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MASS CHEST X-RAY LUNG SCREENING USING ARTIFICIAL INTELLIGENCE FOR CONTROL OF TUBERCULOSIS

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ABSTRACT

Tuberculosis (TB) remains one of the leading causes of infectious disease-related morbidity and mortality worldwide. Caused by *Mycobacterium tuberculosis,* TB is a communicable airborne disease that predominantly affects the lungs, though it can also involve other organ systems. Despite being both preventable and curable, TB remains persistent especially among high-risk and vulnerable populations. A key tactic of the NTEP (National Tuberculosis Eradication Program) is Active Case Finding (ACF), which seeks to identify unreported cases in the community and lessen continuous transmission. There have been reports of multi-drug resistance (MDR), extreme drug resistance (XDR) as recent as 2018 and currently total drug resistance (TDR). This study highlights how AI-assisted Chest X-ray (CXR) diagnosis can transform TB detection, drawing on recent community based experiences and WHO guidance. This pilot study aims to assess the effectiveness of AI based reporting for ACF using chest X-ray screening among high-risk groups in Chennai, India. In the study group AI software was utilised to produce the diagnostic reports of the Chest X-ray. Descriptive statistics were used to report the proportion of abnormal chest X-rays and also presumptive TB cases. AI-assisted chest X-ray screening helps reduce dependence on physicians expertise in low-resource settings.

KEYWORDS: Pilot study, ACF, High-Risk Groups, RNTCP/NTEP, Implementation, Screening, Detection Rate

From the discovery of Mycobacterium Tuberculosis Bacilli in 1882 by German Physician Robert Koch, and the Indian National Sample Survey (NSS) of 1950's, leading to the National Tuberculosis Program of 1962 and the mass usage of the BCG vaccine, domiciliary treatments at TB sanatoria were the way to go in India. The Revised National Tuberculosis Program which was launched in 1993 (pilot) launched in 1997 focussed on the bacillary cases and treatment was delivered by the DOTS Program (Directly observed treatment short course).

Tuberculosis (TB) remains one of the leading causes of infectious disease-related morbidity and mortality worldwide (Ellis *et al.*, 2024). Caused by *Mycobacterium tuberculosis,* TB is a communicable airborne disease that predominantly affects the lungs (pulmonary TB), though it can also involve other organ systems (extra pulmonary TB). Despite being both preventable and curable, TB remains persistent especially among high-risk and vulnerable populations such as people living with HIV (PLHIV), individuals with diabetes mellitus, those suffering from malnutrition, the elderly, and populations residing in overcrowded or low-resource settings. Tuberculosis (TB) remains a leading infectious killer worldwide, with millions of undiagnosed cases fuelling ongoing transmission. Globally, it continues to be a major public health issue that causes avoidable disease and fatalities. 27% of the world's TB cases are in India (Mandal *et al.*, 2023). And there will be over 2.9 million cases with a 4.5 death rate per 100,000 by 2026. An estimated 150,000 new cases and 182 per 100,000 notification rate are reported annually in Tamil Nadu (citation, State TB Report, 2022). A key tactic of the NTEP (National Tuberculosis Eradication Program) is Active Case Finding (ACF) (Anil *et al.*, Prasad *et al.*, 2016; Mary *et al.*, 2020; Dey *et al.*, 2019), which seeks to identify unreported cases in the community and lessen continuous transmission.

Over the years, there have been drug resistance challenges (Picture 1.0), as the treatment for tuberculosis needs to be diligently taken over a minimum of nine months, and hence many individuals drop out of the treatment regimen due to personal complacence or financial challenges. There have been reports of multi-drug resistance (MDR), extreme drug resistance (XDR) as recent as 2018 and currently total drug resistance (TDR). To make things worse, 60% of HIV affected individuals across the world, die due to contracting TB infection. And according the WHO reports, in India every second, one person dies of TB.

Symptom screening alone has limited sensitivity. Many people with TB, especially in early or

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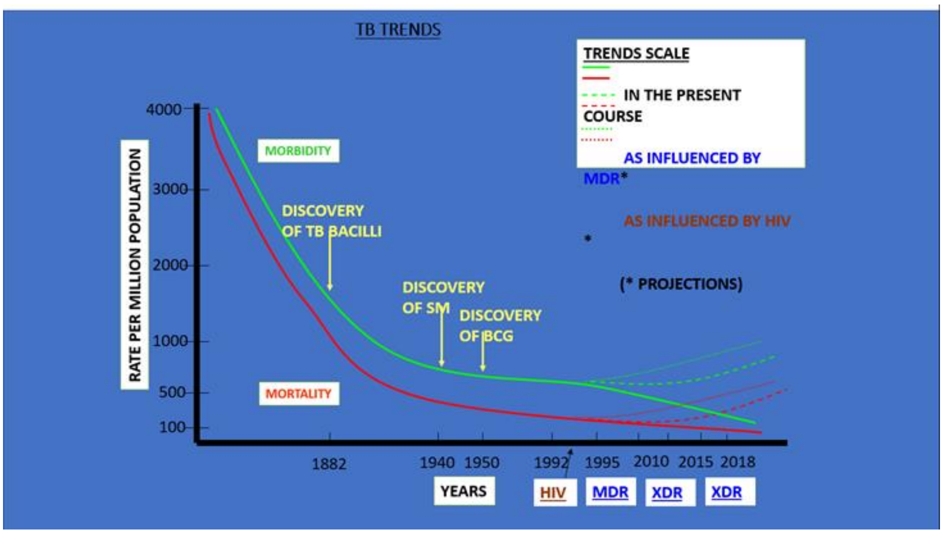
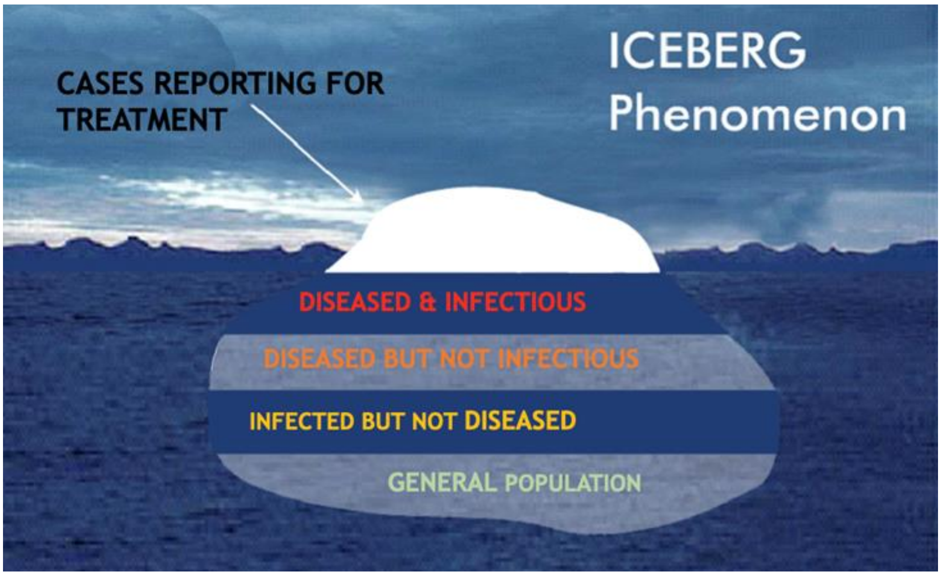
asymptomatic stages, do not present with a persistent cough or other classical signs. This gap contributes to delayed diagnoses and sustained community spread. What the physician sees is only the symptomatic individual which is only the tip of the iceberg (Picture 2.0), and hidden below is the larger group infected but asymptomatic population, still spreading the TB bacilli in the community. It is this group that the mass lung screening program wishes to target. Traditional symptom-based screening often misses individuals with subclinical or asymptomatic disease. Recent advances in artificial intelligence (AI) for interpreting digital chest X-rays (CXR) have created new opportunities for mass screening. This study highlights how AI-assisted Chest X-ray (CXR) diagnosis can transform TB detection, drawing on recent community based experiences and WHO guidance. Artificial Intelligence (AI) in Mass Screening: Computer-aided detection (CAD) software can now interpret chest X-rays rapidly (WHO, 2021; CID, 2024; PLOS Digital Health, 2024) and with performance comparable to expert radiologists. During community screening campaigns, CAD tools can triage thousands of individuals daily, flagging those most likely to benefit from confirmatory molecular tests. This approach ensures efficient use of resources and minimises missed cases.



Pic 1.0



Pic. 2.0

Although NTEP has made notable progress in the state, a significant proportion of TB cases remain undiagnosed or are diagnosed late, contributing to community spread and adverse health outcomes. This study aims to assess the yield of chest X-ray screening for detecting presumptive TB cases by way of reporting using artificial intelligence enabled computer software which could potentially scale-up strategies within the existing public health infrastructure.

AIM

To implement Active Case Finding (ACF) among high-risk populations in Tamil Nadu using chest X-ray screening to facilitate early detection of tuberculosis and assess the effectiveness of AI based reporting for ACF thereby reducing community-level transmission under the framework of the National Tuberculosis Elimination Programme (NTEP).

REVIEW OF LITERATURE

An active case finding (ACF) survey by [10], was conducted in the urban slum areas of the R-South Municipal Ward of Mumbai City for a period of two months from June to July 2012. TB suspects were identified by trained community health volunteers during their home to home visit. These suspects were referred to the designated microscopy centres (DMCs) for sputum examination and those diagnosed with TB were put on anti-TB treatment. A total of 278 TB suspects were identified on enquiring on the presence of symptoms suggestive of TB. Out of them 221(79.5%) patients got tested for sputum examination. Sputum positive TB was diagnosed in 29 suspects and the sputum positivity rate was 13.1%, which was slightly higher than the passive case finding norms of 10% as prescribed under Revised National TB Control Program. Active case finding for tuberculosis in the general community was discouraged for several decades because of high costs of implementation. However, results of the survey suggest that periodic ACF should be incorporated in populations wherever tuberculosis incidence / prevalence is high as there was a definite improvement in the case detection rate.

In a large-scale national intervention [11] to increase tuberculosis (TB) case detection under the National Tuberculosis Programme, the Global Fund-supported Project Axshya implemented active case finding (ACF) among high-risk groups in 300 districts in Indian between April 2013 and December 2014. About 4.9 million households covering 20 million people were visited. This initiative identified 350,047 presumptive pulmonary TB cases (cough of more than 2 weeks), 187,586 (54%) underwent sputum smear examination, leading to 14,447 (8%) smear-positive cases. ACF identified many presumptive TB cases with state-wise variation and can be effectively carried out by trained CVs under supervision. A key challenge was ensuring sputum testing, which was partly addressed through collection and transport efforts.

An international study [12] at George health facility in Lusaka, Zambia evaluated both facility-based and community-based ACF strategies. A total of 18,194 individuals were screened for TB under the study; 9,846 (54%) were screened at the facility while 8,348 (46%) were screened in the community. The results indicated that facility active case finding was more effective in detecting TB cases than community active case finding. Strengthening health systems to appropriately identify and evaluate patients for TB needs to be optimised in high burden settings. At a minimum, provider initiated TB symptom screening with completion of the TB screening and diagnostic cascade should be provided at the health facility in high burden settings. Community screening needs to be systematic and targeted at high risk groups and communities with access barriers.

In another example from India [13], a study was implemented in 60 selected high TB burden wards of Kolkata. A descriptive qualitative investigation with in-depth interviews was carried out after a quantitative cohort study phase utilising regularly gathered data in an explanatory mixed-methods study. Total 3,86,242 individuals who were enumerated by TA's (touch agents) from 92,294 houses, 1132 (0.3%) were identified as PTBP's presumptive TB patients). Only 713 (63.0%) PTBPs visited a referred facility for TB diagnosis. TB was diagnosed in 177 (24.8%). Interviewing each and every individual of the households for symptoms of TB and supporting PTBPs for diagnosis through sputum collection and a transport system can be adopted to improve the yield.

METHODOLOGY

Study Design

This was a cross-sectional descriptive study conducted as part of a pilot initiative under the National Tuberculosis Elimination Programme to implement Active Case Finding among high-risk populations in Tamil Nadu and use computer aided detection software in diagnosis.

Study Setting and Duration

The study was conducted in the city of Chennai, Tamil Nadu state, India, where ACF campaigns were implemented through mobile screening camps. The data collection was carried out over a phased period between 2021 and 2025, covering multiple community and institutional settings, including urban public spaces, police departments, and prisons.

Study Population

The study targeted individuals considered at high risk for tuberculosis due to their demographic, occupational, or living conditions. These included: General public from underserved and urban slum areas; police personnel, due to occupational exposure; and Prison inmates correctional facilities.

Inclusion Criteria

1. Individuals aged 15 years and above

2. Belonging to high-risk groups

3. Present at the camp location during screening

4. Provided informed verbal consent.

Exclusion Criteria

1. Pregnant women.

2. Individuals who did not consent to screening.

Sample Size and Sampling Technique

The sample size was the individuals present during the nine medical camps that I attended, selected based on programmatic feasibility and resource availability. A total of 1047 individuals were approached across the 9 camps, of which all 1047 were successfully screened and included in the final analysis.

Data Collection Procedures

The chest X-rays data were gathered in Chennai, and was collected from the nine mass lung screening camps attended, conducted by a joint project of NGO - Humanitarian Outreach Initiative Foundation and Rotary International; and SRM University for research purposes.

Data collection was carried out by trained field teams consisting of healthcare workers, radiographers, and project staff. The procedures were designed to align with the ethical standards of voluntary participation and confidentiality. The screening process involved the following steps:

1. Community mobilisation: Awareness sessions were conducted prior to each camp to inform the public about the purpose, benefits, and voluntary nature of the screening. Participation in the study was entirely optional, and individuals were informed that refusal to participate would not affect their access to healthcare or other services.

2. Informed consent: Verbal informed consent was obtained from each participant before any data were collected or investigations carried out. Participants were made aware that they could decline to answer any questions or withdraw from the screening at any point, without providing a reason. No questions were mandatory, and confidentiality of all personal information was strictly maintained.

3. Symptom screening: Individuals were first interviewed using a structured symptom checklist based on NTEP guidelines (e.g., cough >2 weeks, fever, weight loss, haemoptysis). Interviews were conducted in a private setting to ensure comfort and privacy.

4. Chest X-ray screening: All consenting participants underwent digital chest X-rays using mobile radiography units stationed at the camp sites. Images were analysed immediately by the AI enabled CAD (computer aided) software, to classify findings as normal or abnormal (tuberculous, non-tuberculous, or other abnormalities).

5. Classification of findings**:** Chest X-ray reports were interpreted by the CAD software and categorised as: Normal, Abnormal – Probably Tuberculous, Abnormal – Non-Tuberculous, Other Non-Specific Abnormalities

Data Management and Analysis

Data were recorded digitally and transferred to a central database. Microsoft Excel and SPSS Version 27 were used for statistical analysis. Descriptive statistics (frequencies, percentages) were generated to summarise:

- X-ray abnormality prevalence
- TB suspect identification rates

Ethical Considerations

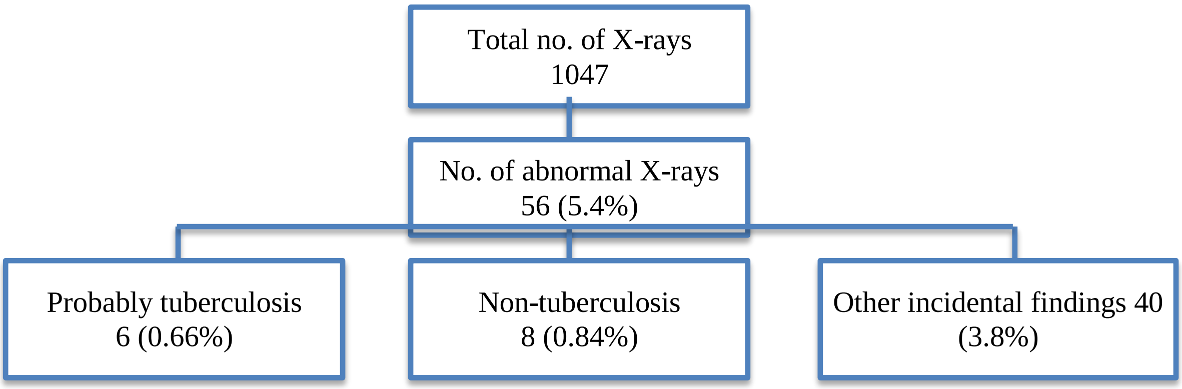
This study adhered to ethical standards under the guidance of the National Tuberculosis Elimination Programme. Approval for the pilot was obtained from the appropriate Institutional Ethics Committee (IEC). Confidentiality of personal information was strictly maintained. Participants identified with presumptive TB were referred to the nearest NTEP (National Tuberculosis Eradication Program) linked diagnostic centre for further testing sputum microscopy or CBNAAT (Cartridge Based Nucleic Acid Amplification Test). No financial incentives were provided for participation.

RESULTS

Overview of Screening Coverage

A total 1047 individuals underwent chest X-ray screening and were included in the final analysis.

FLOWCHART OF PARTICIPANTS SCREENED



Out of 1047 individuals screened, 56 (5.4%) showed abnormal chest X-ray findings reported by physician. Among these, 6 individuals (0.66%) were classified as having radiological features suggestive of TB. A total of 8 individuals (0.84%) had non-TB abnormalities and 40 (3.8%) had other incidental findings.

Classification of Abnormal X-ray Findings

The 56 abnormal chest X-rays were further classified based on radiological evaluation. Among the X-ray positive individuals, 6 cases (0.66% of abnormalities) were categorised as *Probably Tuberculous* and require further diagnostic confirmation and follow-up. Additionally, 8 individuals (0.84%) had *Non-Tuberculous abnormalities*, including cardiomegaly, fibrosis, and other non-specific findings. The remaining 40 cases (3.8%) had other abnormalities of uncertain significance, which, while not indicative of TB, highlight the broader utility of X-ray screening in identifying other health issues. (Table 1)

Table 1: Classification of abnormal X-ray findings

Type of Abnormality	Number of Individuals	Proportion of Total Screened (n=1047)
Probably Tuberculous	6	0.66%
Non-Tuberculous Abnormality	8	0.84%
Other Abnormalities	40	3.8%
Total Abnormal X-rays	56	5.4%

DISCUSSION

This pilot study examined 1047 people over 9 screening camps organised in Chennai (India), with a focus on high-risk populations such as the general public, police officers, and prisoners. The primary goal was to evaluate the feasibility and efficacy of Active Case Finding (ACF) employing chest X-ray as the initial screening method for finding presumptive tuberculosis (TB) cases under the Revised National Tuberculosis Control Program (RNTCP)/National TB Elimination Program (NTEP).

Among the 1047 individuals screened, 56 (5.4%) had abnormal chest X-ray results. Of these, 6 individuals (0.66%) were identified as having radiological signs likely indicative of active tuberculosis, suggesting the potential for early case detection by imaging. The other aberrant findings included 8 instances (0.84%) with non-tuberculous abnormalities (such as cardiomegaly or fibrotic lesions) and 40 (3.8%) with other nonspecific abnormalities that did not explicitly suggest tuberculosis.

The results of this study highlight the vital role that ACF plays as a proactive approach to reach groups that might not otherwise receive a diagnosis. It is feasible, scalable, and maybe economical to use ACF with chest X-ray in conduction with computer aided detection software, as a front-line screening method, particularly in environments with limited resources. It allows for convenience, early identification, quicker turn around time, and referral for confirmatory testing, ultimately contributing to interrupting TB transmission and moving closer toward the goal of TB elimination.

CONCLUSION

The findings from this pilot study demonstrate the feasibility and utility of chest X-ray-based Active Case Finding (ACF) and AI reporting in detecting presumptive TB cases and other thoracic abnormalities among high-risk populations. With an abnormality detection rate of 4.9% and probable TB in 0.66% of screened individuals, the intervention supports early detection and timely referral for diagnosis and treatment.

These insights advocate for the continuation and expansion of ACF initiatives under NTEP, emphasising the integration of radiological screening, computer aided detection software, community outreach, and follow-up diagnostics. Strengthening such multi-pronged approaches can significantly contribute to reducing TB transmission and moving toward national TB elimination goals.

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