# USAID Support to End Tuberculosis

## CAD-AI to improve TB case detection in Vietnam

# Background

- Project:  USAID Support to End TB in Vietnam, implemented by FHI 360 from August 2020-July 2025

- # of UP-XRs and CAD devices used in Vietnam
  - UP-XRs:  10 UP-XR machines, donated through iNTP (with technical assistance from USAID IDDS project)
  - CAD devices procured by USAID Support to End TB:
    - Qure.ai's qXR software and hardware
    - A total of 9 qBoxes deployed in 2022: 5 qBoxes in 5 District health facilities; 4 qboxes in NTP/GF mobile CXR vans for community campaigns.

# Program planning

- Stakeholder engagement:  NTP approval to pilot the technology
- Customs clearance approval:
  - 1st procurement:
    - qBoxes were already available in Vietnam at time of purchase
    - 2nd procurement required importation of four new qBoxes, which was handled by Qure.ai
- Customs clearance was handled by Qure.ai:  qBoxes are considered routine CPU/IT computer equipment.

# Program planning:  Site and population selection

- **7 provinces under USAID Support to End TB** selected for TB burden (~ 20% of Vietnam's notified TB cases) and representation of 3 regions of the country
- **Community campaigns**:  household contacts and other populations known to be at high risk for TB (smokers, diabetics, elderly, underlying lung disease, PLHIV)
- **Health facilities**:
  - Facility selection:  5 facilities selected among 35 with digital Xray in 7 provinces
    - Selected districts had highest number of CXR/month and high commitment from facilities' leadership and healthcare workers
  - Patient selection:
    - Respiratory outpatients; diabetic outpatients; inpatients with lung disease/symptoms
    - For CAD implementation:  expanded to all patients with CXR (with and without respiratory symptoms or diseases)

# Program planning:  deployment and training

- On site deployment
  - Coordinated with Qure.ai team for remote, online technical support
  - Key personnel from NTP and FHI 360 were onsite for deployment in mobile CXR vans to connect radiology PACS system and qBoxes

- Training overview:
  - **TB screening** ("Double X" algorithm) standard operating procedure integrated CAD into workflow
  - **On-site training** to transfer DICOM files from radiology PACS system to qBox
  - **qXR TB user guide**:  written by Qure.ai and translated into Vietnamese
  - **Troubleshooting guide**:  "frequently asked questions" document developed by FHI 360, identifying issues that have arisen throughout implementation

# Program planning - vendor selection and product costs

- CAD vendor options were limited to Asia region to comply with USAID requirements for procurement.
  - Products were not limited to GDF procurement as the purchase was through the USAID funded project and not by the NTP/GF.

- The procurement included
  - One-time deployment
  - License activation and license fee for CXR interpretation, with license validity for 6 months (and recently extended to 8 months for remaining 50,000 CXR)

*Only one system was procured to date by USAID Support to End TB, and no additional items were procured locally.*

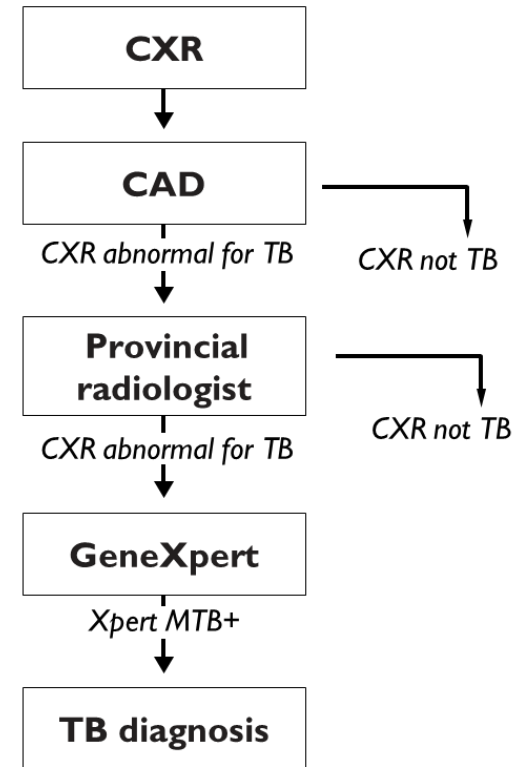# Programmatic implementation with CAD devices

- Stage 1: retrospective qBox analysis of CXR from TB community ACF campaigns conducted in 2020

- Stage 2: Real-time qBox analysis of CXR (2021-2022)
  - ACF:  campaign implementation started in 2021 and continued in 2022
  - ICF in health facilities:  qBoxes deployed in 5 health facilities in 2022

*For both community and facility implementation, on-site radiologists have access to information about symptoms and history.*
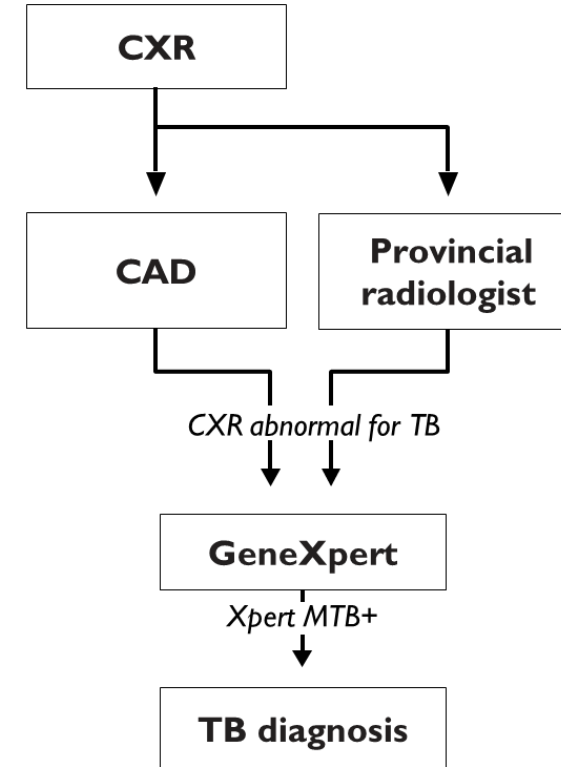
# Screening algorithm

- Threshold scores and models:
  - 0.40: AI first, followed by a human reader
  - 0.60: AI and human readers in parallel
- Confirmatory diagnostic tests: Xpert
  - <10% of CXR triaged for Xpert testing by symptoms
  - Sputum produced on site and either analyzed onsite (if Xpert available) or transported by motorbike to facility with Xpert
- QC/QA for CAD: comparison with central/national level radiologists and bacteriologic confirmation



**CAD first model**

CXR
→
CAD — *CXR abnormal for TB* → | *CXR not TB*
↓
Provincial radiologist — *CXR abnormal for TB* → | *CXR not TB*
↓
GeneXpert
*Xpert MTB+*
↓
TB diagnosis

**CAD parallel model**

CXR
→ CAD | Provincial radiologist
*CXR abnormal for TB*
↓
GeneXpert
*Xpert MTB+*
↓
TB diagnosis

Two primary objectives for AI/DL interpretation of CXR for TB
- Maximize TB detection
- Minimize unnecessary GeneXpert testing
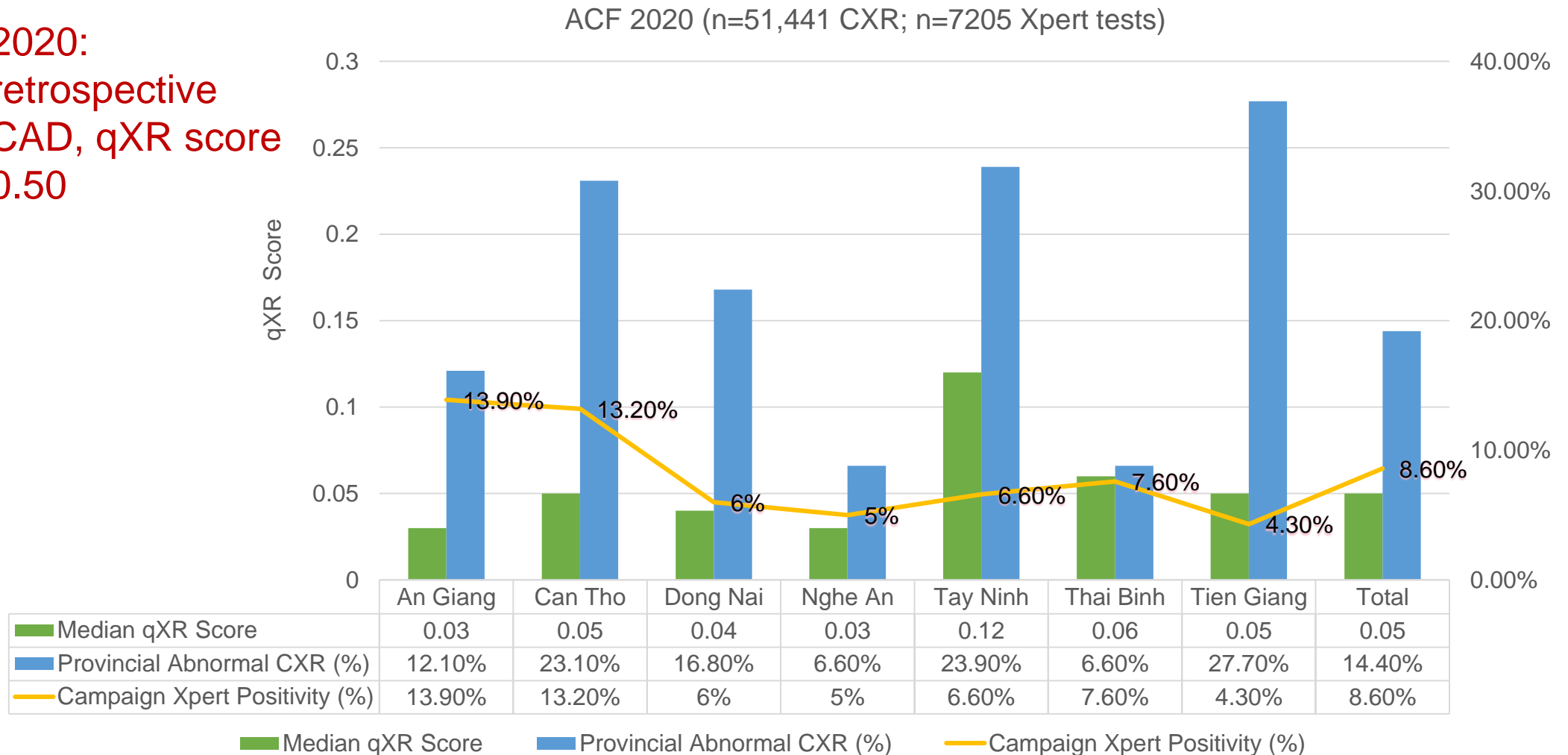
# Threshold score selection

- Threshold scores and selection
  - Initial CAD retrospective analysis score = 0.50, pre-set from manufacturer
  - Threshold score for real-time analysis:
    - 2021: planned for two scores (0.40 CAD first and 0.60 CAD parallel)
    - 2022: utilized one score (0.40, CAD first)
  - Main variables for selecting the threshold score
    - Xpert capacity, Xpert cartridge availability
    - Target Xpert positivity rate
- Threshold score performance
  - False negatives on CAD are difficult to ascertain as we are not Xpert testing below the radiology threshold (CAD or human)
  - False positives on CAD:  currently using radiologists to "re-read" abnormal CXR, to improve specificity of CAD interpretation.
- *What future plans are there for the localization of the threshold?*  Pending discussions with NTP.

# Using CAD-AI software to optimize CXR interpretation for triaging Xpert testing in 7 provinces of Vietnam

- Objective: to develop CAD-AI analysis programmatic framework that will facilitate
  - **<u>Selecting AI threshold score and model</u>**:  pragmatic and adaptable for different provinces and settings (communities, facilities, UP CXR)
  - **<u>Interpreting AI results post-implementation</u>** for optimal TB case detection yield and to improve quality of CXR interpretation by human physicians
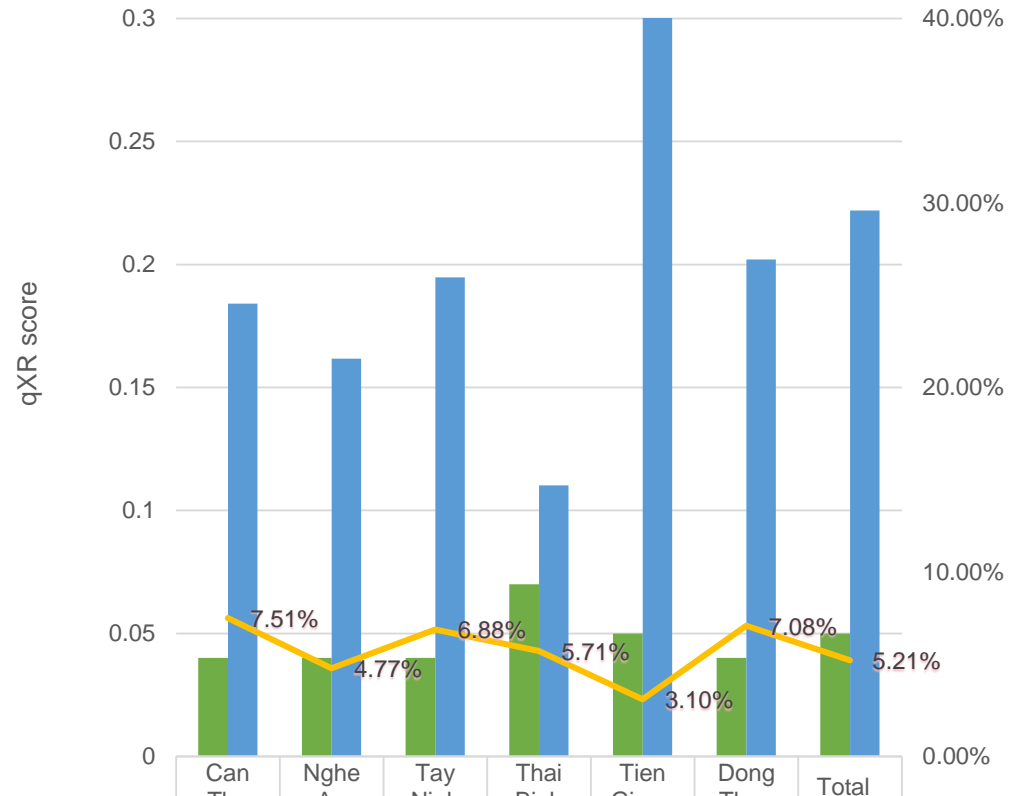
# The background CXR abnormality as measured by median/IQR qXR score and % CXR abnormality by humans: some provinces are "mis-matched" on CXR abnormality and Xpert positivity.

2020:
retrospective
CAD, qXR score
0.50

### ACF 2020 (n=51,441 CXR; n=7205 Xpert tests)



| | An Giang | Can Tho | Dong Nai | Nghe An | Tay Ninh | Thai Binh | Tien Giang | Total |
|---|---|---|---|---|---|---|---|---|
| Median qXR Score | 0.03 | 0.05 | 0.04 | 0.03 | 0.12 | 0.06 | 0.05 | 0.05 |
| Provincial Abnormal CXR (%) | 12.10% | 23.10% | 16.80% | 6.60% | 23.90% | 6.60% | 27.70% | 14.40% |
| Campaign Xpert Positivity (%) | 13.90% | 13.20% | 6% | 5% | 6.60% | 7.60% | 4.30% | 8.60% |

■ Median qXR Score   ■ Provincial Abnormal CXR (%)   — Campaign Xpert Positivity (%)

2021: real-time CAD/AI with multiple models (CAD 1st and parallel) and scores

2022: real-time CAD/AI with one model (CAD 1st) and score (0.40)

ACF 2021 (n=17,090 CXR, n=3740 Xpert tests)

| | Can Tho | Nghe An | Tay Ninh | Thai Binh | Tien Giang | Dong Thap | Total |
|---|---|---|---|---|---|---|---|
| Median qXR score | 0.04 | 0.04 | 0.04 | 0.07 | 0.05 | 0.04 | 0.05 |
| Provincial Abnormal CXR (%) | 18.41% | 16.17% | 19.48% | 11.02% | 39.03% | 20.20% | 22.19% |
| Campaign Xpert Positivity (%) | 7.51% | 4.77% | 6.88% | 5.71% | 3.10% | 7.08% | 5.21% |

ACF 2022 (n=28,112 CXR, n=4302 Xpert tests)
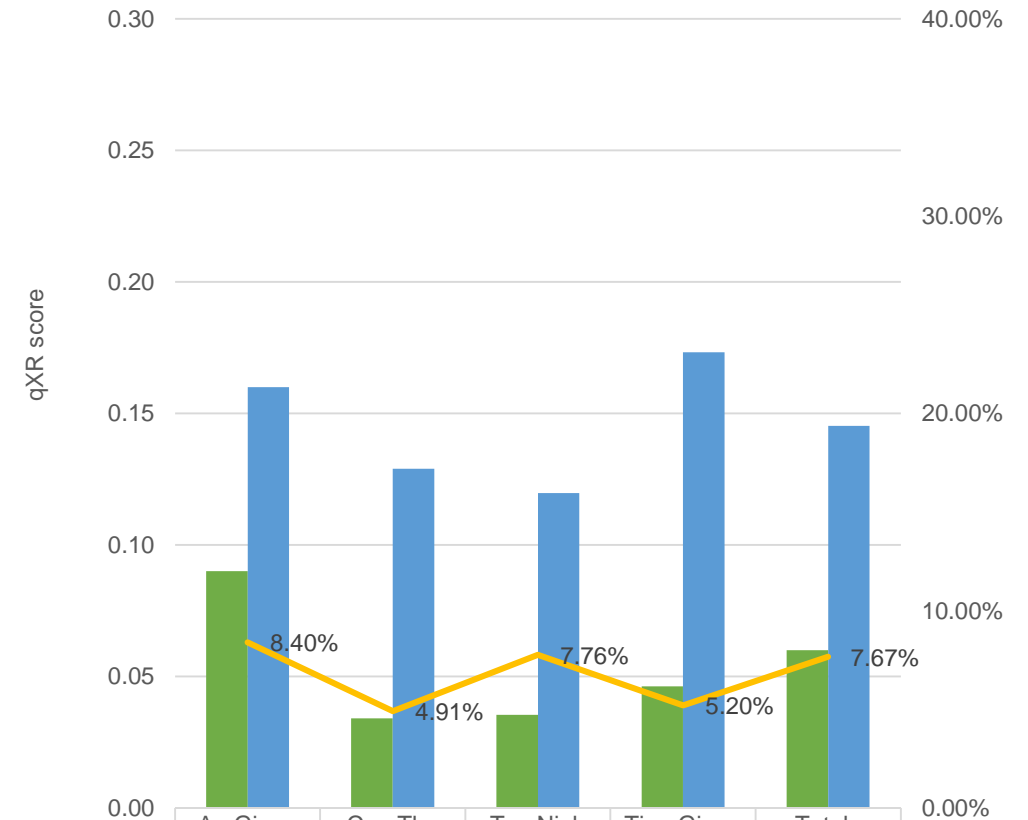
| | An Giang | Can Tho | Tay Ninh | Tien Giang | Total |
|---|---|---|---|---|---|
| Median qXR Score | 0.09 | 0.03 | 0.04 | 0.05 | 0.06 |
| Provincial Abnormal CXR (%) | 16.00% | 12.90% | 11.98% | 17.33% | 14.52% |
| Campaign Xpert Positivity (%) | 8.40% | 4.91% | 7.76% | 5.20% | 7.67% |

# Observations from 3 years of ACF implementation with CAD-AI

- *How does CAD-AI optimize Xpert positivity? By improving precision around a "target" PPV?*
  - Variance in Xpert positivity rate appears higher in campaign without CAD (2020) and with variable CAD application (2021), and lower with one CAD model and score (2022)
- Several demographic/clinical characteristics likely affect Xpert positivity yield, independent of AI score triaging Xpert testing:
  - e.g., % old TB, % smoker, % male, % cough or with any symptom
- Without Xpert testing below the CXR threshold (CAD or human), it is only possible to *estimate* sensitivity and Xpert positivity rate
  - *Sample below CAD threshold at start of implementation?*
  - *Target CXR abnormality rate rather than Xpert positivity rate?*

# Operational set-up

- **Location**:
  - Community screening:  mobile CXR vans either at commune health posts or district health centers
  - Health facilities:  qBox on radiology computer
- **Radiation protection methods** used/ required
  - Radiation protection: CXR machine is enclosed in a separate partition within the mobile van
  - Radiologist and radiology tech stand/sit behind the protective partition, separated from CXR machine.
- **Set-up**:
  - Connecting the qBox with the laptop via secure router
  - After CXR is completed, DICOM file automatically transferred to qBox. Within 1-2 minutes, CAD results are read on qXR portal.

# Equipment for setting up qBox with PACS system

- qBox hardware

- External monitor connected to qbox via HDMI/Thunderbolt

- Keyboard and mouse connected via USB 3.0 port

- Secure router:
  - Connect qBox & PACS system with static IP;
  - Connect to internet for online technical support for deployment and troubleshooting

- LJ45 Lan Wires: To transfer DICOMs to qBox from client system which has PACS software

# Equipment set-up and system in use


Equipment set-up


Systems in use
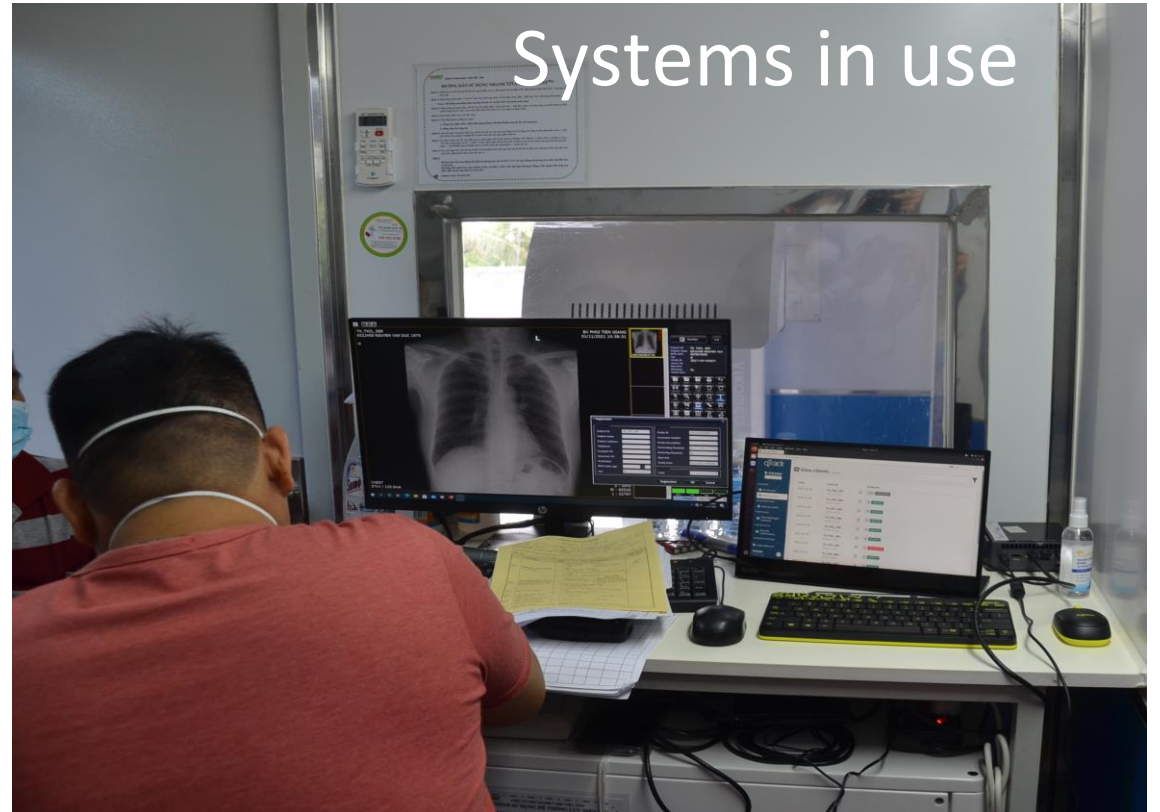
# Interoperability with health information systems

Routine TB surveillance in Vietnam is managed through NTP's VITIMES system:  DS-TB, DR-TB, and LTBI

- **CAD and ACF** data are entered into an online platform (ACIS) which is bidirectionally linked with VITIMES
- **Health facility ICF/CAD**:  CXR results are manually entered into HIS in each facility, which are then extracted by VITIMES

# Data storage and privacy

- **CAD data storage and back-up**:
  - Data are downloaded onto a password protected external hard drive and then uploaded onto a secure password-protected server

- **Data privacy measures**
  - qBoxes are offline
  - Mobile CXR vans: all CXR are deidentified
  - Facility CXR: image sent to CAD software is de-identified
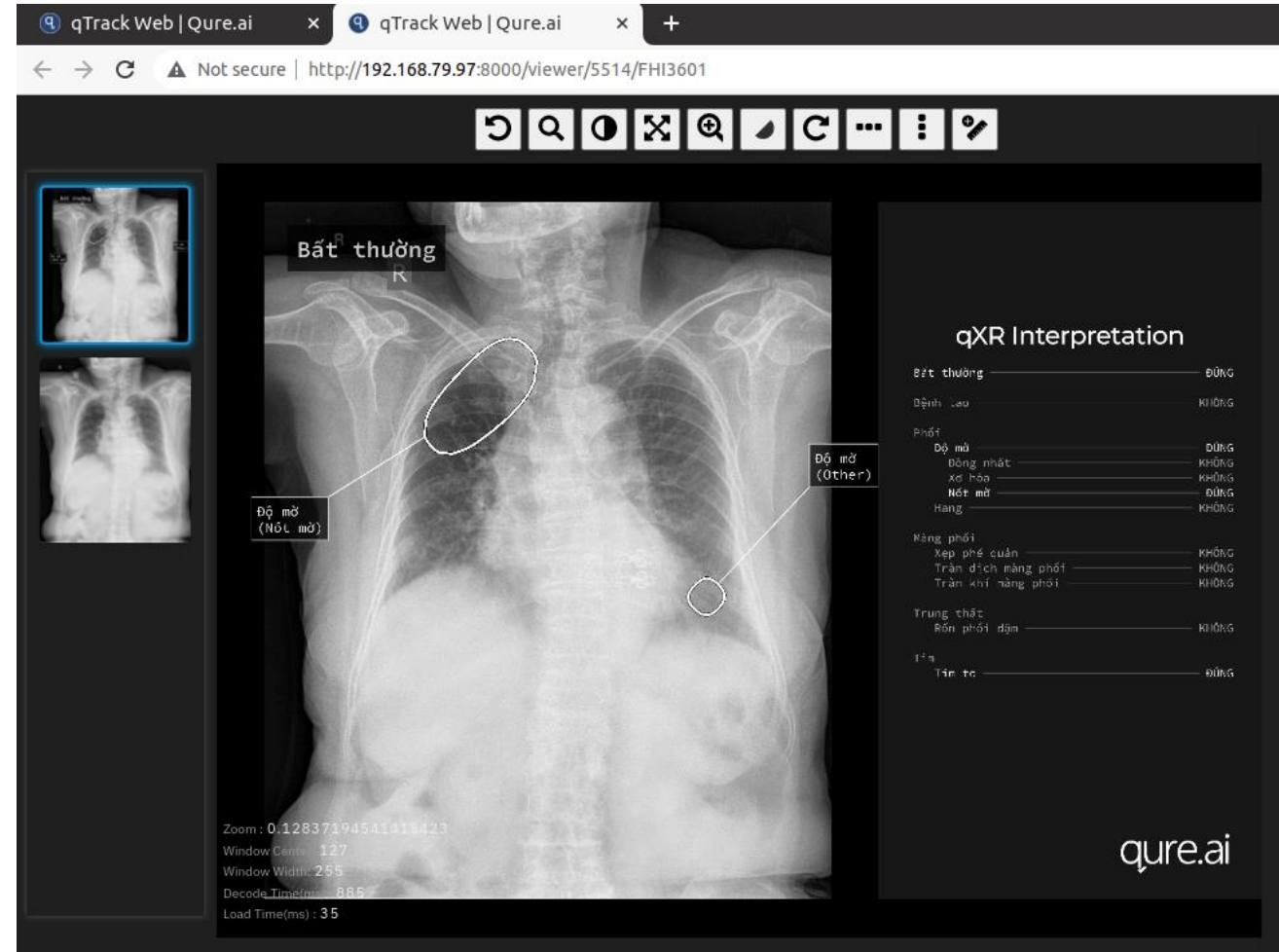
# Scaling up: NTP Vietnam plans to expand CAD nationally

- Scale-up will include:
  - *Both community and facility CAD implementation and expansion to additional provinces*
  - *Ultra-Portal CAD AI for targeted ACF campaigns*
- Preparation
  - *Develop national guideline and SOP: for both community and facility implementation*
  - *Selection of CAD software, CAD model, and threshold score:*
    - Balance between sensitivity and specificity may be more critical with national scale-up (will need cost effectiveness analyses)
    - Score selection: will continue to refine methods for analysis framework; piloting Iterative Threshold Score Calibration

# Challenges

- <u>Total processing time is slow</u>: 1.5-2 minutes is very slow for busy community campaigns. Radiologists in health facilities have not complained about this (yet).
- <u>qXR connectivity starts very slowly </u>in the beginning of the day in mobile CXR van.
  - Despite connections confirmed (ping, qXR login), the first image of the day may take 15-25 minutes.
- <u>Intermittent lost connectivity</u> from PACS system to qBox: requires radiologists to reset the system, which delays processing
- <u>Different time zone </u>with CAD provider: this is critical for on-line, real-time support

# What would you do differently next time?

- Prepare for technical needs during set-up and ongoing troubleshooting; tech team from manufacturer must be available for real-time support
- Consider cloud CAD as opposed to offline qBox
  - qBox and PACS system currently both connect using the cables to the same router
  - With CAD cloud, we may face new type of delay due to internet connectivity, especially when the van door is closed