

 July, 2025

Whitepaper

CAD4TB in practice:

Real-world applications in TB programmes for impact



Content

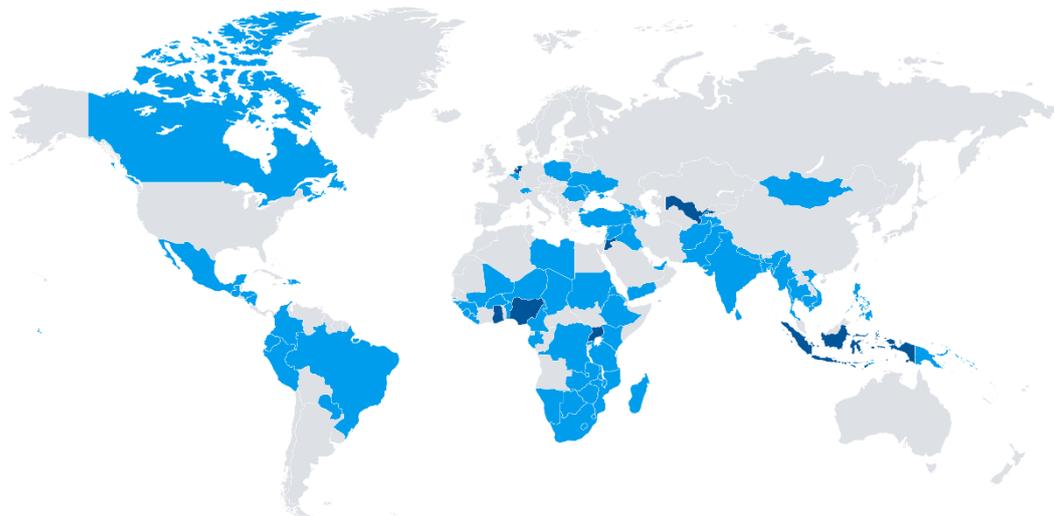
Overview	3
1. Guidelines and policies on using CXR and AI for systematic TB screening	5
2. CAD4TB innovation journey	6
3. CAD4TB	7
3.1 General description	8
3.2 Scientific validation	9
3.3 Threshold Score Selection	10
3.4 Economic analysis	11
3.5 Deployment	13
3.6 Monitoring & evaluation: CAD4TB Platform	16
3.7 Data storage, export, and interoperability	21
3.8 Data privacy & security	22
3.9 CAD4TB upgrades, updates, and add-on features	22
4. Training, support & maintenance.....	23
5. Consideration to implement CAD4TB for TB programs	24
6. Validated results from CAD4TB	25
7. Global implementation of CAD4TB.....	27
Annexe 1: Sensitivity and Specificity.....	28
Annexe 2: Highlights of CAD4TB Publications	29

Preface

This document aims to support the Ministries of Health, National Tuberculosis Programs, NGOs, and private health providers in selecting, incorporating, and implementing AI-enabled Computer-Aided Detection (CAD) for TB screening and triaging, particularly in resource-constrained settings. It outlines the technical aspects and deployment of CAD4TB, a World Health Organization (WHO)-evaluated CAD software. The document seeks to facilitate the optimal use of CAD4TB by considering clinical needs, local infrastructure, operational environments, human resources, budgets, and total cost of ownership.

About us

Delft Imaging is a social enterprise headquartered in the Netherlands with regional offices in Africa and Asia. We are committed to eradicating tuberculosis by promoting health equity. We achieve this through providing reliable and sustainable diagnostic imaging solutions to emerging countries and harnessing the power of digital technology, including AI.



Delft Imaging has implemented TB projects in over 85 countries. With 2,500+ radiology systems and CAD4TB delivered, we are proud to say that we have facilitated the TB screening of over 32 million people globally.



OVERVIEW



Product name	CAD4TB
Software Version	8
Certification	CE Class IIa. CE 0044 marked.
Input	<ul style="list-style-type: none"> • Can be used to process CXR images from stationary, portable, and ultra-portable X-ray systems • CXR image format: DICOM, PNG*, JPEG* • Chest X-ray type: PA (Posterior-Anterior)
Output	<ul style="list-style-type: none"> • Tuberculosis probability score based on a bacteriological reference ranging from 0 to 100. • Abnormality score that denotes lung abnormalities, based on a radiological reference ranging from 0 to 100. • A heatmap indicating potential tuberculosis abnormalities as a coloured overlay on the original chest X-ray image. • The cardiothoracic ratio helps evaluate the size of the heart, which may indicate cardiomegaly (an enlarged heart).
Add-On Features*	<ul style="list-style-type: none"> • CAD4TB Platform for Monitoring & Evaluation support • Cardiothoracic ratio • Silicosis detection
Language	Arabic, Bengali, English, French, Portuguese, Russian, Spanish, Tagalog, Thai, Urdu, and Vietnamese
Intended Use	CE approval for adults and children aged 4 years and above
Implementation Setting	<ul style="list-style-type: none"> • Active case finding • Community outreach • Facility-based screening • High HIV prevalence areas • IDP/Refugee camps • Passive case finding • Prevalence surveys • Prisons, etc.
X-ray Integration	Any digital X-ray machines from major manufacturers
Deployment	Online, offline, hybrid
Data Export	CSV file, Cloud, PACS/RIS, API
Price Structure	Perpetual license or per-use basis
Procurement	<ul style="list-style-type: none"> • Pooled procurement: Stop TB Partnership's GDF, PFSCM/Wambo • Direct contact with Delft Imaging

Publications	Over 100 scientific publications highlight accuracy and effectiveness.
Impact	Facilitate TB screening for 32 million+ people across 75+ countries.

Deployment Options

	Offline	Offline (with DI's X-ray)	Online	Hybrid
				
Hardware	CAD4TBbox	CAD4TBbox	No need	CAD4TBbox
Installation	Plug-in	Plug-in	No need	Plug-in
Internet	No need	No need	Stable connection	Stable connection for synchronisation
Data Process	On-site	On-site	In-cloud	On-site or In-cloud
View Results	<ul style="list-style-type: none"> Pre-configured tablet (included in CAD4TBbox) Any laptop, tablet, smartphone 	<ul style="list-style-type: none"> X-ray workstation /console laptop Pre-configured tablet (included in CAD4TBbox) Any laptop, tablet, smartphone 	<ul style="list-style-type: none"> X-ray workstation /console laptop Any laptop, tablet, smartphone 	<ul style="list-style-type: none"> X-ray workstation /console laptop Any laptop, tablet, smartphone
Access to Results	Locally on CAD4TBbox	Locally on CAD4TBbox	Multiple locations	Locally on CAD4TBbox or Multiple locations
Data Storage	Save data locally: <ul style="list-style-type: none"> CAD4TBbox External hard drive 	Save data locally: <ul style="list-style-type: none"> CAD4TBbox External hard drive 	<ul style="list-style-type: none"> Cloud 	<ul style="list-style-type: none"> CAD4TBbox External hard drive Cloud
Data Export	<ul style="list-style-type: none"> CSV file API 	<ul style="list-style-type: none"> CSV file API 	<ul style="list-style-type: none"> Cloud DICOM/PACS Server API 	<ul style="list-style-type: none"> CSV file Cloud DICOM/PACS Server API
Software updates/upgrades	USB	USB	Online access	Online access
Support	Help Desk	One-Stop Help Desk for X-ray & CAD	Help Desk and Online	Help Desk and Online



Among individuals aged 15 years and older in populations in which TB screening is recommended, CAD software programmes may be used in place of human readers for interpreting digital chest X-rays for screening and triage for TB disease.

**WHO consolidated guidelines on tuberculosis
Module 2: Screening**

1. Guidelines and policies on using CXR and AI for systematic TB screening

Chest X-ray (CXR) plays a critical role in the early detection of TB and is fundamental to achieving the targets outlined in the WHO End TB Strategy. However, its effectiveness is curtailed by the scarcity of radiologists, especially in resource-constrained settings. To address this challenge, Computer-Aided Detection (CAD) was developed to interpret CXR accurately and improve case detection.

In 2021, the WHO released updated guidelines, including the recommendation for using CAD in systematic TB screeningsⁱ. CAD4TB is one of the solutions included in the technical evaluation to support the recommendation. Subsequently, it was included in the 2025 WHO policy statement technical evaluation, where it again met the performance standards for TB detection using chest X-rays.

Key stakeholders' strategic documents highlight the importance of CXR and CAD. The Global Fund Strategy (2023-2028)ⁱⁱ and the TB Information Noteⁱⁱⁱ underline the role of digital X-rays in early and accurate TB diagnosis, focusing on finding missing people with TB and prioritizing screening interventions. The latest plan includes scaling up and improving systematic screening for TB with more sensitive CXRs and CAD software.

Additionally, X-rays are deemed valuable in the context of Resilient and Sustainable Systems for Health, Community System Strengthening, and Pandemic Preparedness. They are used for integrated and multi-disease screening and diagnosis in relation to respiratory care and case management services.^{iv}

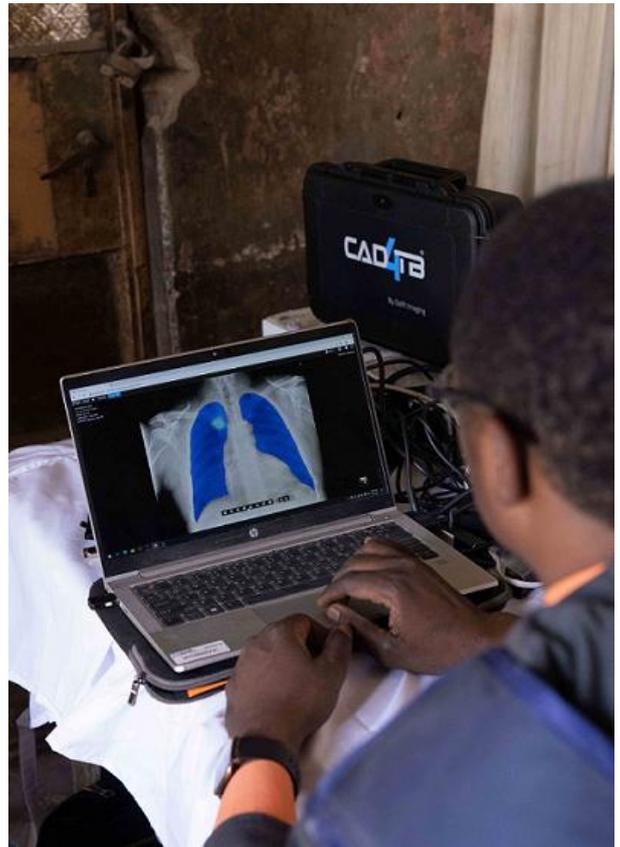
The Stop TB Partnership's Global Plan to End TB 2023-2030^v highlights the need to leverage modern technologies. Solutions like CXRs with CAD enhance the rapid detection of TB and expand early diagnosis, including at sub-clinical stages. The plan highlights that digital CXRs are highly valuable in pulmonary TB screening in combination with confirmatory tests, especially in populations with high TB rates.

USAID's Global TB Strategy 2023-2030 aims to maximize TB detection in individuals of all ages by increasing access to new technologies, such as portable digital X-rays with AI.

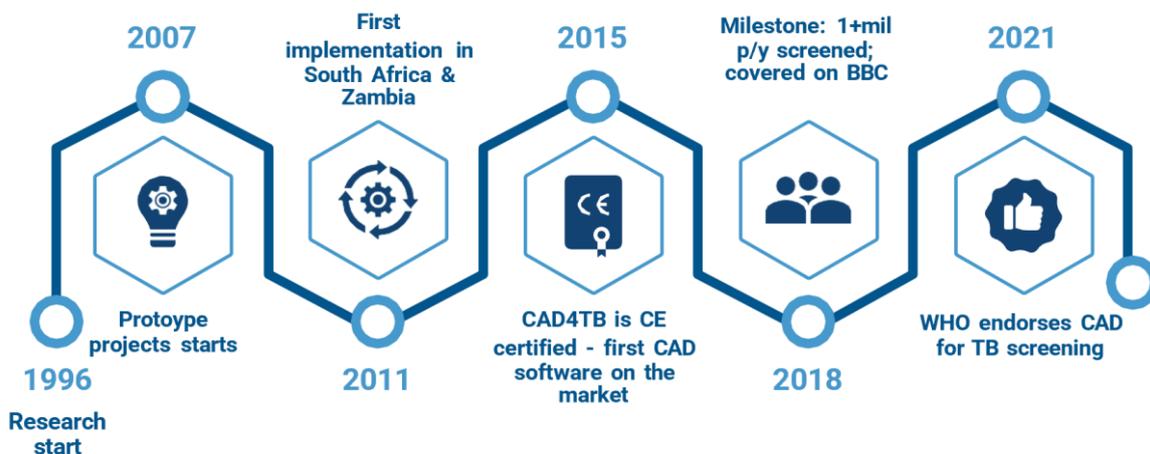
2. CAD4TB innovation journey

Delft Imaging is a pioneer of Computer-Aided Detection (CAD) for TB screening and has revolutionized TB detection. The journey began with the realization that countries with a high TB burden and resource-constrained settings often lack qualified personnel to interpret CXR accurately on-site. We envisioned a technological solution, using AI, to bridge this gap.

Research on CAD4TB began in 1996, with the prototype projects commencing in 2007. Since 2008, we have collaborated with the Diagnostic Image Analysis Group at Radboud University Medical Centre to develop a solution that addresses the limitations of human interpretation of X-ray images. This collaboration resulted in the development of CAD4TB, a software optimized for the computer-aided detection of tuberculosis. In 2011, the software was first implemented in South Africa and Zambia. CAD4TB obtained CE certification in 2015, becoming the first CAD software to do so. Since then, it has been adopted by early users in Africa and Asia for TB prevalence surveys and TB screening programs. Subsequently, this breakthrough led to the recommendation of CAD for TB screening and triaging by the World Health Organisation (WHO) in 2021. These new digital tools are now being rolled out globally with funding from the Global Fund, USAID, the EU, and the World Bank.



Specifically, in settings where access to radiology services is limited, AI-enabled CAD software significantly improves the value of diagnostic imaging. We have gained extensive experience successfully deploying cutting-edge yet user-friendly technology that addresses the realities of healthcare delivery in resource-constrained settings.



3. CAD4TB

CAD4TB (Computer-Aided Detection for Tuberculosis) is state-of-the-art software that automatically analyzes digital Chest X-ray images. The current CAD4TB is version 8, Class IIa CE certified by the notified body 0044 Dekra. CAD4TB 8 is certified for use on individuals ages 4+.

CAD4TB takes a frontal chest radiograph (PA) as input and produces several outputs:

- Tuberculosis probability score based on a bacteriological reference ranging from 0 to 100. Indicates the likelihood of tuberculosis presence in the chest X-ray.
- Abnormality score that denotes lung abnormalities, based on a radiological reference ranging from 0 to 100.
- Generates a heatmap indicating potential tuberculosis abnormalities as a coloured overlay on the original chest X-ray image.
- The cardiothoracic ratio helps evaluate the size of the heart, which may indicate cardiomegaly (an enlarged heart).

*CAD4TB can also be supported by CAD4Silicosis for the rapid detection of silicosis-related abnormalities.



The screenshot displays the CAD4TB X-ray AI Module interface, which is divided into several sections:

- Patient Information:** Contains fields for Archive, PatientID (4593768), Name (Z.N. Anonymous), Gender (Female), and Date of birth (1965-12-27). A barcode with the number 4593768 is also present.
- Patient Symptom Information:** Lists symptoms such as Cough (Yes (6 days)), Fever (No), Shortness of breath (No), and Household TB (No).
- Patient lab results:** Shows "No Lab Results registered for Patient".
- CAD4TB Assessment:** Displays key metrics: Abnormality v8 (99.32), Abnormality Report v8 (Possible Abnormal (99)), CAD4TB v8 (95.91), TB Report 8 (Possible TB (96)), and Cardiothoracic ratio 8 (0.42).
- Heatmap:** A central image showing a chest X-ray with a color-coded heatmap overlay indicating potential tuberculosis abnormalities. A white box labeled "Heatmap" points to this area.
- Quick actions:** A sidebar on the right offers options like Print Report, Registration, Symptoms, XRay-AI, and Lab.

A callout box highlights the Patient Information section, listing the following data points:

- ID number
- Name
- Date of birth
- CAD4TB Score
- Binary classification

CAD4TB X-ray AI Module

The CAD4TB is designed to support readers in detecting presumptive TB rapidly, accurately, and cost-effectively. It does not require skilled human readers to determine whether or not the subject is a presumptive TB case requiring further confirmatory testing. Furthermore, CAD4TB addresses inter- and intra-reader variability and enables almost instant onsite chest radiograph.

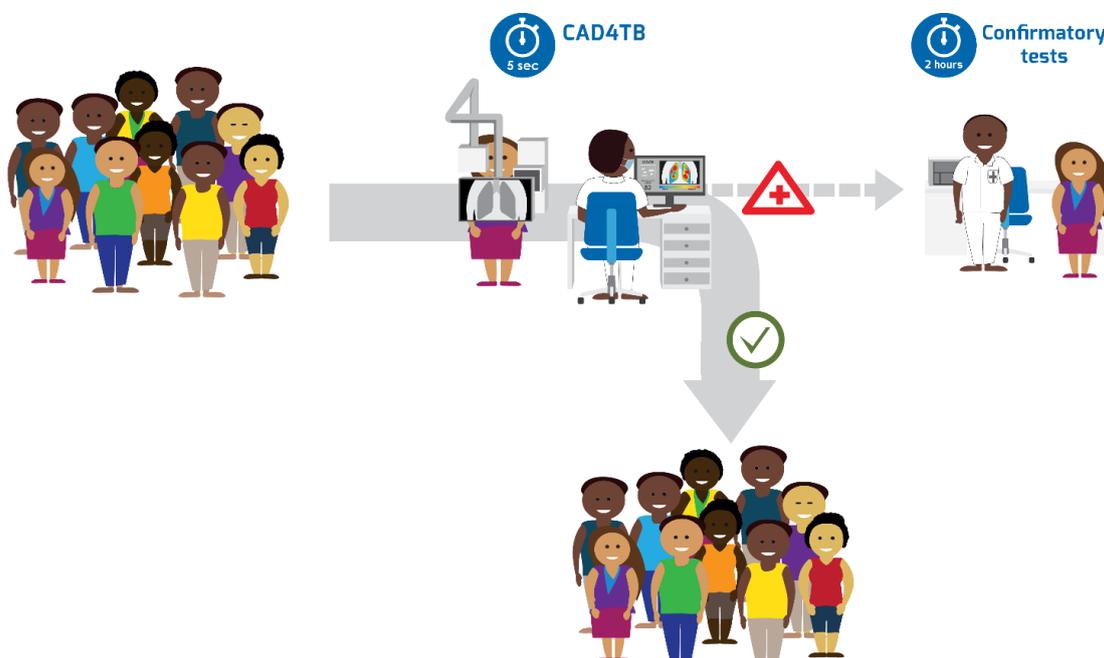


Illustration of the TB screening algorithm in line with WHO recommendations

Based on the set threshold and the outputs, users can take CAD4TB results into account in their clinical work:

- Ask CAD4TB presumptive TB patients to undergo further testing and submit sputum to perform a confirmatory test;
- A skilled human reader can read abnormal chest images from Xpert MTB/RIF or Truenat-negative patients to determine the next steps for a clinical diagnosis of TB or other lung diseases.

3.1 General description

CAD4TB is software based on deep learning principles. It accepts posterior-anterior (PA) chest X-ray images and normalizes the input to ensure proper processing of images from different X-ray machines.

Tuberculosis may manifest in different abnormal structures, such as diffuse textural patterns, focal patterns, pleural-related abnormalities, lymphadenopathy, and cavities. CAD4TB leverages state-of-the-art machine learning techniques based on deep learning to detect these abnormalities. It draws on a large training set of X-ray images acquired from various sites in multiple countries. With the expert knowledge of experienced lung physicians, abnormal lung regions have been annotated and used to develop and train the system.

3.2 Scientific validation

CAD4TB is the most rigorously validated CAD technology for TB screening and triaging. Over 100 publications highlight its technical capabilities, operational performance, cost-effectiveness, and reliability. This includes the accuracy, daily throughput, cost-efficiency, Xpert cartridges saving, and benefits of integrating CAD4TB for TB screening algorithms. CAD4TB is endorsed by the WHO as the scientifically proven CAD for digital chest radiography, meeting the Target Product Profile values outlined in the WHO Consolidated Guidelines on TB and the WHO Global Tuberculosis Report 2022^{vi}.

A complete list of CAD publications is available at <https://www.delft.care/publications/>.

Publication highlights (see annexe 2)

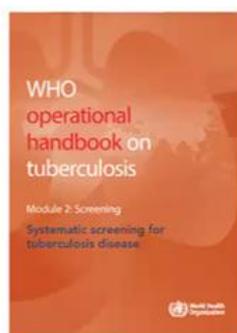
	CAD4TB met WHO's Target Product Profile values (Sensitivity > 0.90 and Specificity > 0.70)	Multiple studies
	Performs on par or significantly better than human radiologists.	Multiple studies
	Daily screening yields 2.5 times higher with CAD4TB in comparison to screening without.	Murphy et al. Nature Scientific Reports, 2020.
	Case detection increased by 22% with CAD4TB being used as a second CXR reader.	Philipsen et al. IJTLD, 2019.
	With high throughput scenarios, the per-screen cost for CAD4TB is 73% lower than a radiologist for ACF and 61% lower for facility-based screening.	Bashir et al. PLOS One. 2022
	Xpert tests used 75% savings when using CAD4TB at a sensitivity of 79.7% and more than 50% savings at a sensitivity of CAD4TB above 90%.	Qin et al. The Lancet Digital Health, 2021.
	TB & Diabetes screening: High accuracy with CAD4TB as a TB screening tool among people with diabetes.	Habib et al. Nature Scientific Reports, 2020.
	TB & HIV: added-value with universal HIV screening increased timelines and completeness of HIV/TB diagnosis.	MacPherson et al. PLOS Medicine, 2021.
	CAD has the potential to be a useful additional diagnostic tool for paediatric tuberculosis.	Palmer et al. PLOS Global Public Health. 2023.

3.3 Threshold Score Selection

Principles of the CAD4TB threshold

A threshold is used on the CAD4TB score to classify a chest radiograph as normal or abnormal. This threshold can vary depending on the setting and program. For instance, a program focused on not missing a single case, for example, in TB prevalence surveys, may opt for a relatively low threshold to maximize sensitivity. This low CAD4TB abnormality threshold score will reduce specificity, leading to more cases being defined as 'abnormal' and requiring follow-up tests. On the other hand, a program with budget constraints might aim to use follow-up tests only on the most abnormal (likely to be TB) cases. In such a scenario, they may opt for a higher CAD4TB threshold. This will maximize budget efficiency at the risk of missing cases with lower scores. The WHO operational handbook on tuberculosis also outlines the principles of the CAD threshold.^{vii}

There is no one-size-fits-all CAD threshold score. The optimal score will depend on the screening objectives and the conditions under which the CAD is used. Therefore, the choice for threshold should be determined by the user.



“ As threshold values for CAD products are not static or consistent across software or even versions of the same software, the user must determine the most appropriate abnormality or threshold score for their setting and use case, above which a confirmatory diagnostic test would be conducted. Identifying the ideal threshold for each use of CAD requires decisions on the goals and acceptable costs of screening.

WHO operational handbook on tuberculosis Module 2

Optimizing the threshold

There are various ways to optimize a threshold by strategically adjusting it to align with project requirements, such as budgetary constraints or the availability of follow-up testing. For instance, a program with access to around 50 follow-up tests daily would optimize its threshold to ensure the detection of the 50 most abnormal cases on an average screening day.

The Special Programme for Research and Training in Tropical Diseases has developed a toolkit for CAD calibration^{viii}.

Different CAD versions and threshold

Due to variations in sensitivity and specificity across different versions of CAD4TB, employing the same threshold will result in varied outcomes. Hence, it is pivotal to consider adjusting the threshold after upgrading CAD software to a newer version.

If there are noticeably fewer patients with scores above the threshold after a CAD software update, the set threshold may be too high and require further analysis. The StopTB Partnership published a paper describing this issue by comparing suppliers' different CAD/AI versions^{ix}. As a result, we also recommend conducting a verification study for clients who have used other CAD4TB versions.

Threshold score support by Delft Imaging

Delft Imaging can support TB programs with a CAD4TB verification study to determine, based on data, the optimal threshold. For this study, we request a minimum of 100 images, classified as normal or abnormal based on bacteriologically confirmed results. Based on the images, we can provide an ROC curve reflecting your program's sensitivity, specificity, and optimal threshold levels. Please note that these images will be processed solely to perform the verification study. As part of our commitment to supporting users to realize optimal CAD4TB impact, the verification study is free of charge.

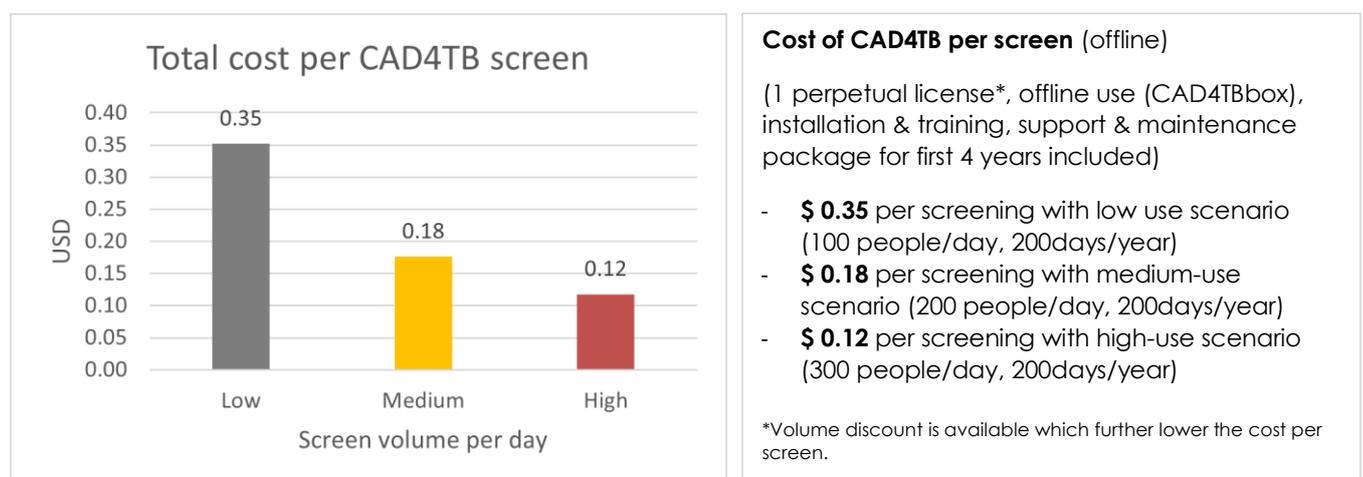
3.4 Economic analysis

CAD4TB is available as a perpetual license or pay-per-use. With a perpetual license, users can use CAD4TB for an X-ray system without any expiry date. To receive software updates and upgrades, users must opt for the CAD4TB support and maintenance package when purchasing the license.

The perpetual license structure makes it easier to determine the total cost of ownership of CAD4TB and the total cost per CAD4TB screen over a period. Below is the total cost per CAD4TB screen per daily screening throughput based on different screen volume scenarios for an offline use CAD4TB perpetual licence, including installation and training, support, and maintenance package extension, acquired via the Stop TB Partnership's GDF catalogue.

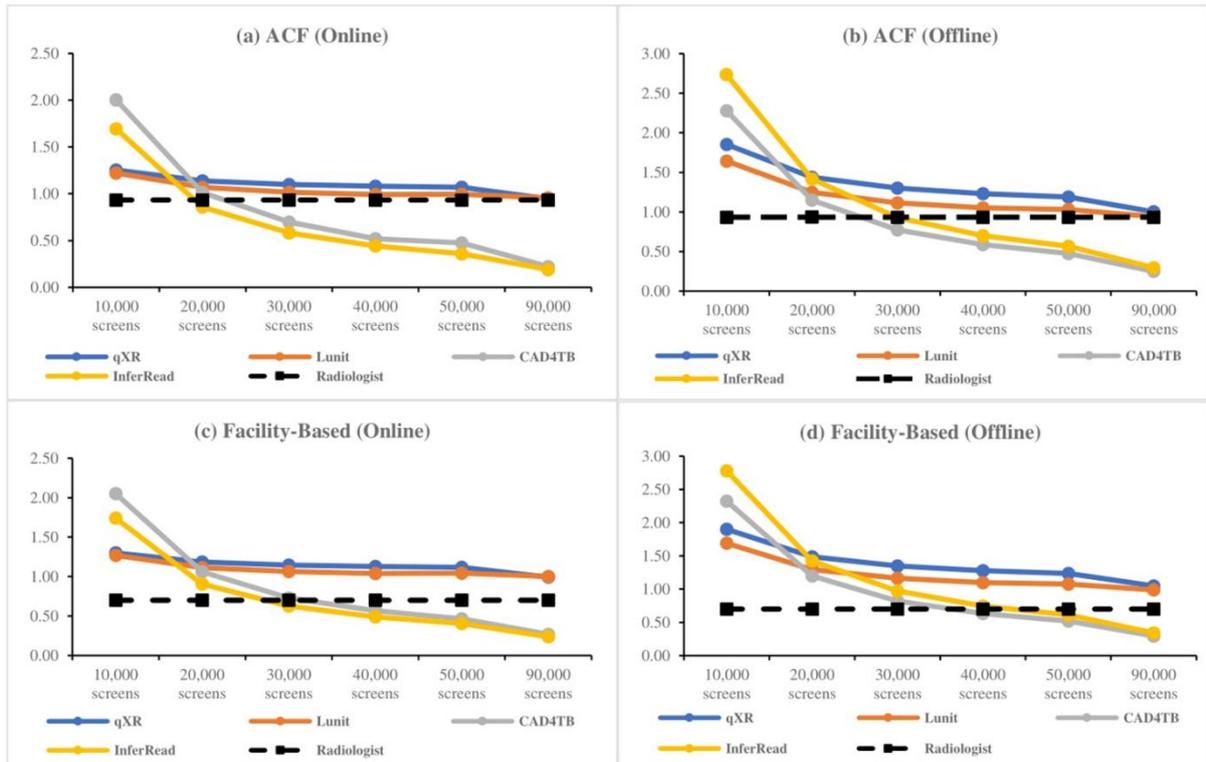
In these scenarios, the total cost per CAD4TB screen is marginal. Additionally, it reduces the number of Xpert cartridges required. Hence, CAD4TB proves to be a highly cost-effective tool for systematic screening, offering substantial benefits in terms of case notification yield, screening efficiency, and cost savings.

Meanwhile, projects anticipating smaller screening volume may opt for pay-per-use. Delft Imaging can advise on the optimal CAD4TB bundle price structure, considering the project objectives.



(The estimated scenarios can be adjusted)

A recent study in Pakistan (S. Bashir. et al. 2022) suggests that CAD4TB is the most economical CAD software for offline deployment. It concludes, “the per-screen costs for the two CAD software programs (CAD4TB and another product) that had a perpetual licensing costing structure are considerably lower than the cost with radiologists for high throughput in ACF scenarios and facility-based screening scenarios^x.”



Cost per screen with CAD vs. radiologist for different scenarios & throughput volumes (Bashir et al.)



The Zero TB Initiative using CAD4TB for active case finding (Pakistan)

3.5 Deployment

Integration with digital X-ray Systems

The DICOM standard is used to integrate X-ray systems with CAD4TB software. CAD4TB can read images from any digital X-ray machine from major manufacturers, including stationary, mobile, and ultra-portable X-rays. X-ray machine validation is voluntary but may be performed if desired.

Mode of Deployment: Offline, Online, Hybrid

Offline

The **CAD4TBbox** is a mini-computer that enables CXR analysis without an internet connection. It can be connected to a digital X-ray unit using a DICOM connection via a WiFi connection.

The CAD4TBbox contains the CAD4TB AI algorithm, an SQL database (PACS), and a local **web server** on which users can access the images through a local WiFi connection.

The image analysis takes place on-site, enabling an almost instant (~5 seconds) heatmap presentation and scoring of abnormalities.

CAD4TB outputs can be viewed on an X-ray workstation/console laptop¹, a pre-configured tablet that comes with CAD4TBbox, or any other laptop, tablet, or smartphone using a web browser connected to the local CAD4TBbox network. It does not require any special viewing software.

CAD4TBbox has a storage capacity for CXR images and an external hard drive for saving images locally. Since it has no power autonomy, CAD4TBbox requires a power supply. The box can be powered by a solar power pack system that comes with the Delft Light portable X-ray system in a backpack.

The design allows for rapid and stable screening in locations without internet access, which is crucial for operations in hard-to-reach locations. It is highly relevant for settings with high daily throughput, limited or no internet connectivity, or programs coping with restrained budgets for data exchange over the mobile phone network.



CAD4TB Offline solution: main components



CAD4TB results shown on X-ray console and tablet

¹ Possible with Delft Imaging's X-ray systems (e.g. Delft Light). For other X-rays, it depends on providers whether it supports viewer system integration.

System connection

Offline

Our offline CAD4TB solution comes in an all-in-one compact case containing a CAD4TBbox with all necessary cables already connected. This configuration expedites installation and streamlines the connection between CAD4TB and digital X-ray machines, minimizing cumbersome cable connections. Additionally, the case protects the hardware during transportation and in challenging weather conditions.



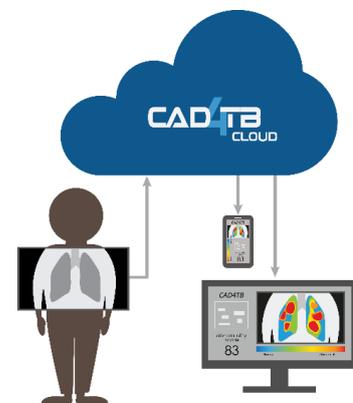
Online

The **CAD4TBcloud** uses the cloud server. Placing a SIM card in the router allows all local field sites to be interconnected to an aggregated cloud server.

With everything pre-installed and available in the cloud, no installation is required.

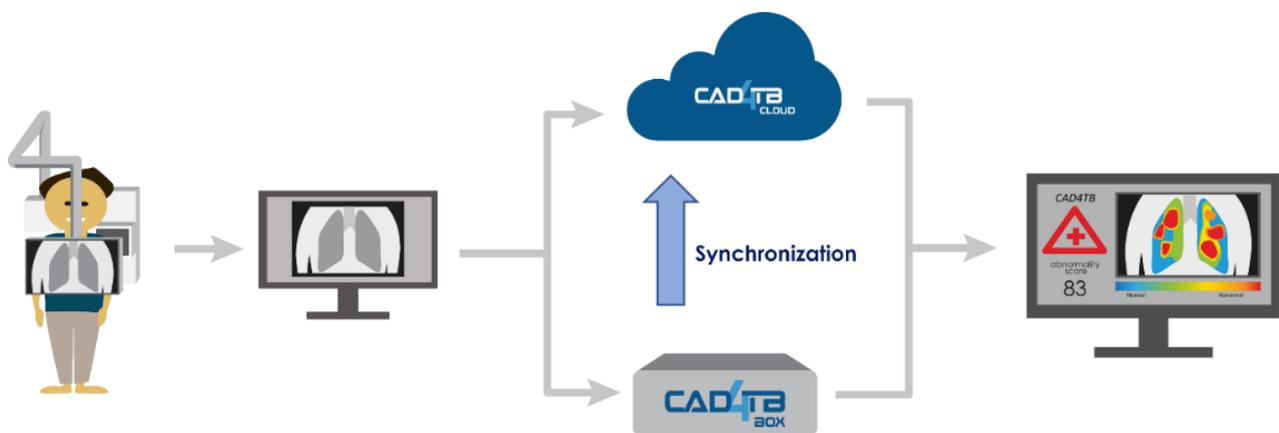
The upload program enables users to send compressed CXR images and anonymize them if required. The images are processed in the cloud, and the speed of the CAD4TB processing time depends on the internet bandwidth.

We are available to discuss in-country or on-premises servers upon request.



Hybrid

The hybrid mode enables users to combine/alternate between offline and online methods described above. **Data synchronization is possible from the CAD4TBbox to CAD4TBcloud as soon as a stable internet connection is available.**



CAD4TB process flow (Online, Offline, Hybrid)

Integrating CAD4TB and our digital X-ray systems

Although CAD4TB can be used with any digital X-ray machine, using it with our X-ray systems (CompassDR, EasyDR, MAC, Delft Light, Delft Ultra) enables more streamlined implementation.

- CAD4TB is pre-configured on the X-ray console laptop.
- The patient registration process is streamlined by avoiding duplicate data input.
- Users can view CAD4TB results on the X-ray console laptop.
- The solar power pack included with our X-ray systems can power the CAD4TBbox.
- Procurement, delivery, installation, training, and combined support and maintenance for CAD4TB and X-ray systems are provided through a single service contact point and helpdesk, ensuring rapid response times, efficient issue resolution, and reduced total cost of ownership.



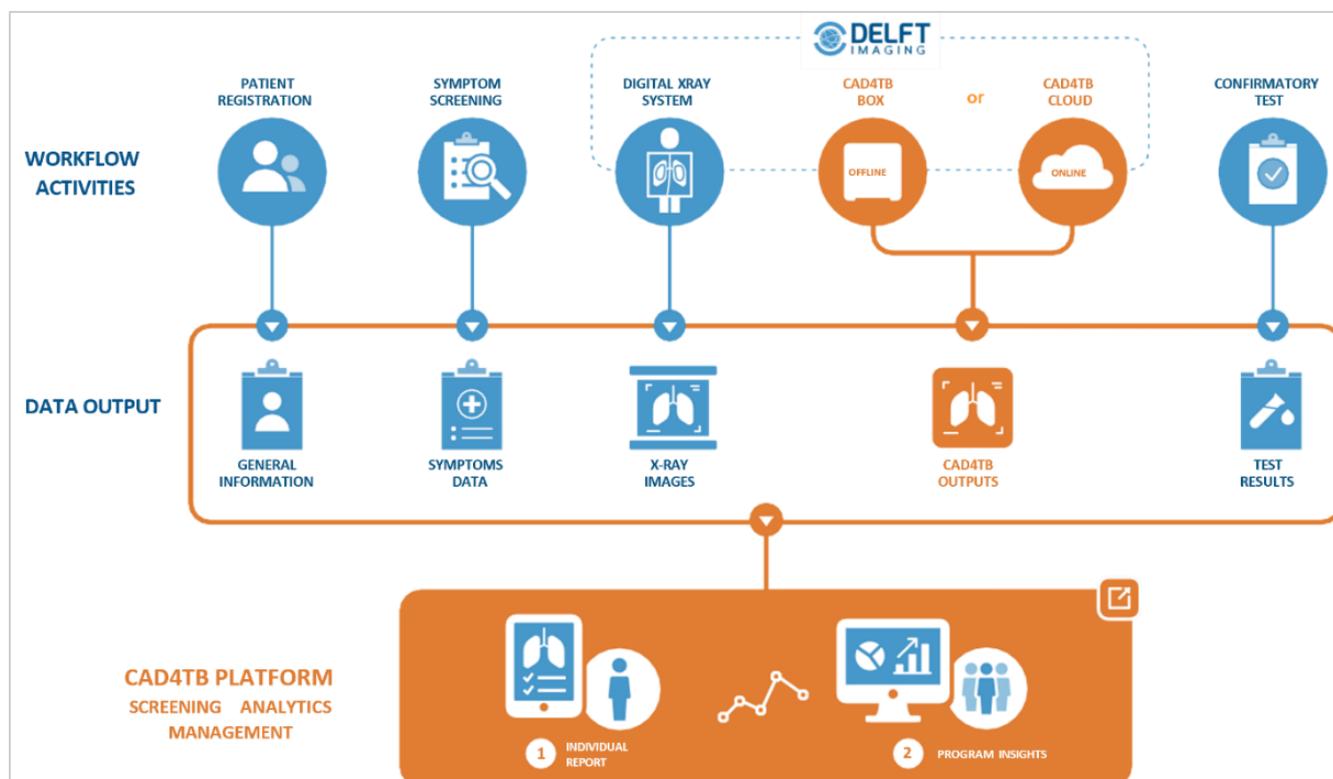
Nigeria: Active case-finding using Delft Light (portable digital X-ray in backpack) and CAD4TB



(Left) Ghana: Containerized clinic with EasyDR (Stationary X-ray) and CAD4TB
 (Right) Uganda: Mobile Clinic with EasyDR and CAD4TB

3.6 Monitoring & evaluation: CAD4TB Platform

The CAD4TB Platform is a workflow platform that enables digitized TB screening data management. **The platform comes with CAD4TB software** (no need to purchase it separately) and does not require any special viewing software.



Available in both online and offline modes, users can access the platform on any PC, laptop, tablet, or smartphone through a browser. The platform offers multiple languages, including Arabic, Bengali, English, French, Portuguese, Russian, Spanish, Tagalog, Thai, Urdu, and Vietnamese.

The platform enables a transition from paper-based to digitalised data-driven TB management and decision-making. When an internet connection is available, the CAD4TB platform seamlessly integrates data across multiple locations and generates aggregated insights that can be reviewed from different locations. These insights will allow users to further optimize TB screening programs for increased case notification yields.

Advantages of the CAD4TB Platform

- Centralized platform for all screening information, monitoring and evaluation (M&E), and data-driven TB control
- Serves as the primary data entry point for health workers
- Improved data quality and avoidance of data fragmentation/multiple data entries
- Simplified data access and governance



The CAD4TB Platform provides the following modules:

- Registration
- Symptom screening with customizable questionnaires
- X-ray AI (X-ray image and CAD4T report: heatmap, scores, report field)
- Lab results: Serves as the primary data entry point for health workers from other systems (e.g., lab systems)
- Insights for aggregated data



Implementation example using CAD4TB Platform

Registration and symptom screening



AI-powered CAD4TB

X-ray



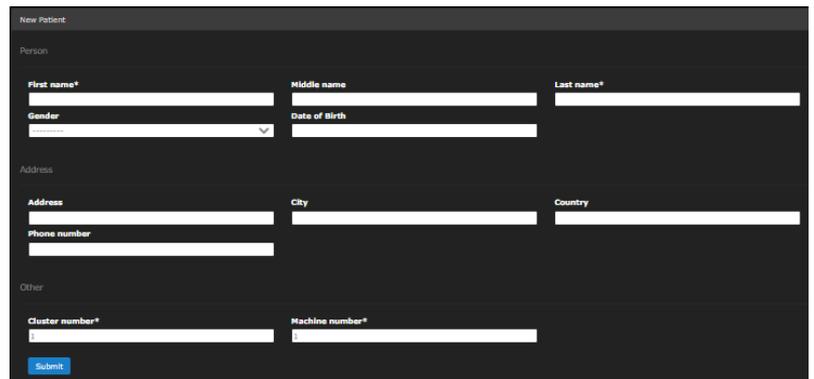
Reporting and insights



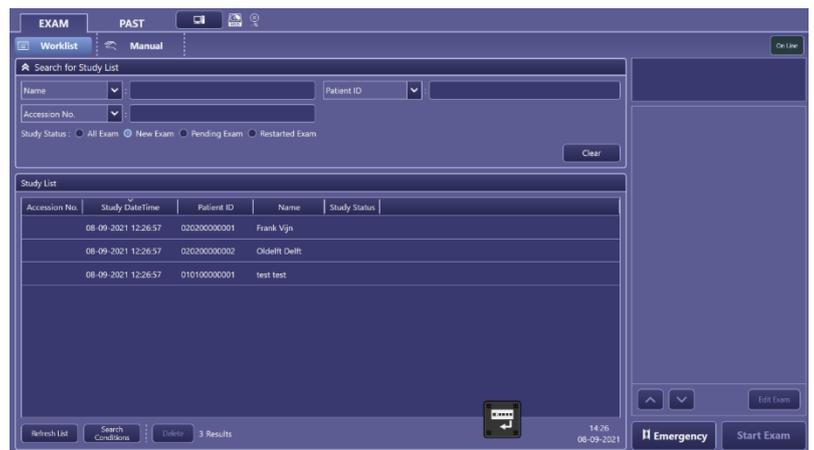
CAD4TB Platform implementation steps

Registration module

This module includes fields such as first name, middle name, last name, gender, date of birth, address, city, country, phone number, cluster number, and machine number (unique ID). Registration is typically done before capturing an image.



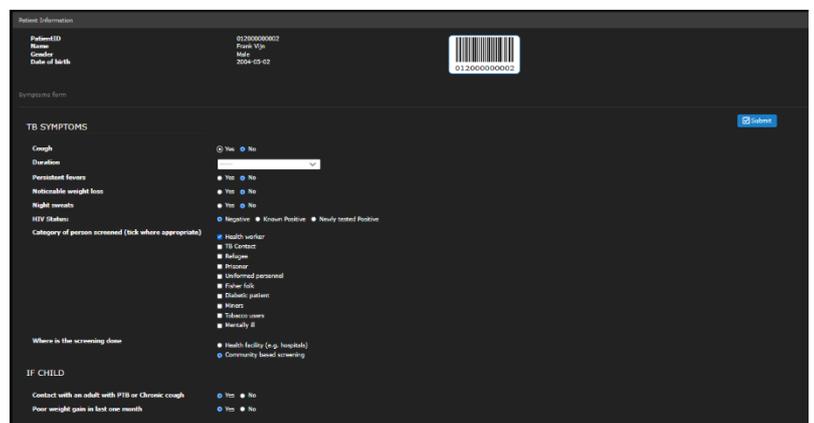
CAD4TB 8 allows for DICOM Modality worklist integration on selected X-ray models. After registering a patient on the CAD4TBbox, you can open the worklist windows on the X-ray console and select the patient you want to X-ray. The patient's details are then automatically available in the DICOM image, eliminating the need to manually re-enter them on the X-ray console. This ensures a seamless data transfer once the image is transferred to the CAD4TBbox.



Accession No.	Study DateTime	Patient ID	Name	Study Status
08-09-2021 12:26:57	020200000001	Frank Vijn		
08-09-2021 12:26:57	020200000002	Oldelft Delft		
08-09-2021 12:26:57	010100000001	test test		

Symptom module

The Symptoms module is used to register and track a pre-configured list of TB symptoms for patients registered in the system. It is customizable, and additional information can be added to the platform based on the program's requirements.



Patient Information

Patient ID: 020000000002
 Name: Frank Vijn
 Gender: Male
 Date of birth: 2004-09-02

Symptoms form

TB SYMPTOMS

Cough: Yes No

Duration:

Protracted fever: Yes No

Noticeable weight loss: Yes No

Night sweats: Yes No

HIV Status: Negative Known Positive Newly tested Positive

Category of person screened (tick where appropriate):

- Health worker
- TB Contact
- Refugee
- Prisoner
- Unemployed person
- Father/son
- Diabetic patient
- Menstr
- Tuberculous users
- Mentally ill

Where is the screening done:

- Health facility (e.g. hospital)
- Community based screening

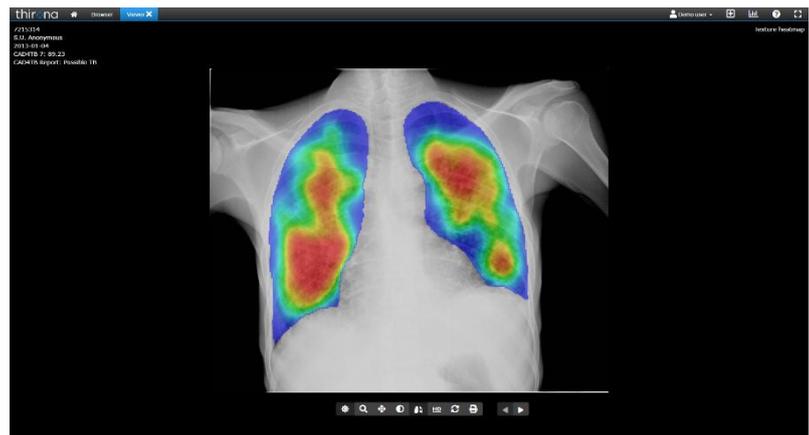
IF CHILD

Contact with an adult with PTB or Chronic cough: Yes No

Poor weight gain in last one month: Yes No

X-ray AI

The X-ray AI module consists of the X-ray image, CAD4TB report, scores, heatmap, and TB Report field (Binary classification “Possible TB” or “No TB”).



Lab results

The Lab module enables users to link patients to GeneXpert and RIF Resistance results, allowing them to synchronize all information in one place. This information can be uploaded to the cloud or sent to another system using the API.

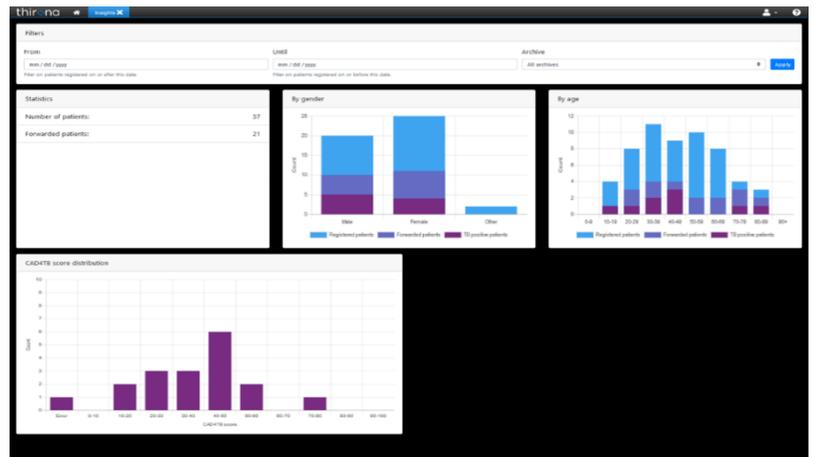
Reporting

The Report module shows a report for an individual using aggregated information from all modules. The page contains important information, such as symptoms, lab results, and X-ray AI scores with a heatmap. The report can be printed using an approved/designated printer.



Insights

The Insights module shows aggregated data in convenient graphs, including the screened population's demographics and X-ray scores. Hovering over or selecting a data point reveals detailed information. Data can be filtered within a specific time frame (e.g., a month of screening).



CAD4TB Platform Demo

You can access the CAD4TB Demo from our website: <https://www.delft.care/cad4tb/>

3.7 Data storage, export, and interoperability

Data storage & viewing

Offline use	Online use
<p>All data and information (patient information, symptoms, X-ray image, CAD4TB heatmap and score, lab result, and insights) are locally saved on the CAD4TBbox or an external hard drive. Users can view data and information on-site.</p>	<p>A dedicated cloud server can view data and information. This facilitates data access from multiple locations, enabling the programme managers at the central level to review data and monitor information on dashboards.</p> <p>There is an option for data and image hosting, plus storage on the in-country server.</p>
Hybrid use	
<p>Data synchronization from CAD4TBbox to the cloud is possible. All the collected data saved in the CAD4TBbox can be synchronized to the cloud when the internet connection is available. For instance, a program may conduct outreach campaigns in remote areas using the offline solution, then synchronize data once the team returns to a city with a stable internet connection and uploads data to the cloud. This means that whenever the user uploads the data to the cloud, another user in a different location can access the data for review. New data can be synced to the cloud when the internet is available.</p>	

Data export

There is a range of options for exporting CAD4TB data and information. For offline use, users can manually download all locally saved data on CAD4TBbox using the CSV file. For online use, CAD4TB cloud backup and access are possible.

Interoperability

In addition to the above approaches, there are options for data integration with the DICOM/PACS server or API functions.

DICOM connection to another (PACS) system

CAD4TB uses the DICOM standard for image transfers and supports Storage Class Provider (SCP) and Storage Class User (SCU) classes. This means that CAD4TB can output a secondary capture image, including the heatmap and CAD4TB score, to another PACS system.

API

CAD4TB contains an application programming interface (API) to retrieve information from the database. This information can be used in your application to make specific changes to the database and add new data. Multiple versions of the API are supported. Please consult the correct version of the technical documentation for the required information.

3.8 Data privacy & security

Based in the Netherlands, Delft Imaging complies with the stringent EU data privacy and security regulations, including the General Data Protection Regulation (GDPR). The data are only used for purposes beyond providing the CAD4TB results for the clients if given explicit written permission. Any data processed by CAD4TB remains the property of the clients.

If a patient's DICOM data needs to be sent, it is de-identified and (pseudo) anonymized before being sent to the server. This ensures no personal information is transferred over the internet and guarantees compliance with privacy regulations. We safeguard data, privacy, and security with complete transparency.

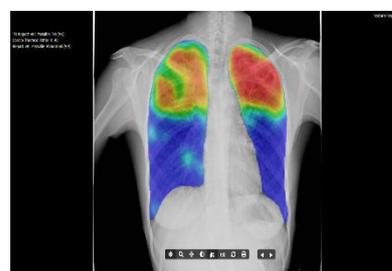
3.9 CAD4TB upgrades, updates, and add-on features

Delft Imaging periodically releases CAD4TB upgrades and updates to enhance performance, usability, and facilitate integrated service delivery. The support and maintenance package includes software patches, updates, and upgrades that are accessible in both online and offline solutions. The timing of performing updates and upgrades is determined by the users.

Ability to detect other abnormalities

The latest CAD4TB includes CAD modules that automatically detect the following abnormalities. These innovations further increase the diagnostic value of chest radiographs in TB screening and support the people-centred approach with multi-disease impact.

- **Lung (non-TB) Abnormality Score:** Besides detecting presumptive TB, the latest version offers AI algorithms to detect other pulmonary abnormalities (score 0-100). It supports triage of non-TB abnormalities using CXR images.
- **Dynamic Threshold for optimized calibration:** This feature analyzes previous CAD4TB results while considering available bacteriological testing capacity. It then suggests an optimized threshold for a screening project.
- **Automated Cardiothoracic ratio (CTR):** Potential early signs of health failure (**Cardiomegaly**), incidentally or occasionally found during TB prevalence surveys or community-level screenings.
- **Offline CAD4Silicosis:** This module generates a score (0-100) related to the likelihood of silicosis-related abnormalities, without an internet connection. CAD4Silicosis box enables rapid, onsite silicosis detection.



4. Training, support & maintenance

We aim to ensure uninterrupted operations, maximum uptime, and efficiency for our clients. To achieve this, we consider capacity building, support, and service as essential components of our offerings. Our qualified teams of experts provide training, seamless installation, and reliable services and maintenance, including a 24/7 help desk with well-trained and experienced engineers in different time zones.

Training

The CAD4TB training includes theoretical and practical aspects of software administration and utilization. The training and materials are available in multiple languages: Arabic, Bahasa Indonesia, Bengali, English, French, Portuguese, Russian, Spanish, Tagalog, Thai, Urdu, and Vietnamese. More languages are available upon request. Moreover, we offer installation support to integrate CAD4TB with our digital X-ray systems or the existing digital X-rays from other manufacturers.

Support & maintenance

The CAD4TB support and maintenance package includes regular patches for the software, upgrades, and updates for software and hardware (CAD4TBbox). Software updates and upgrades incorporate the latest functionalities and improved AI algorithms, ensuring our clients can always access the latest features. For instance, the recent CAD4TB upgrades include:

- New AI modules for cardiothoracic ratio and Silicosis;
- Expansion of M&E insights;
- Customizable screening workflow;
- Data synchronization from offline (CAD4TBbox) to online (CAD4TBcloud);
- Multi-lingual support.

Subsequent software upgrades include expanding lung abnormalities detection, improved features, and new functionalities.

To address any reported issues promptly, our helpdesk and remote support teams ensure issue resolution within a single working day from the day of reporting. Furthermore, our regional offices in Ghana and Indonesia, alongside our in-country local service partners, professionally support clients' operations with web-based and on-site technical assistance for rapid response and issue resolution.

In addition, we offer three one-day remote refresher training sessions to minimize system failure risks and two online preventive maintenance sessions annually. The follow-up training sessions support maintaining the capacity of trained personnel and facilitate new staff onboarding. The support is available in English, French, and Russian. Additionally, our trainees can benefit from Delft Imaging's eLearning platform, which enables flexible access to valuable resources.

5. Consideration to implement CAD4TB for TB programs

It is critical to consider the following steps when adopting CAD for your TB programs. Delft Imaging is available to advise on the optimal implementation mode and solution package to maximize the benefit of CAD.

Planning

- Country's regulatory approval for CAD (if applicable)
- Availability of digital X-rays
- Availability of internet connectivity
- Data process, storage, and interoperability requirement
- Screen settings, target population, and mode of deployment: online, offline or hybrid
- Screen volume: perpetual license or pay-per-use model (for estimated running cost)
- Strongly recommend including Training and Service & Support packages

Procurement

- Pooled procurement (GDF catalogue, PFSCM) or direct contact to Delft Imaging
- Consideration of volume discount

Training & Installation

- Onsite, Onsite or Hybrid

Implementation

- Optimizing threshold score

Service & Support

- Helpdesk (call, web-base, on-site support)
- Availability of local service provider
- Software updates & upgrades
- Planned Preventive Maintenance
- eLearning



CAD4TB and Delft Light training (right: DR Congo, left: Bangladesh)

6. Validated results from CAD4TB

TB-burden



Active case-finding, Pakistan

- Since 2017, a total of 76 mobile clinics with CAD4TB facilitate over 4 million screenings.
- ACF intervention is an effective strategy to find missing TB cases in hard-to-reach areas and enables early TB diagnosis.
- Reference: "Implementation of an active case-finding intervention by using mobile vans equipped with digital X-rays and Gene Xpert machines to reach the missing TB cases in Pakistan" Sidra Azmat Mercy Corps, Pakistan.



Community-based active case-finding, Nigeria

- Delft Light and CAD4TB were distributed to eight high TB-burden states with many hard-to-reach areas.
- Ultraportable digital X-ray with CAD has significantly improved high-quality TB care to hard-to-reach underserved populations.
- REFERENCE: A. Ihesie et al. (2022, Nov. 8-11). *Scaling up ultra-portable digital X-ray with computer-aided TB detection in Nigeria*. The Union World Conference 2022.



Active case-finding, Peru

- Large-scale TB case finding using mobile vans equipped with X-ray, CAD4TB and GeneXpert machine deployed to 214 different locations.
- CAD4TB resulted in rapid identification of people in need of further testing, while mobile vans brought services closer to the communities.
- REFERENCE: Stop TB Partnership (2022) REACHING THOUSANDS IN NEED: USING ARTIFICIAL INTELLIGENCE IN MOBILE VANS.



Mass & remote TB screening, Indonesia

- CAD4TB has been used for mass screening among inmates etc.
- The CAD4TB is in line with the radiologists' expertise and has good sensitivity in high-risk TB populations.
- REFERENCE: "Utilization of CAD4TB for Mass and Remote TB Screening in Indonesia", Dr Lituhayu B. Putri, Fullerton Health Indonesia, presented at Delft Imaging's Webinar on 14th October 2021.



Response active case-finding, Uzbekistan

- Delft Light and CAD4TB deployed to 7 cities/provinces including hard-to-reach locations.
- CAD4TB help reduce the work of doctor and simplify the workflow, easing and helping patients rapidly. Heatmap is easier to identify abnormalities.
- REFERENCE: A. Umarov (2023, July 25). Experience on ultra-portable X-ray and CAD implementation in Uzbekistan, Delft Imaging webinar.

Health screening, the Middle-east



- Support Syria, Lebanon, Jordan and Iraq with CAD4TB through collaboration with IOM.
- CAD4TB usage as it allows early detection of the disease, addresses the human resource gap, is accurate, accessible and affordable technology and improves the decision making.

• REFERENCE: C. Togara, (2023, March 28) Introducing CAD/AI in Challenging Operating Environments (COEs) - lessons learned from the Middle East Response (MER). Delft Imaging webinar.

Intensified TB case-finding, Zambia



- Deployed OneStopTB clinic with CAD4TB to 30 TB hospots.
- TB notification increased by 49% through introduction of the mobile clinic. Use of the MOST clinic is making a significant contribution to TB case notifications in the Copperbelt Province in Zambia, help close the gap between notified TB patients and estimated incidence".

• REFERENCE: The 52nd UNION conference "Intensified TB case finding in Copperbelt Province, Zambia: Contribution of Mobile One-Stop TB Clinic", Onety Hanyuma, PATH Zambia.

People living with HIV, Uganda



- Supported five health facilities in conducting TB screening among people living with HIV using digital X-rays and CAD in Uganda.
- TB screening with CXR improved TB case detection with higher yield among PLHIV and contacts compared to other groups.

• REFERENCE: B. Aldo et al. (2022, November 8-11). Intensified TB case-finding using digital X-ray and CAD4TB among people living with HIV receiving care at health facilities in Uganda. The Union World Conference on Lung Health 2022.

Prison screening, Nigeria



- TB case finding at Kano Central Correctional Center in a high-risk setting for transmission of TB using OneStopTB mobile clinic equipped with digital X-ray, CAD4TB and GeneXpert machine.
- Intervention was highly effective and significantly increased case finding in a short period of time

• REFERENCE: The 52nd UNION conference "Report of an outbreak of Tuberculosis in Kano Central Correctional Center, Kano, Nigeria", Tukur et al., KNCV Nigeria

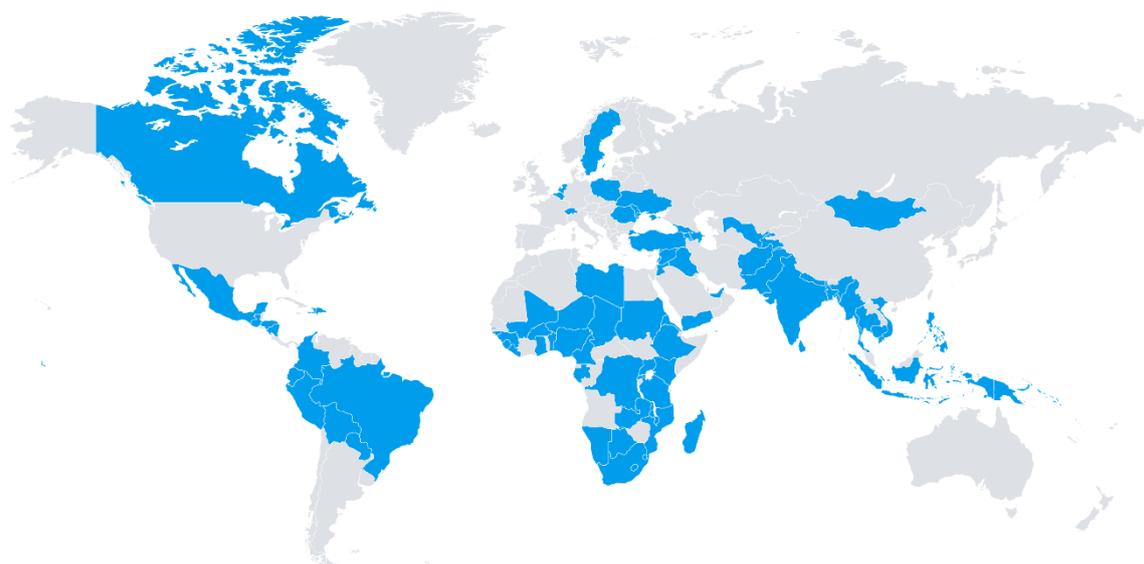
TB prevalence survey, Cambodia



- Applying new digital technologies for the 3rd National Prevalence Survey, including Delft Light and CAD4TB to improve/assure technical quality and management efficiency.
- CAD4TB is used to prevent major errors of human readers.

• REFERENCE Cambodia Prevalence Survey Core Team (2023, July 26). Experience Sharing: Implementation of Delft Light and CAD4TB in the 3rd National TB Prevalence Survey in Cambodia. Delft Imaging webinar.

7. Global implementation of CAD4TB



(as of July 2025)

Africa		Asia Pacific		Americas		Europe & Central Asia		Middle East	
Benin	Malawi	Afghanistan	Brazil	Armenia	Iraq				
Botswana	Mali	Bangladesh	Bolivia	Azerbaijan	Jordan				
Burkina Faso	Mozambique	Cambodia	Colombia	Belgium	Lebanon				
Cameroon	Namibia	Timor Leste	Dominican Republic	Georgia	Palestine				
Chad	Niger	India	Ecuador	Moldova	Syria				
DR Congo	Nigeria	Indonesia	Guatemala	Poland	UAE				
Eritrea	Rwanda	Kiribati	Haiti	Romania	Yemen				
Eswatini	Sierra Leone	Mongolia	Honduras	Netherlands					
Ethiopia	South Africa	Myanmar	Mexico	Sweden					
Gabon	Sudan	Nepal	Nicaragua	Switzerland					
Ghana	Tanzania	Pakistan	Paraguay	Tajikistan					
Guinea	The Gambia	PNG	Peru	Ukraine					
Guinea-Bissau	Uganda	Philippines		Uzbekistan					
Kenya	Zambia	Singapore							
Lesotho	Zimbabwe	Solomon Islands							
Liberia		Sri Lanka							
Madagascar		Thailand							
		Vietnam							

Annexe 1: Sensitivity and Specificity

In artificial intelligence software, there is always a trade-off between sensitivity (proportion of positive images (i.e., having TB) correctly labelled as positive) and specificity (proportion of negative images (i.e., not having TB) correctly labelled as negative) of a system.

This trade-off is best made visible in a ROC curve, as shown in Figure 1. When opting for high sensitivity, for example, 95%, the software will detect 95% of all people in the population carrying the disease. However, the higher sensitivity causes a lower specificity. When sensitivity is 95%, the specificity is around 50%. This means that of all the subjects classified as possible TB, only 50% will carry the disease. In other words, too many people will be classified as carrying the disease.

The ROC curves in Figure 1 show that version 7 is indeed 'better' at detecting TB than version 6 because of the higher Area Under the Curve (AUC) due to the changed training reference.

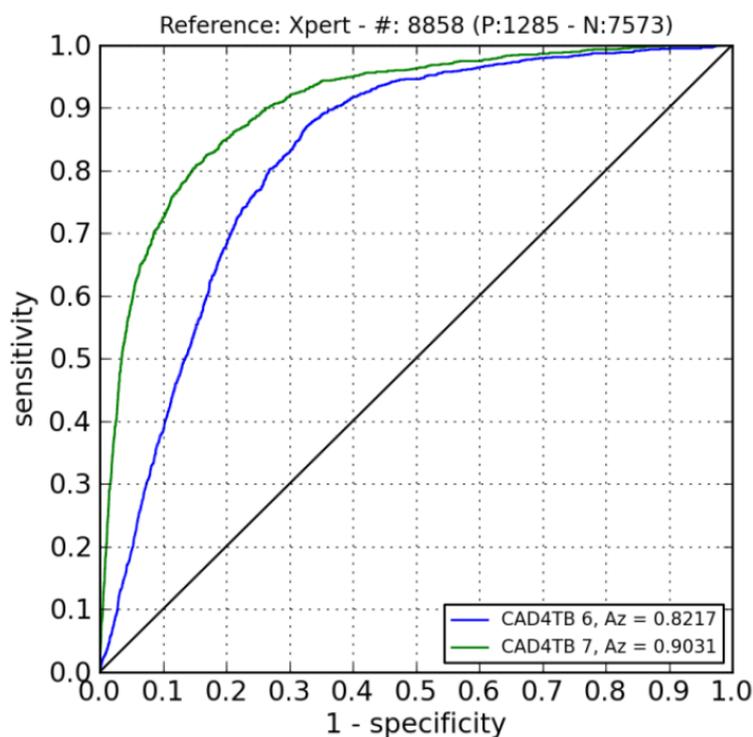


Figure 1. ROC Curve

ROC curve: This curve is created by plotting the True Positive Rate (sensitivity) against the False Positive Rate (1-specificity) at various threshold settings.

Annexe 2: Highlights of CAD4TB Publications

Performance

The newer version (CAD4TB 7) significantly outperformed the predecessor (CAD4TB 6), performing better than human readers and meeting WHO TPP values.	[Z. Qin et al., PLOS Digital Health, 2022]
CAD4TB v7 and two other CAD software solutions emerged from this evaluation as excellent alternatives for human CXR interpretation, performing on par with the Expert Reader and significantly better than the Intermediate Reader.	[Vietnam: A. Codlin et al., Nature Scientific Report, 2021]
CAD4TB performs significantly better than human readers.	[Qin et al., The Lancet Digital Health, 2021] [Tanzania: Breuninger et al., PLOS One, 2014]
CAD4TB is an accurate tool for community-based TB screening for prevalence surveys in Kenya. CAD4TB 6 met the optimal WHO TPP (Target Product Profile).	[Kenya: Mungai et al., medRxiv, 2021]
CAD4TB is on par with human expert readers.	[Vietnam: A. Codlin et al., Nature Scientific Report, 2021] , [South Africa: Fehr et al., npj digital medicine, 2021] , [G. Tavaziva et al., Clinical Infectious Diseases, 2021] , [Pakistan: Murphy et al., Nature Scientific Reports, 2020] , [Philippines: Philipsen et al., IJTLD, 2019] , [London: Melendez et al., IJTLD, 2018] , [Zambia: Melendez et al., IJTLD, 2017] , [South Africa: Hogeweg et al., IEEE Trans Med Imaging, 2015] , [Tanzania: Steiner et al., Public Health Action, 2015] ,
CAD4TB met the WHO's TPP at 90% sensitivity.	[Qin et al., The Lancet Digital Health, 2021]
In a community-based multi-disease screening survey in an HIV-endemic rural area, CAD4TB achieved comparable sensitivity and specificity to the radiologist. CAD4TB has the potential to replace radiologists for triaging CXRs in prevalence surveys.	[South Africa: Fehr et al., npj digital medicine, 2021]
In Tanzania, CAD4TB performance was significantly better than a clinical officer's.	[Tanzania: Breuninger et al., PLOS One, 2014]

Efficiency

Delft Light portable digital X-ray and CAD4TB in parallel with the WHO 4-symptom screen achieved a lower pre-diagnostic loss of presumptive TB cases. Additionally, the W4SS + portable X-ray with CAD screen-based intervention was more efficient for TB case yield: four times the number of TB cases yield than symptom-only-based screening intervention.	[Nigeria: Babayi et al., Public Health Action, 2023]
Ultra-portable X-rays with CAD were overall well received to decentralise radiological assessment for TB.	[Qin et al., PLOS ONE, 2023]
The per-screen costs for the two CAD software programs with a perpetual licensing costing structure are considerably lower than the cost with radiologists for high throughput in ACF scenarios.	[S. Bashir. Et al., PLOS ONE, 2022]

<p>TB screening using Delft Light Backpack X-ray and CAD4TB during community-based ACF in hard-to-reach Niger Delta communities of Nigeria showed a high TB prevalence among participants. Nationwide deployment of the instrument in hard-to-reach areas is recommended.</p>	<p>[Nigeria: B. Odume. et al., Public Health Action, 2022]</p>
<p>CAD4TB v7 had a significantly higher AUC than v6, 0.903 (95% CI: 0.897–0.908) compared to 0.823 (0.816–0.830).</p> <p>CAD4TB 7 results in a steep initial increase of Xpert test saved. Until a threshold of 75, greater numbers of Xpert tests can be saved using CAD4TB v7.</p>	<p>[Z. Qin et al., PLOS Digital Health, 2022]</p>
<p>A combination of chest X-ray analysis by CAD4TB and symptomatology is of immense value in screening a large population at risk in a developing, high-burden country. It is significantly a more effective tool for screening and early diagnosis of TB in individuals who would otherwise go undiagnosed.</p>	<p>[Pakistan: Nishtar et al., Pak J Med Sci, 2022]</p>
<p>Using CAD4TB can save molecular tests such as Xpert tests.</p>	<p>[Qin et al., The Lancet Digital Health, 2021], [Pakistan: Habib et al., Scientific Reports, 2020], [Pakistan: Zaidi et al., Nature Scientific Reports, 2018], [Bangladesh: T. Rahman et al., European Respiratory Journal, 2017]</p>
<p>All five AI algorithms (incl. CAD4TB) significantly outperformed the radiologists and reduced the number of Xpert tests required by 50% while maintaining a sensitivity above 90%.</p>	<p>[Qin et al., The Lancet Digital Health, 2021]</p>
<p>Triage using AI-based CXR interpretation can be cost-effective and even cost-saving relative to standard practice among persons with suspected TB in Pakistan. These results are likely applicable to other low-income, high-TB-burden settings.</p>	<p>[Nsengiyumva et al. Open Forum Infectious Diseases, 2021]</p>
<p>Community-based screening with innovative activities, comprising sensitive screening and diagnostic tools, including a digital X-ray and CAD4TB, effectively improves TB case detection.</p>	<p>[Pakistan; A. Wali et al., Public Health Action, 2021]</p>
<p>CAD4TB, as a triage tool to pre-screen people with diabetes for Xpert testing, can improve case-detection while potentially reducing program costs with more rational use of expensive molecular tests.</p>	<p>[Pakistan; Habib et al., Nature Scientific Reports, 2020]</p>
<p>In Pakistan, the cost per screened subject using CAD4TB v6 is almost half in comparison to screening without, while almost 2.5 times higher daily throughput.</p>	<p>[Pakistan; Murphy et al., Nature Scientific Reports, 2020]</p>
<p>Used as a pre-screening system in TB-endemic regions, CAD4TB allows for the testing of much larger numbers of subjects at a fraction of the cost.</p>	<p>[Pakistan; Murphy et al., Nature Scientific Reports, 2020]</p>
<p>In the Philippines, CAD4TB as a second reader showed a 22% increase in TB detection and could help detect additional TB-positive cases that were initially missed at limited additional costs.</p>	<p>[Philippines: Philipsen et al., IJTL, 2019]</p>
<p>In Pakistan, CAD4TB, as a triage tool, could minimise the use of expensive molecular tests in low-resource settings.</p>	<p>[Pakistan; Zaidi et al., Nature Scientific Reports, 2018]</p>
<p>Reduces cost per identified TB case and the cost per screened subject by almost half.</p>	<p>[Philipsen et al., Nature Scientific Reports, 2015]</p>
<p>Useful where trained human readers are scarce.</p>	<p>[Muyoyeta et al., PLOS One, 2014]</p>

Paediatric TB

<p>The performance of CAD4TB v7 to identify TB in children (<13 years) significantly improved after fine-tuning it with a set of well-characterised paediatric chest x-rays. CAD has the potential to be a useful additional diagnostic tool for paediatric tuberculosis.</p>	<p>[South Africa: Palmer et al., PLOS Glob Public Health, 2023]</p>
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Key and Vulnerable Populations

TB / HIV

<p>In a community-based multi-disease screening survey in an HIV-endemic rural area, CAD4TB achieved comparable sensitivity and specificity to the radiologist. HIV serostatus did not impact CAD4TB's performance.</p>	<p>[South Africa: Fehr et al., npj digital medicine, 2021]</p>
<p>Digital CXR using CAD4TB with universal HIV screening significantly increased timelines and completeness of HIV and TB diagnosis.</p>	<p>[Malawi: MacPherson et al., PLOS MEDICINE, 2021]</p>
<p>Combined use of mobile X-ray and CAD4TB to identify TB among high-risk groups to improve early TB diagnosis can deliver a major contribution to TB control in Romania.</p>	<p>[Romania: B. Mahler et al., BMJ Open, 2021]</p>
<p>In an HIV-negative population, CAD4TB v6 met WHO-recommended minimal accuracy for pulmonary tuberculosis triage tests.</p>	<p>[F.A. Khan et al., The Lancet Digital Health, 2020]</p>

Diabetes

<p>CAD4TB offers good diagnostic accuracy as triage for TB screening among diabetes patients.</p>	<p>[Pakistan: Habib et al., Nature Scientific Reports, 2020]</p>
<p>CAD4TB with X-ray systems allowed not only rapid and systematic triage to Xpert testing but also found quantitatively more TB-like abnormalities in those with Diabetes Mellitus.</p>	<p>[Bangladesh: K. K. Paul et al., Science Direct, 2020]</p>
<p>In Indonesia, CAD4TB has the potential as a triage tool for TB screening in people living with diabetes, thereby significantly reducing the need for microbiological examination.</p>	<p>[Indonesia: R.C. Koesoemadinata et al., IJTLD, 2018]</p>

Screening in Prison

<p>Screening by mobile X-ray systems with automated interpretation could reduce the number of confirmatory tests required and enable screening to be more rapid in high-burden TB settings while still maintaining sufficient sensitivity.</p>	<p>[Brazil: Soares et al., The Lancet Regional Health – Americas, 2023]</p>
<p>The inclusion of digital CXR in systematic TB screening detected additional TB cases among inmates that would otherwise have been missed, and using CAD4TB may also improve the performance of the screening algorithm.</p>	<p>[South Africa: Kim et al., IJTLD, 2020]</p>
<p>High uptake of new screening tools, such as digital X-rays with CAD4TB, may be particularly feasible, reliable, and highly acceptable in prison settings.</p>	<p>[Pakistan: Wali et al., BMC Public Health, 2019]</p>
<p>CAD4TB reliably evaluates CXRs from a mostly asymptomatic prison population, with a performance comparable to local readers in Tanzania.</p>	<p>[Tanzania: Steiner et al., Public Health Action, 2015]</p>

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