhance current diagnostic methods, acknowledging the necessity for improved accessibility, cost-effectiveness, sensitivity, awareness, and infrastructure. Over the past decade, there has been a significant increase in investment in various techniques and technologies for TB treatment. These efforts include precision medicine, improved surveillance, program management, prevention strategies, AI-supported early diagnosis, monitoring, and optimization of patient care. Around 23% of the global population is estimated to have LTBI [4]. In India, the estimate is 35-40% of the population [5]. Identifying whom to test for latent tuberculosis infection (LTBI) can be challenging since individuals often do not seek care due to the absence of symptoms. Therefore, testing and treating a large section of the population presents a challenge. AI has the potential to identify areas that are more vulnerable and, require greater interventions. By using a range of input parameters, a potential AI solution can forecast the probability of LTBI progressing into active TB.

Early detection of active TB cases in a community is critical in breaking the chain of transmission. Globally, 2.9 million TB cases are unreported (the gap between estimated cases and newly diagnosed cases) due to underreporting of diagnosed cases or underdiagnosis [6]. AI can accelerate medical diagnosis by swiftly and accurately analyzing medical images like chest X-rays within minutes. For example, AI-based software called qXR, rapidly classifies X-ray scans, identifies lung abnormalities, and highlights them on the X-ray, enabling the detection of TB within minutes and linkage to treatment on the same day [7]. Although AI-assisted X-ray reading has the potential to detect radiological lesions promptly but it has limitations of differential diagnosis and identifying lesions of other diseases.

There is a hypothesis that the cough sounds produced by individuals with pulmonary tuberculosis (TB) may possess a distinct signature. Therefore, if an AI solution can learn the characteristics of these cough sounds, it could classify individuals in real-time as either healthy or likely to have tuberculosis. An AI-based mobile platform called "Swaasa," currently undergoing validation with support from the India HealthFund & ACT Grants, utilizes a mobile phone's microphone to record cough sounds from a patient. These sounds are analyzed to identify unique cough signatures, enabling the rapid detection of possible TB presence within seconds [8]. But the reliability of AI study of cough sound is being assessed in large cohorts before making it a universal screening tool. Even then, it may becomea screening test but not diagnostic of tuberculosis, which we may require complementing it with symptomatic screening.

AI-enabled reading and interpretation of diagnostic tests can help improve the efficiency and accuracy of test results. One such example is the AI-enabled reading and interpretation of Line Probe Assay (LPA) strips used for the diagnosis of Drug-resistant tuberculosis. But first we have to ensure the availability of these tests both in public and private sectors.

Adherence to medication poses a significant challenge for patients with TB [9]. Electronic medication monitors, capable of transmitting text messages, have been effectively used in low-resource settings with a high burden of TB. Virtual directly observed treatment via video (VDOT)allows providers to remotely observe patients taking medication through smart phones or tablets. Both of these technologies still require substantial input from healthcare workers to interpret the signals they send. Artificial intelligence holds promise in reliably recognizing patterns and gestures, enhancing the effectiveness of these tools. For instance, AI-enabled software in VDOT can identify unique features of individuals taking medication, generating a distinct signature transmitted to caregivers. This approach could also benefit other clinical monitoring scenarios beyond TB treatment[10, 11, 12, 13].

Drones can be used as crucial tools to connect primary healthcare facilities to hospitals by delivering patient information and samples in rural areas [14]. A study highlighted the use of drones for transporting biological specimens with a finding that that time saving was 20–30% less in the urban model but 65–74%in the rural areas using drones at higher speeds. Finally, a study from Ghana [15] proves that an AI-enhanced medical drone application in the healthcare supply chain (HSC) contributes significantly to the host country's HSC and sustainable development goals (SDGs).

The future of AI in healthcare lies in Generative-AI (Gen AI), which provides instant outputs that are often indistinguishable from human-generated content. Gen AI is the new kid on the block as far as the healthcare revolution is concerned, offering solutions from real-time clinical decision support to personalized patient interaction. Number of Gen AI startups in India has more than doubled in the last three years.

AI applications in TB control hold significant promise in various aspects of prevention, diagnosis, and treatment. AI could make an impact in early detection and assistance in diagnosis where AI algorithms can analyze chest X-rays and CT scans to detect TB lesions with high accuracy, enabling earlier diagnosis and intervention. AI-powered tools can assist healthcare providers in interpreting diagnostic tests such as sputum smear microscopy, molecular tests, and serological assays, improving diagnostic accuracy and speed. AI can be beneficial in the drug discovery process by analyzing vast datasets to identify potential drug candidates and predict their efficacy against TB bacteria, including drug-resistant strains. AI can play an important role in epidemiological surveillance by analyzing various epidemiological data and also help in healthcare resource allocation by predicting TB incidence, treatment outcomes, and healthcare utilization, enabling policymakers to allocate resources more efficiently and effectively. Public Awareness can be improved with the help of AI which can facilitate the development of interactive educational tools, chatbots, and virtual simulations to raise awareness about TB. Other Areas where AI can be advantageous is in treatment Optimization by analyzing patient data to personalize treatment regimens, Telemedicine and Remote Monitoring. AI-powered predictive modeling can analyze behavioral data to understand factors influencing TB transmission and develop targeted interventions for behavior change and prevention.

The future of TB control holds great potential for improving outcomes, reducing transmission, and ultimately, achieving global eradication goals. However, it's essential to address challenges such as data privacy, equity, and implementation barriers to ensure that AI innovations benefit all communities affected by TB.

Last but not least, while the adoption of AI in healthcare offers numerous potential benefits, it also raises significant ethical, legal, and social concerns. The development and deployment of AI-based solutions must address issues such as data safety, sharing, and privacy. For instance, while AI can facilitate easy diagnosis and access to healthcare, unsupervised use may pose risks. Therefore, establishing an ethical and regulatory framework is essential before integrating AI into health research and healthcare delivery.

Integrating AI into TB diagnosis offers a valuable opportunity to enhance and automate screening and detection processes. However, successful adoption requires addressing challenges such as establishing standardized reporting guidelines, addressing diagnostic variations, resolving implementation issues, enhancing technical expertise, developing assessment frameworks for AI technology, and securing sufficient financial resources. Collaboration among physicians, researchers, innovators, funders, implementers, and policymakers is crucial for effectively tackling these challenges.

In conclusion, AI has great potential in identifying the areas which are more vulnerable and can help in improving the outcomes through early diagnosis by rapid detection of TB by identifying cough sounds and improving the efficiency and accuracy of test results by AI-enabled reading and interpretation of diagnostic tests. AI can be favorable in effective treatment optimization and it can help in treatment adherence by telemedicine and remote monitoring. Drones via AI can be useful in bridging the gap between primary healthcare facilities and tertiary care hospitals. It can be effective in transporting biological specimens and can contribute to healthcare supply chain management. AI can be fruitful in reducing transmission and ultimately achieving TB eradication goals.

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