In the coming decades, artificial intelligence (AI) has the potential to fundamentally transform the global health landscape (1), and turbocharge the fight against TB. (2) Yet, despite the promise of AI-based technologies, adoption rates remain low in many TB-endemic communities today. To ensure that innovative new AI technologies are more widely adopted, cross-sectoral actors working on TB must achieve two objectives.

First, they must clearly articulate AI’s value proposition - demonstrating both how AI tools are being utilized today in the fight against TB and how they can be leveraged effectively in the future.

Second, they must identify the specific structural, technical, and attitudinal barriers which are undermining the adoption, implementation, and administration of programs in TB-endemic communities.

If these two objectives are achieved, the global health community will be in a much stronger position to facilitate the adoption of AI-based solutions, which in turn will strengthen overall efforts to detect, treat and manage this lethal disease. (3)

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**What is AI?**

The European Parliament defines AI as the capability of a computer program to perform tasks or reasoning processes that we usually associate with intelligence in a human being.


Our working definition of AI in healthcare in this work is deliberately broad; it includes a functional continuum from the application of rules-based systems through to cutting-edge methodologies that include classic machine learning, representation learning, and deep learning.
HOW AI IS BEING LEVERAGED INTO THE FIGHT AGAINST TB

FACILITATING READING OF CHEST X-RAYS FOR FASTER, MOST COST-EFFECTIVE TB SCREENING

Several computer-aided detection (CAD) tools have been developed to date. For example, PSC members Delft Imaging and Qure.ai offer a range of digital X-ray systems and computer-aided detection tools which leverage AI to automatically process and assess chest X-rays (CXR) for TB-related abnormalities.

These technologies can be used both to help radiologists accelerate the interpretation of patient chest X-rays and to provide an initial diagnosis in the event of a shortage or unavailability of radiologists, a widespread problem in many TB-endemic areas. X-rays are recommended for triage or screening in order to identify the people who need further confirmatory testing. Rapid molecular tests are then subsequently used for formal diagnosis.

Although chest X-Rays have been found to play a vital role in the early detection of TB in children and adults who are at higher risk, adoption of these technologies has been constrained by a range of challenges, including lack of availability of human readers and insufficient infrastructure. To overcome these constraints, many practitioners and health systems have successfully utilized AI-powered CAD software, which automate the interpretation of digital CXR images. These technologies can help programs identify TB cases as early as possible and help practitioners expedite the start of TB treatments, to stem the further spread of the disease.

Overall, using chest X-ray screening as triage improves TB detection, as CAD products can be applied to both TB screening and triaging interventions to quickly and efficiently screen large populations to identify individuals in need of additional care. CAD products are especially beneficial in resource-constrained countries and regions with a high burden of TB and limited access to radiologists, as these tools make spotting TB cases more efficient. Using AI to read CXR also supports the ability to standardize scoring methods and reduce the number of follow-up tests while keeping sensitivity high and lowering costs.
Importantly, several studies have shown that AI-powered tools are better than or equal to humans at reading and interpreting CXR for signs of tuberculosis. An independent June 2022 study examining the latest World Health Organization-recommended CAD software tools in Bangladesh found both the CAD4TB (PSC Member Delft Imaging) and qXR (PSC Member Qure.AI) to be more effective than human readers at screening for TB. (8) In an earlier study of Bangladeshi patients (2014-2016), researchers analyzed the efficacy of five AI algorithms and found each of them to be better than radiologists at detecting TB. (9) A forthcoming FIND (Foundation for Innovative New Diagnostics) study evaluating three of the leading AI-powered TB detection tools also found each to be as effective as human readers. (10)

For these reasons, in March 2021, for the first time, WHO published recommendations explicitly encouraging the use of CAD for TB triage and screening: “CAD technologies have the potential to increase equity in the reach of TB screening interventions and in access to TB care if they facilitate the scale-up of radiography for TB screening and triage and improve the interpretation of images.” (11) As of February 2023, there were three TB-specific, WHO-approved CAD products on the market and an additional five which were on the market but not yet approved by WHO. (12)

To support adoption of these solutions at the country level, the Stop TB Partnership’s Digital Health Technology Hub offers direct support to TB program administrators looking to leverage the newest digital tools, including AI-powered CAD software (13) (14). AI4HLTH, an initiative spearheaded by the Stop TB Partnership and the Foundation for Innovative New Diagnostics (FIND), is an online resource center featuring CAD products aiding in the diagnosis of TB. The program helps provide implementation-relevant information to country level decision-makers. (15) In 2021, the Stop TB Partnership’s Global Drug Facility (GDF) included CAD software and ultra-portable digital X-ray systems for the first time in its diagnostic catalog. As part of its work, GDF also helps TB programs secure access to quality-assured CAD software. (16) And in March 2023, Google, working in partnership with Right to Care, announced its commitment to provide 100,000 free TB screenings in Sub-Saharan Africa, to help with early detection and diagnosis. (17)
PSC MEMBERS SPOTLIGHT

Delft Imaging

Delft Imaging’s CAD4TB, the first CE-certified AI-powered CAD software tool available on the market, has been recognized by TB programs supported by the Global Fund, the World Bank, the UN (United Nations), the United States Agency for International Development (USAID), and the Stop TB Partnership’s TB REACH. The technology has been operational in over 60 countries worldwide to assist TB programs, impacted over 14 million people and has been validated by over 60 scientific publications.

Qure.AI

Qure.AI’s qTrack is an end-to-end disease management platform which enables effective disease response and care cascade management by providing ready access to all patient information to relevant stakeholders. qXR aids in the detection of multiple abnormal findings on a chest X-ray in less than 1 minute.10,11 The current version of qXR has been trained and tested on 5 million chest X-rays acquired globally. qXR & qTrack have been deployed across 60+ countries and offer a variety of deployment models to suit the workflow of the programs – fully online cloud mode, a completely offline mode, or a hybrid mode to support sync to the cloud in the presence of internet. The applications are also available in multiple languages.

IMPROVING THE ACCURACY OF EXISTING DIAGNOSTIC METHODS

Al and Machine Learning (ML) algorithms are also being leveraged to improve and enhance the classification, interpretation and analysis of data already being collected by TB programs.

Microscopic Examinations

AI is being used to develop products which offer automatic TB bacilli detection on slides. A recent study from China found that a TB-AI tool showed high sensitivity for the recognition of bacilli. (18) Expanded use of such technologies could help in addressing shortages of trained pathologists, support the scale-up of standardized screening tools, streamline use of molecular tests, and decrease the chances of misdiagnosis in resource-limited settings.
Cough Identification and Tracking

Cough Identification is another promising area in which AI is poised to substantially improve TB screening efforts, with several AI-powered cough tracking apps already available on the market. (19) Timbre, a screening mobile app developed in India, uses artificial intelligence and machine learning to make cough interpretations to predict whether a patient is TB-positive or not. (20) The app requires the presence of a medical practitioner or a healthcare worker to record the cough of a patient using a microphone array, and results are almost immediately available.

Hyfe, another cough detection application, also uses artificial intelligence to track cough frequency and identify cough trends to help with condition management for TB and other lung diseases. The app can be used easily by all smartphone users from the comfort of their homes and empowers patients to better understand patterns and correlations of their cough, so that they can better manage their health. (21) Other algorithms, such as DeepBreath, initially developed to predict the diagnosis and outcome of COVID-19 from breath sounds, are showing promise as potential tools for the identification of other respiratory diseases, including TB. (22)

All these technologies could also help make TB screening and detection efforts more cost-effective and efficient in the coming years. Smartphone-powered screening apps, for example, could help rural health providers better determine which TB patients truly need to be transported to regional health centers. Advancements in data sharing could also help governments allocate limited TB resources more efficiently.

Line Probe Assays (LPA)

Artificial intelligence can also support programs in interpretation of assays. For instance, in India, the National Tuberculosis Elimination Program (NTEP) has developed a Steering Committee to identify other areas where AI and ML can be used to improve TB outcomes. To date, a solution to read, interpret and transmit results of LPA has been developed to reduce time and improve accuracy of interpretation. (23)
IDENTIFYING TB ‘HOTSPOTS’ AND MAPPING OUTBREAKS

AI-empowered tools can help identify ‘hotspots’ for TB screening campaigns and help health care workers recognize people receiving TB treatment who may need specialized attention and support. According to WHO’s Global TB Report 2022, “reductions in the reported number of people newly diagnosed with TB in 2020 and 2021 suggest that the number of people with undiagnosed and untreated TB has grown, resulting first in an increased number of TB deaths and more community transmission of infection and then, with some lag-time, increased numbers of people developing TB”. An estimated 10.6 million fell ill with TB worldwide in 2021, an increase of 4.5% from 10.1 million in 2020. (24)

As we know that key populations carrying the highest burden of TB include people living with HIV, pediatric contacts of TB patients, migrants, miners, and other communities that have poor access to health in general, using AI on a large scale can support the mapping of potential outbreaks and therefore help identify where best to focus active case finding (ACF) efforts and how to best use available screening resources (25) (26) (27)

Some countries are using AI to look for patterns and identify potential hotspots of COVID-19 cases. These applications could be translated to the TB context while allowing for more accurate and efficient differentiation between TB cases and other lung diseases.

IMPROVING TB TREATMENT, ADHERENCE AND CASE MANAGEMENT

Treatment

By quantifying the trend of radiological changes in conjunction with clinical information, using AI-empowered chest X-ray tools also can help practitioners better measure disease progression. Understanding radiological markers of disease severity can also assist clinicians in personalizing treatment by reducing over- or undertreatment with standard regimens. These possibilities need to be researched and validated, but once established, they can help in reducing the dependence on cumbersome microbiological tests.
Adherence

Some healthcare providers in India also noted that using AI for screening strengthened treatment adherence initiatives. Indeed, patients who do not feel better shortly after seeing a doctor tend to switch and interrupt treatment regimens more frequently. As AI provides more rapid, accurate results, patients’ likelihood of visiting different doctors and trying different treatments decreases. (28) Program managers can also leverage AI-power inforatics tools to improve patient-provider communications, a key driver of improved adherence to TB regimens. (29) In a recent pilot study in Uganda, AI-powered tools were shown to be an effective replacement for medical professionals, who have traditionally been tasked with observing patients as they ingest medicine. (30)

Case Management

AI also has the potential to improve TB case management in multiple ways, including by enhancing decision-making support for clinicians, improving patient monitoring programs, and identifying red flags across the care continuum via advanced pattern recognition. (31) AI could also be utilized as a workaround to a common challenge in TB case management: inadequate or insufficient patient records. With large datasets, AI could be used to help flag individual patients over time, even if the patients’ records are incomplete. (32)

2

MANY BARRIERS HINDER UPTAKE OF AI-POWERED TOOLS IN TB-ENDEMIC COUNTRIES

Despite ongoing efforts to expand the use of AI to tackle TB, and even though AI tools have been successfully implemented in some clinical settings to date, overall utilization of AI-based solutions remains limited in many endemic countries. (33) Many programs in high-burden countries still lack the sufficient healthcare infrastructure needed to optimize AI. Specific issues include the lack of availability of digital X-ray devices, regulatory and legal hurdles, and misaligned financial structures and incentives for adoption of new tools. (34)

Inaccurate perceptions of AI as a complex tool can also scare off prospective users. (35) Another challenge is that some AI-tools being deployed have biased algorithms which can cause underdiagnosis of patients from specific subgroups, exacerbating health inequalities and undermining provider trust. (36)
Fundamentally, decision-makers in Health Ministries often do not have a clear sense of the operational and economic advantages of using AI-empowered tools. Further, similar to the concerns expressed over Cloud adoption, some stakeholders have expressed concerns that adoption of these technologies will make it harder to protect patient data and privacy. (37) (38) Overall, stakeholders tend to think that the initial costs to use AI tools are too high; they also fear that AI-powered devices might be too difficult to understand and implement.

An additional misconception, one not unique to endemic areas, is that increased adoption of AI will displace workers from their current roles. (39) Inadequate data structuring is another impediment to progress. Without sufficient work being undertaken to standardize TB data, AI software cannot be fully optimized and, in some cases, cannot be leveraged at all. (40) Another misconception is that users of AI-supported software must always have an internet connection. Depending on the product, it is possible to use AI tools in offline environments, though having a permanent internet connection gives access to more options for cloud synchronization for data storage and timely software updates. (41)

3

THE ROAD AHEAD: ACTIONS THE PRIVATE SECTOR CAN TAKE TO IMPROVE AI ADOPTION

To overcome these many barriers, we believe private sector organizations must take specific actions in the coming years.

*Private sector leaders must better engage country-level decision-makers to improve AI awareness, education, and training*

Country-level decision-makers need more information at their disposal about the advantages of leveraging AI-powered tools in TB programs. To help facilitate greater adoption, cross-sectoral global health leaders, particularly private sector leaders, must more directly connect with country-level decision-makers. The private sector must create and distribute clear, well-designed materials addressing common questions and misconceptions, and develop a comprehensive repository of case studies, based on successful implementation programs in endemic areas, which can be used in one-on-one consultations.
Companies must do more to help make a case for increased adoption of AI, by specifically communicating the benefits of utilizing CAD for TB programs. But they must also better explain the practical requirements for the implementation of AI-supported solutions. Stakeholders should also explore innovative models, like RAD-AID’s Friendship Data Trust, to help secure buy-in from these decision-makers. The Trust, for example, provides lower resource institutions with free access to AI-powered tools in exchange for anonymized patient data. (42)

Providing needed trainings for relevant personnel who use AI solutions in the field is also important. The Stop TB Partnership’s GDF catalog offers installation and training packages for procuring CAD software, and such practical training should be an integral part of the roll-out of new technologies. The global health community can build on these types of initiatives to ensure training is more widely accessible. Further, the private sector must acknowledge the possibility of algorithmic bias and take all the necessary steps to address this challenge, including working with local partners to ensure that all training sets have sufficient representation of all groups or classes. (43)

**Private sector organizations must do more to help governments develop infrastructure needed to unleash the full potential of AI**

Private sector organizations should be more proactive in supporting national government leaders, to help ensure they have the resources to equip more hospitals and healthcare facilities with AI-powered imaging tools for diagnosis. Moreover, though the vast amount of data generated from TB programs will be helpful in developing new AI applications and uses in the TB response, extensive efforts still need to be undertaken to improve the interoperability of TB data in many countries, as explained in our other paper “Improving Connectivity in the Fight Against TB”. (44) In addition to working to ensure program-level interoperability is strengthened, private sector organizations must also help health systems access the large and diverse data sets needed to truly optimize the power of AI. (45)

Additionally, private sector organizations should do more to work with governments to help expand the tools that were rapidly developed and deployed during the COVID-19 pandemic, in order to improve TB surveillance and better predict TB outbreaks and potential hotspots of MDR-TB and other mutations. Doing so will not only help improve TB screening and detection, but could also help countries to identify other health conditions. (46) Companies should also continue to make the case with governments for greater investments in broader health system strengthening efforts, which will in turn also help ensure health systems are better able to integrate new AI tools.
The evidence is clear: AI is a crucial element in developing non-invasive, affordable, and easily accessible tools for TB treatment, adherence, and case management. Overcoming the many barriers to AI adoption in endemic countries would meaningfully advance the fight against TB in many impacted communities and would yield wide-ranging benefits in efforts to combat TB – from improving diagnosis with cost efficiency to helping with clinical decisions, to better predicting TB hotspots and the development of drug-resistant TB cases and other mutations.

AI-powered tools are also a promising method to relieve some of the heavy workload of pathologists, while decreasing chances of missed diagnosis. Moreover, AI-powered CXR technologies can address challenges beyond just detection, and they hold particular promise in detecting radiological indications of lung cancer, occupational health diseases like silicosis and chronic conditions like COPD and in overall lung health management.

Thus, new investments in AI technologies are poised to generate add-on benefits for the healthcare ecosystem writ large. To make this a reality, cross-sectoral stakeholders must work with health systems to pilot and scale the adoption of AI tools soon.

Disclaimer: This paper mentions several organizations and their products in the digital health space for the purpose of creating awareness about potential use cases of similar technologies in the fight against TB. However, neither STOP TB Partnership nor Data and Diagnostic group under Private Sector Constituency (PSC) endorses any particular organization or product. Readers are recommended to use their discretion while engaging the organizations and/or using these products.
End Notes

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