



Artificial Intelligence in Tuberculosis Control in India: A Review

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Abstract

Tuberculosis (TB) is a chronic infectious disease caused by the bacterium *Mycobacterium Tuberculosis*, which most commonly affects the lungs but can also impact other parts of the body such as the kidneys, spine, and brain. India continues to carry one of the highest burdens of tuberculosis (TB) globally, necessitating scalable, rapid, and accurate diagnostic and prognostic tools. This literature review examines applications of artificial intelligence (AI) particularly machine learning (ML) and computer-aided detection (CAD) in TB screening, diagnosis, and treatment adherence within India. It assess AI-driven chest X-ray interpretation systems like qXR, Genki, DeepTek, DxTB, large-scale model validations, adherence prediction frameworks, and pilot deployments like mobile vans, slum-based screening. Key challenges and research gaps are identified, including dataset diversity, real-world integration, fairness, and cost-effectiveness in resource-limited settings. The review synthesizes lessons from contemporary initiatives like Wadhwani AI and mobile diagnostic units under the NTEP. This study highlights the landscape of AI driven tuberculosis screening. Concluding remarks focus on the identification of research gap and suggests strategic pathway for long term, sustainable integration of AI into TB elimination programme of our country.

Keywords

Artificial Intelligence, tuberculosis, Machine Learning, Healthcare; Computer Aided Detection, TB elimination

1. Introduction

Tuberculosis (TB) is a prolonged infectious disease caused by *Mycobacterium tuberculosis*. Primarily affecting the lungs, it can also disseminate to other organs including the spine, bones, kidneys and brain. Its transmission occurs through airborne droplets released when an infected individual coughs or sneezes. This disease is prevalent in overcrowded, poorly ventilated or unsanitary environments. Despite being both preventable and curable, TB remains a major public health concern worldwide. As reported by the World Health Organization (WHO), in 2023, approximately 10.6 million new TB cases and 1.3 million associated deaths occurred globally keeping it among the deadliest infectious disease [9].

In India, tuberculosis has evolved into a pressing public health concern claiming an estimated 220,000 lives each year and accounting for nearly a quarter of the world TB cases[16]. Through the National TB Elimination Program (NTEP), earlier known as RNTCP the government has implemented a comprehensive diagnostic measure featuring sputum microscopy , CBNNAT (Gene Expert) and Truenat testing to eliminate TB by 2025[16]. However, despite a well-established surveillance system, several challenges persist that delay diagnosis and hinder effective disease control in the country.

Over the past half-decade, several research initiatives and AI- driven pilot projects are instituted in India to monitor and strengthen treatment of Tuberculosis [4]. National TB Elimination Programme(NTEP) has implemented AI powered screening tools in collaboration with organizations like Wadhvani AI to identify TB cases in slums and remote village areas with the support of community health workers and mobile vans[21]; [20]. These types of medical diagnostic frame works contribute the rapid processing of medical data, thus facilitate the early stage disease detection. This advancement supports continuous patient surveillance and timely medical intervention [22].

As global technological advancements continue, AI powered methods like Computer Aided Detection (CAD) and Machine Learning (ML) have become pivotal in improving the accuracy of TB identification. Such innovations promote timely diagnosis and treatment, enhance drug management and ensure that people in underserved rural and semi urban communities receive prioritize care. This review examines the operational scope of diverse AI tools, discusses their limitations and evaluates their contribution to India's on-going efforts to eradicate tuberculosis.

These tools are useful in early diagnosis, but more research is needed to understand how they work and how much they are enabling to improve the health care system. In everyday medical practice it is also important to see how well these tools fit with public health program, data system and daily work of doctors, nurses, lab technicians and community health workers[23].

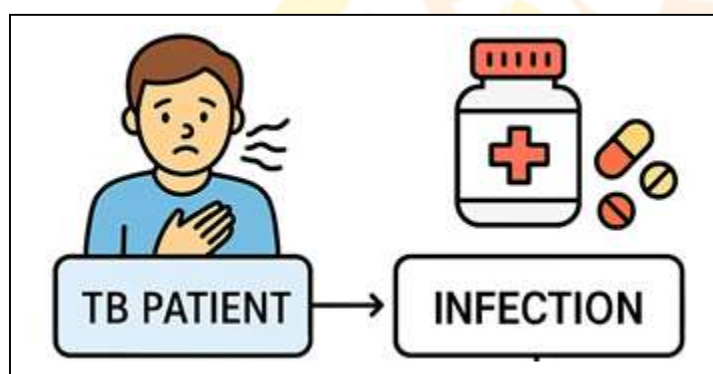


Fig: 1 TB Patient for Predictive Analysis of Tuberculosis Treatment

1.1 Potential and Challenges of AI Integration in India's TB Control Efforts

Artificial Intelligence (AI) is a technology through which human intelligence is stimulated in machines so that through programming the machines are trained to think, learn, and make decisions like humans. In the field of healthcare system, by the use of large datasets, algorithms, and computing power the AI can be used to assist in diagnosis, prediction, treatment planning, query integration, fetching data and security play also important role. [41,42,43,44]. Key AI tools, like machine learning and deep learning which help the system to learn patterns and analyse images from medical data. Computer-Aided Detection (CAD) systems image detection tool, which help to detect variations in chest X-rays and other images. In these days these technologies are innovatively implemented for a faster and accurate detection of diseases and its management. Now- a-days these are used in resource-limited settings like rural India, where skilled medical professionals and diagnostic infrastructure may be limited to offer a faster, more accurate, and scalable solutions.

AI is rapidly emerging as a key enabler in addressing diagnostic gap with in India's health care system, where overcrowding and unequal access to diagnostic resources remain persistent issues. By combining automated X-ray interpretation with patient data analysis AI tools are capable of accurately identifying TB symptoms. Applying Predictive Analytic and Machine learning these systems enhances diagnostic process and treatment prediction [24], [25]. They assist health care providers in minimizing diagnostic errors and prioritizing patients at higher risk, facilitating immediate medical responses. Since these systems operate automatically, they can continuously monitor patients, send reminders and promote medications on time. This also reduces the chances

of drug resistant TB and improves recovery [26]. Still, putting these tools into real- life health care needs proper planning. Issues like ethics, data privacy, security and fitting the technology with existing system must be handled carefully. In a country as diverse as India, the technology also needs to support people from all income levels, languages and health backgrounds equally [20].

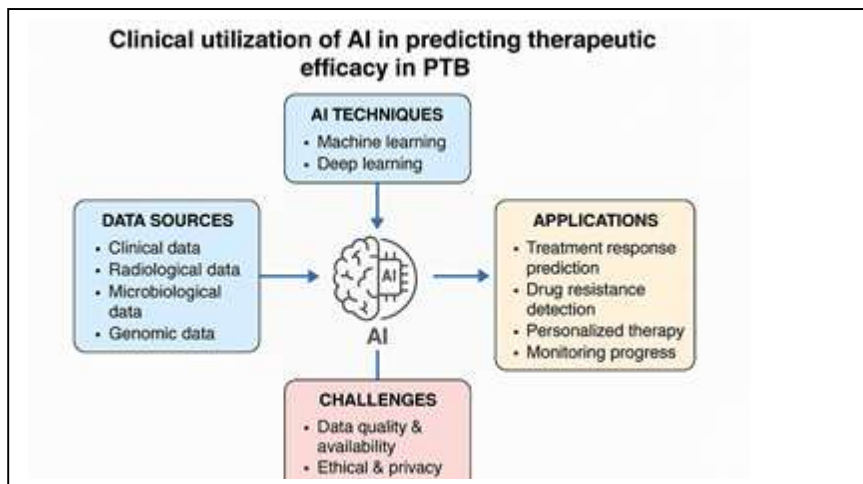


Fig 2. Clinical utilization of AI in predicting therapeutic efficacy in PTB

2. Literature Review

2.1 AI-Enabled Chest X-Ray Screening: AI/ Deep learning algorithms to automatically detect signs of pulmonary tuberculosis from chest X-ray images, enabling faster and more accurate diagnosis.

2.1.1 qXR (Qure.ai): qXR is an artificial intelligent based chest X-ray screening tool, which has been introduced in India since 2020 to analyse chest X-rays for the detection of TB. Its integration in public health system now spans into more than 100 hospitals across 17 states enabling both urban and rural area to strengthen their TB screening capacity and improve early diagnosis. Since its introduction, over 75000 people have been screened using this technology. It was observed that the interval between diagnosis and treatment initiation was reduced to nearly half of its actual duration while the incidental TB case detection in Mumbai hospitals was increased by 20% [6].

In Nagpur, A PATH led initiative showed that AI increased TB detection by 15.8% including cases overlooked by radiologists [14]. Similarly, a comprehensive evaluation of five CAD platforms including qXR and CAD4TB confirmed that these AI systems consistently outperformed human readers in radiographic TB diagnosis. However, diagnostic accuracy varied across patient subgroups and referral pathways, it shows that AI tools need to be adapted and tested locally before large-scale use [1].

2.1.2 Genki (AI based mobile CADe software)

Genki is an AI based mobile software, which is considered as a highly accurate AI tool used in health screening for the diagnosis and detection of TB. It was firstly used in Chennai in 2022. Four diagnostic units were installed in the rural areas of Chennai to screen the health condition of the people. Around 25,598 individuals of different age and genders were undergone the screening and produced a strong and accurate result of Tuberculosis. Genki system could provide an overall accuracy of 96.9% with the sensitivity of 98% and the specificity of 96.9%. [11]. Moreover, the reports indicate that Genki is capable of producing results approximately in 60s thereby minimizing the diagnostic delay and limits expensive tests to only those cases which is pre-identified by the AI system[20].

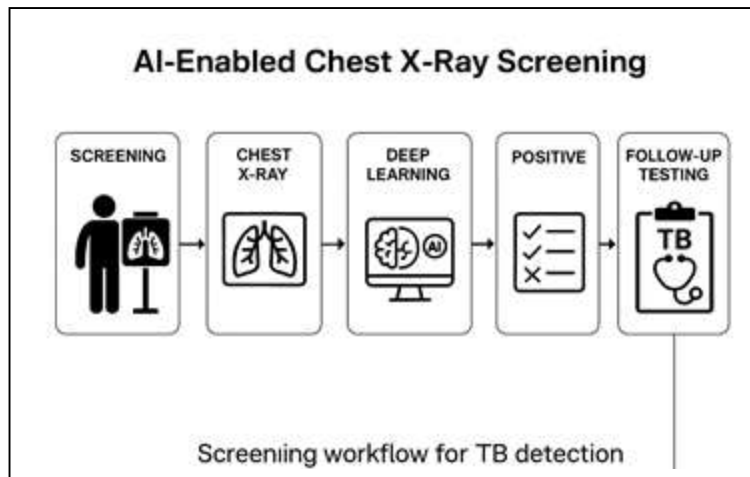


Fig3: Image shows a comprehensive end to end screening workflow of TB detection

2.1.3 DeepTek DxTB Tool

DxTB is an AI powered TB detection tool, developed by DeepTek to examine X-ray images and detect pulmonary TB. DxTB can run on the cloud or as an edge based service in setting with limited or no internet connectivity. Radiologists can access imaging studies through dedicated dashboard and give their expert feedback and validation [12].

The system has been deployed in mobile vans and imaging centres as a part of TB screening initiatives. It was utilized to analyse more than 70,000 chest radiographs during the TB Free initiative in Chennai helping to detect TB cases more quickly [12]. This integration significantly reduced turnaround time with referential decisions made possible several weeks to hours [12].

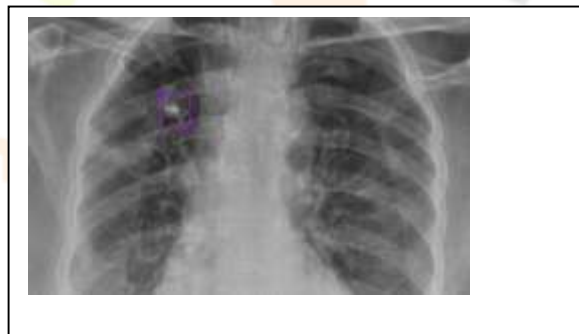


Fig: 4 From Point AI to Point TB: DeepTek Detects Tuberculosis from X-Rays

2.1.4 Other AI Developments

The Sanjay Gandhi Postgraduate Institute of Medical Sciences (SGPGIMS) in Lucknow created an AI-based application called DecXpert that can detect tuberculosis from medical images and other data within few seconds with accuracy about 95%. This application has earned a reputation for reliability. Its credibility is further strengthened by the recognition by the World Health Organization (WHO) as a trusted tool for TB detection [7].

In addition to existing tools, the Multi Pathology AI system offers a high remarkable accuracy in chest X-ray interpretation. This system has been trained on a massive data set of 5 million X-rays collected from all over India. The system has attained precision of 99.8% and 99.6% recall in differentiating normal from abnormal findings. This capability makes it a valuable asset for mass screening programmes especially in low resource environments with limited radiology expertise [3]. The Normalized Free Network is another AI model specially designed to detect tuberculosis achieving an accuracy of 99.9%. it serves as powerful tool for efficient and large scale health care applications[2].

2.2 Treatment Adherence Prediction

Machine learning (ML) models integrated with Natural Language processing (NLP) system are made to the detection of the risk of early dropouts. These models are very accurate and well trained systems by taking real data from the NIKSHAY system (Karnataka state). This work addresses data heterogeneity, fairness, and understandable, with pilots underway for broader deployment under India's Central TB Division [5]. These types of models would help the health care workers to detect TB in early stage and potentially save the life of people.

2.2.1 Implementation and Public Health Integration

India stated a step ahead to implement AI technology to detect and treat tuberculosis effectively and efficiently especially where health care facilities are limited. In Delhi, as a part of National TB Elimination Program (NTEP) 21 AI powered portable X-ray units were implemented to check TB cases in a slum and around 9,200 people were examined and found 37 TB cases that helped to reduce the risk of spreading the disease [17]. Similarly, AIIMS Patna launched a rural TB screening campaign using handheld X-ray devices and mobile AI kits for the early detection and cure of Tuberculosis [18]. In Nagpur, under NIIDAN-TB pilot project, AI based mobile vans were used to test around 100,000 people to detect and give an immediate treatment for TB. This initiative helped for on-site testing, detection, confirmation and care all in one visit. This program was integrated into Nikshay and nutritional and treatment support structures [19]. Wadhvani AI collaborates with state governments (e.g., Haryana) to develop AI models predicting drug resistance, risk stratification, and treatment completion, supporting over 4 million consultations per month

Location	Technology Used	Goal
Delhi	Portable AI X-rays	Detect TB in slums
Patna	Handheld devices + AI kits	Screen rural populations
Nagpur	Mobile vans + AI + lab testing	Screen 100,000 people with full support
Haryana & others	Predictive AI models	Improve treatment outcomes at scale

Table1. The table shows AI and portable tech to fight TB in a smarter way

3. Research Gaps

Even though the many researches and implementations are made still there are some gaps:

- Dataset Diversity and Generalizability:** Many AI models are trained on specific datasets taken from specific places like Chennai, Mumbai that gives limits of generalizability as the demographic data and imaging pattern will be different in other places like rural area underserved places and other states and cities [1].
- Operational Challenges & Workflow Integration:** several operational challenges can be arise in implementing AI Tools like qXR in low resource environment such as software logistics, connectivity, training, and workflow integration. These barriers can hinder the effective adoption and scalability of such technologies, even when the potential clinical benefits are substantial [14].
- Fairness and Access :**
While some machine learning models try to ensure fairness, most AI tools do not include fairness audits or explanations of how they work. These features are important because they help doctors to trust the AI and make sure it treats all patients fairly [5].
- Cost-effectiveness and Sustainability:** usage of AI tools can be expensive we have to spend a lot of money in the beginning for the installation of software, computers, internet, for the training of health staff and on-going maintenance. These costs can make it hard for hospitals especially in low-resource areas.
- Integration with National Programs**
Although AI models show efficacy, they often lack seamless incorporation into NTEP workflows (e.g., Nikshay, molecular labs), limiting impact.

4. Conclusion

AI-driven tools made transformative opportunities for the detection, diagnosis and monitor Tuberculosis across India. These tools have the potential for large scale applications as they are fast, accurate and suitable for rural areas where access of health care system and medical staff is limited. Their implementation is helping India to move steadily towards the TB elimination goal of the country. Nevertheless several challenges are still to be addressed. First, it is essential to ensure that AI tools functions effectively in all regions rural and semi urban stings. Second, proper integration with existing health system is necessary. Third, step must be taken to minimize bias and guarantee fair and equal treatment to all patients. Finally, maintain the cost-effectiveness.

To turn the potential of AI into real progress in fighting TB, everyone needs to work together. This includes researchers, the government, NGOs like Wadhvani AI, Qure.ai, and DeepTek, and public health organizations. By collaborating, they can combine their knowledge, resources, and efforts to make AI tools truly effective in TB control.

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