CHEST X-RAY SCREENING

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STOP TB FIELD GUIDE

Stop TB Partnership

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StopTB Field guide 8: Chest X-Ray Screening

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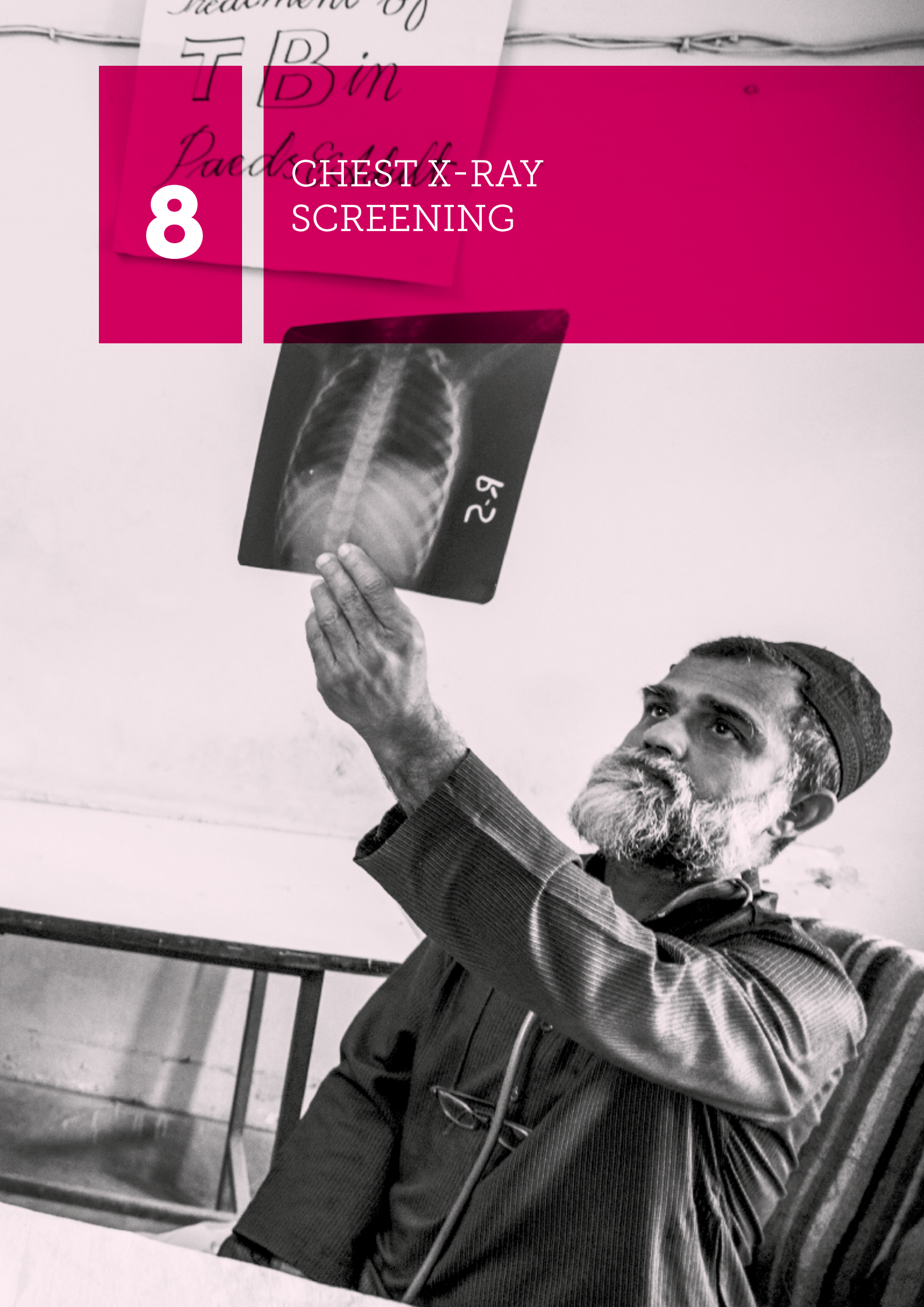

PURPOSE OF THIS DOCUMENT

This document is one in a series of 11 field guides produced by Stop TB Partnership in collaboration with the Global Fund to Fight AIDS, Tuberculosis and Malaria, Interactive Research and Development Global (IRD), KIT Royal Tropical Institute, and multiple global experts and implementation partners. These field guides rely on the practical experience and expertise of implementers and are meant to help national TB programmes and other TB programme managers to identify the best strategies for finding people with TB who are missed by routine health services.

This document is not to be treated as guidance, but rather as a collection of considerations, tools, experiences and examples that highlight the successes and challenges in implementing effective TB case-finding interventions. It aims to support TB programme implementers in planning and making informed decisions around implementing chest X-ray services within the framework of interventions aimed at finding missing people with TB.

This field guide has gone through extensive peer review by the agencies and individuals acknowledged below. It presents a range of examples from peer-reviewed literature and implementation practice. Where not cited, examples are provided by TB REACH.

Acknowledgements

The production of these field guides represents a significant effort, bringing together more than 60 experts from over 30 different institutions globally in the spirit of partnership to help address a major barrier in the TB response: the fact that millions of people with TB are still missed by the current routine health systems.

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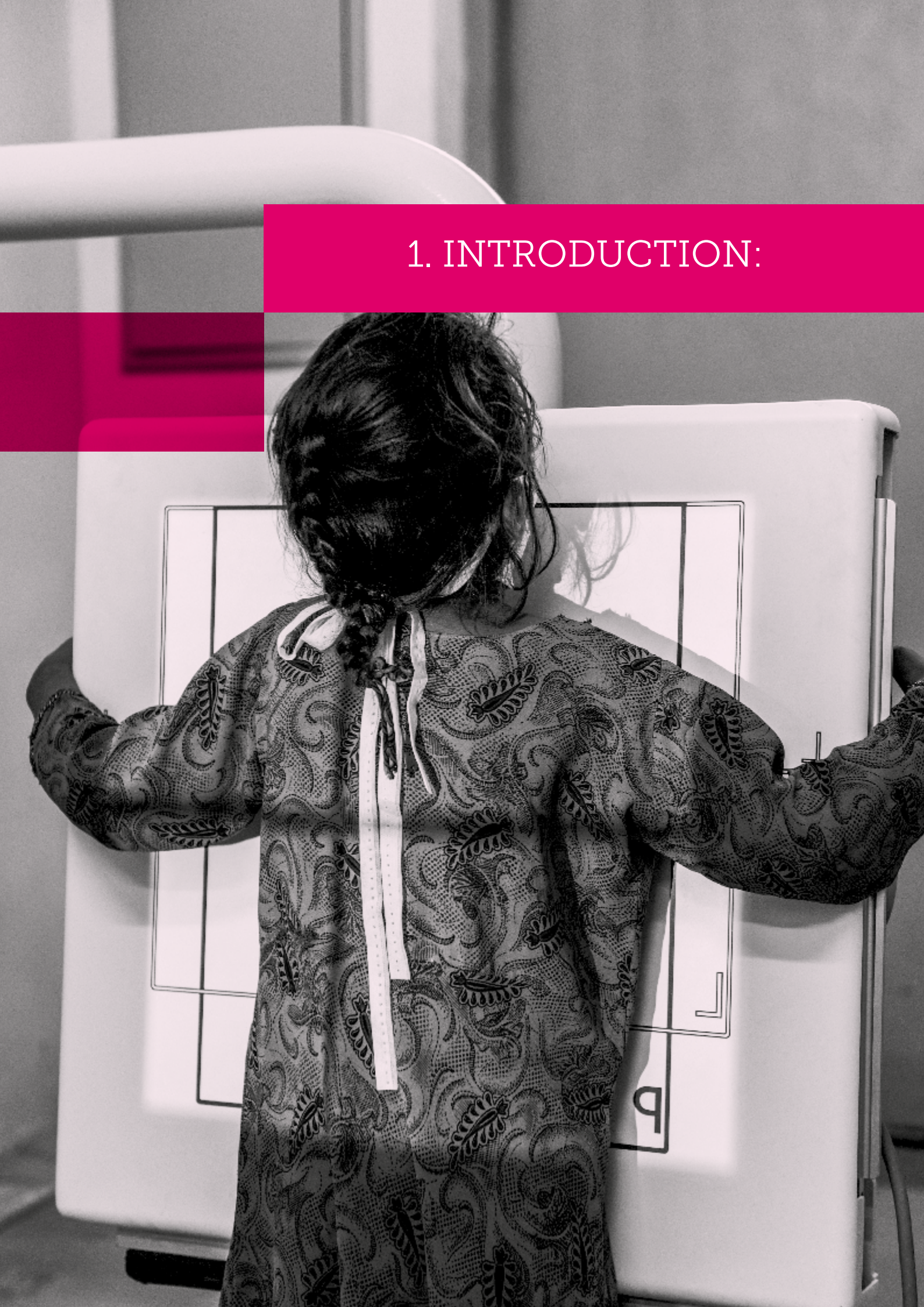
Abbreviations

AIDS	Acquired immunodeficiency syndrome
AFB	Acid-fast bacilli
CXR	Chest X-ray
DOTS	Directly observed treatment, short-course
HIV	Human immunodeficiency virus
IGRA	Interferon-gamma release assay
LED	Light-emitting diode
LMIC	Low- and middle-income country
MDR-TB	Multidrug-resistant tuberculosis (defined as resistance to rifampicin and isoniazid)
NTP	National TB programme
SOP	Standard operating procedure
SMS	Short message service (text message)
TB	Tuberculosis
TBI	Tuberculosis infection
TST	Tuberculin skin test
WHO	World Health Organization
ZN	Ziehl-Neelsen
Xpert	Xpert MTB/RIF assay (a cartridge-based nucleic acid amplification test [NAAT] used for rapid tuberculosis diagnosis)

1. INTRODUCTION:



In the 1940s and 50s, mobile mass radiography was a commonplace strategy for tuberculosis (TB) screening in wealthy countries (1). Millions of people in the United States and Europe were screened for TB using only chest X-ray (CXR) (1,2). These radiological surveys were so vast that some even covered more than 90% of a country's population (3,4). Research at that time showed that a strategy of CXR screening, isolation of people with infectious TB and provision of TB treatment could significantly reduce a community's TB burden (5,6).

However, the reliance on CXR for diagnosis resulted in both over- and under-treatment of TB. Furthermore, research from high-burden settings began to show that the majority of people with TB were aware of their symptoms and many had already sought care for their condition (7,8). Together, these findings ushered in an era of TB control that focused on health systems strengthening. The World Health Organization (WHO) issued a series of Expert Committee reports culminating in the 1974 recommendation to abandon indiscriminate CXR screening in favour of improving passive, facility-based TB services and laboratory testing, primarily smear microscopy (9,10). Among the reasons cited were the small proportion of patients found overall during mass campaigns, the large time gaps between mass campaigns where incident TB diagnoses were missed, the lack of trained personnel and poor access to vehicle maintenance services. In subsequent decades, the directly observed treatment (DOT) strategy was developed and implemented through strengthened national TB programmes, resulting in large increases in the number of people detected and treated for TB in low- and middle-income countries (LMICs).

For the past decade, there has been a persistent gap between the number of people estimated to have TB and the number detected, treated and reported by governments (11). The global TB community is now looking to close this gap by using new strategies to improve TB detection. In comparison to verbal screening, CXR is more sensitive and more accurate and efficient in identifying people in need of follow-on diagnostic testing. Renewed interest in this old screening tool is also linked to improvements in X-ray and computer-aided detection technologies, the high proportion of culture-positive patients who are asymptomatic (as indicated by prevalence surveys), the high costs of rapid molecular diagnostics and strategic targeting of year-round mass campaigns. Evolution of the economies in most high-burden countries also means that access to trained staff and vehicle repair services are no longer the insurmountable barriers they may have been in the 60s and 70s. All of these factors have resulted in the ability of CXR to improve TB detection and prioritize diagnostic resources. Technological advances and the use of digital radiography now mean that CXR screening is more efficient, faster and safer for patients and implementers in a variety of settings. This field guide discusses the use of CXR to improve TB detection, shares lessons from recent implementation activities and outlines methods for measuring impact.

2. WHY USE CHEST X-RAY SCREENING?

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CXR is a versatile tool for TB programmes that are seeking to improve TB detection. There is no standardized algorithm determining the use of CXR in every setting and in every case finding approach. Instead, CXR screening may support and boost other services by finding more people in need of diagnostic testing, prioritizing the allocation of limited diagnostic resources and helping to diagnose TB in those with negative laboratory results.

2.1 Chest X-rays to aid clinical diagnosis

Clinically diagnosing TB disease

Despite WHO's earlier recommendations against the use of mass mobile radiography screening, CXR has continued to play a role in TB diagnosis for individuals with bacteriologically-negative test results (12). In order to minimize the chances of over-diagnosis, CXR has often been placed at the end of diagnostic algorithms, after symptom screening and diagnostic testing. In many settings, patients are prescribed broad-spectrum antibiotics and in some cases even a repeat CXR before clinical diagnoses are confirmed. However, this diagnostic work-up involves multiple health system interactions and substantial costs for patients, resulting in missed opportunities for diagnosis as well as patient drop-out.

The sensitivity of acid-fast bacilli (AFB) smear microscopy is low (generating many false-negative results), and clinical diagnosis should be an essential part of TB programmes for vulnerable groups, such as children, people living with HIV, people with extra-pulmonary TB and even a significant proportion of people with pulmonary TB.

In a few regions, particularly in Western Africa and Latin America, the majority of people treated for TB have a bacteriologically-positive diagnosis (mostly smear-positive) (11). Table 1 shows high- and medium-burden countries that have very high proportions of bacteriologically-positive TB notifications among their incident TB notifications. Expanding the use of CXR could bridge the gap by increasing clinical diagnosis and finding the people who are missed by smear microscopy. Since people with smear-negative TB have already submitted samples for laboratory testing, they have likely presented at a health facility because they are unwell. Over-reliance on low sensitivity and often delayed laboratory tests might be preventing those individuals from being notified and receiving prompt treatment.

Table 1. Countries with the highest proportion of new bacteriologically-confirmed TB notifications

(among those treating more than 7,500 people for TB in 2016 and excluding high-income countries)

Country	Estimated incident TB burden	New & relapse TB notifications	New bac-confirmed TB notifications
Sierra Leone	22,000	14,114 (64.2%)	10,731 (76.0%)
Niger	19,000	9,921 (52.2%)	7,225 (72.8%)
Senegal	22,000	12,878 (58.2%)	9,169 (71.2%)
Haiti	20,000	15,302 (76.5%)	10,378 (67.8%)
Bolivia	12,000	7,681 (64.0%)	5,169 (67.3%)
Nigeria	407,000	97,279 (23.9%)	65,154 (67.0%)
Madagascar	59,000	29,001 (49.2%)	18,696 (64.5%)
Mexico	28,000	22,193 (79.3%)	14,145 (63.7%)
Colombia	16,000	12,581 (78.6%)	7,973 (63.4%)
DR Congo	254,000	130,596 (51.4%)	82,387 (63.1%)

In the private health care sector, particularly in Asia, a large proportion of TB diagnoses are made using CXR (13). Private clinicians are often reluctant to prescribe AFB smear microscopy due to its poor sensitivity (many false-negatives); meanwhile, people in the private sector lack access to rapid molecular assays due to the costs involved. Embracing CXR is often an essential step in ensuring the success of private sector engagement initiatives. A more detailed discussion on the role CXR can play in private sector programmes can be found in the field guide on private sector engagement in this series.

Managing TB infection

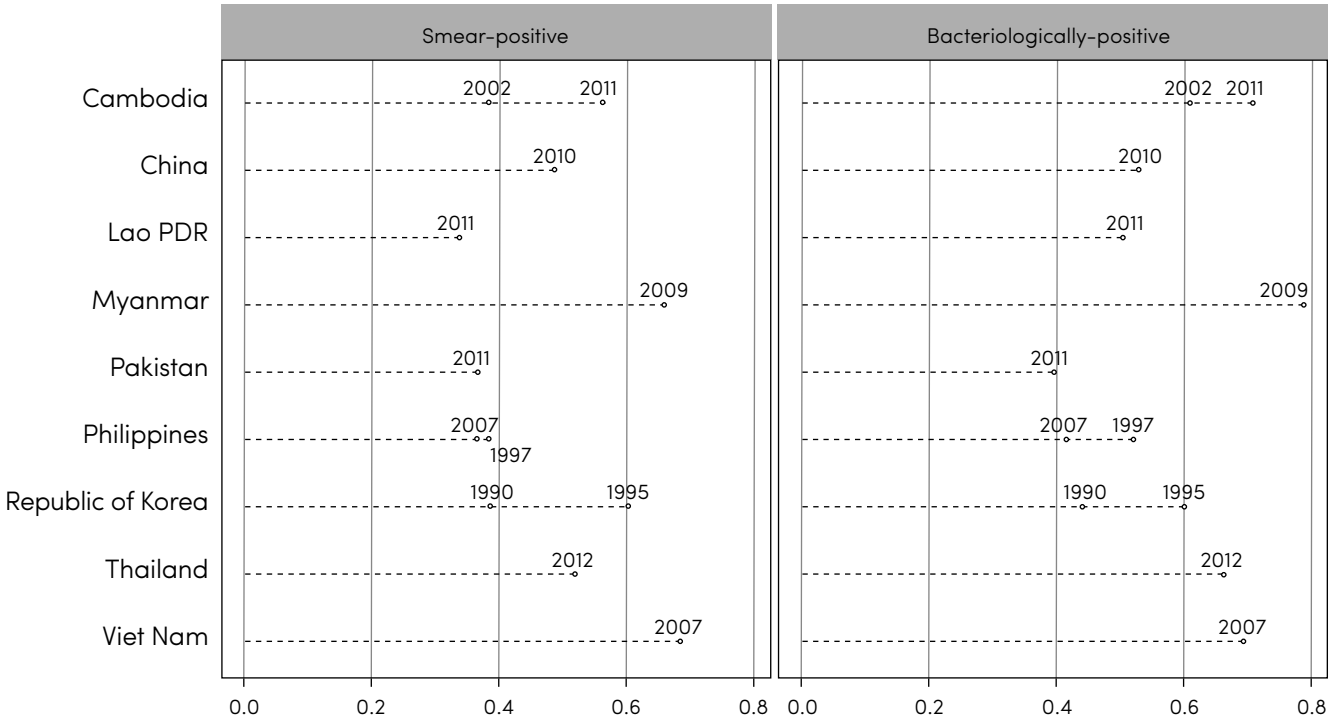
CXR has played a continuous role in contact investigations and identifying which people should receive preventive therapy for TB infection (TBI). People who have been exposed to TB bacteria are usually tested for TBI using a tuberculin skin test (TST) or interferon-gamma release assay (IGRA). However, because these tests are unable to distinguish between TBI (non-infectious) and active TB disease (infectious), a follow-on CXR is often performed to rule out active TB before preventive therapy is prescribed. This use for CXR is set to increase, following the release of new WHO TBI screening and treatment guidelines for LMICs, which greatly expand the number of people who are eligible for preventive therapy (14). This methodology is also particularly important for increasing preventive therapy uptake among children.

2.2 Identification of people with suspected TB

CXR is still the most sensitive tool available for identifying people in need of follow-on diagnostic TB testing. Since TB prevalence surveys are meant to accurately measure a country's TB burden, they use the most sensitive screening algorithm possible: any individual with one or more TB symptoms (i.e. cough, fever, weight loss or night sweats) and/or an abnormal CXR is indicated for TB testing on culture and increasingly with molecular assays (15).

The results from nine TB prevalence surveys in Asia showed that 40–79% of adults with culture-positive, pulmonary TB did not report having a cough or haemoptysis, but were detected only because CXR screening identified radiographic abnormalities (16) (Fig. 1). These findings have stark implications for TB prevention and care efforts in the End TB Strategy era: Considering that people with infectious TB might not have TB symptoms or might not self-report their symptoms, verbal screening strategies alone may not be sufficient in many settings.

Figure 1. **Proportion of people with TB without symptoms but with a positive CXR across nine prevalence surveys in Asia**



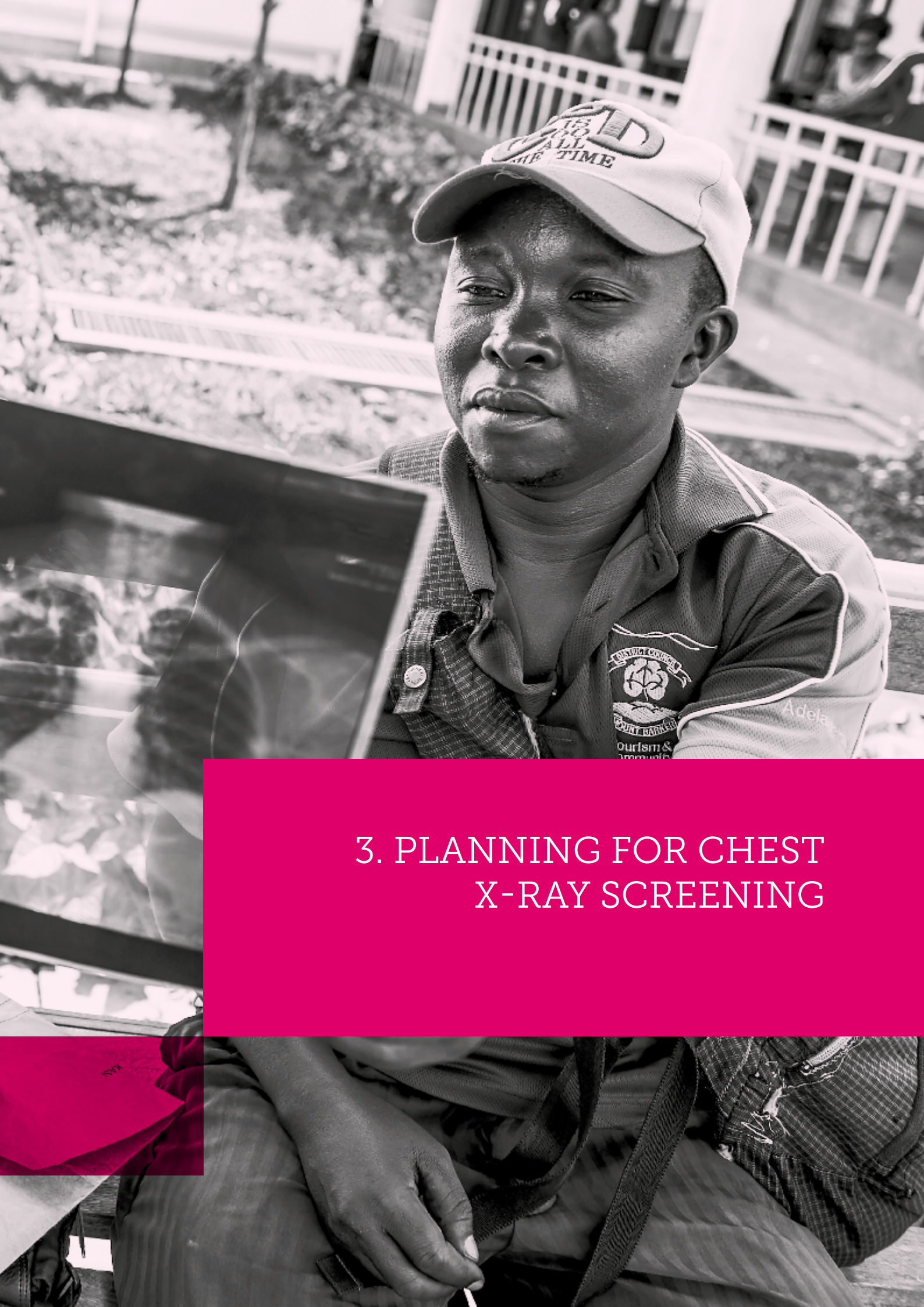
If symptom screening only includes cough of any duration or prolonged cough, in many settings, the majority of people with infectious TB will not be tested or detected. Although this screening strategy will likely identify individuals with the most severe and infectious TB, the large numbers of missed individuals with less severe TB can still contribute substantially to TB transmission in the community. It is likely that TB will self-resolve and infectiousness will dissipate in some people who do not report TB symptoms; however, a recent study from South Africa demonstrated that any CXR abnormality was predictive of poor outcomes (continued disease or death) among a cohort of people with confirmed drug-resistant TB who did not start treatment and who had little to no symptoms (17). No longer regarded as an expensive and logistically complex case-finding approach, CXR is being increasingly used to identify people with TB in the absence of other highly sensitive screening tools.

2.3 Triaging follow-on diagnostic testing

The key challenge in symptom screening for TB is that cough, fever, unexplained weight loss, and night sweats are not specific to TB and can be associated with many other conditions. Consequently, the vast majority of TB diagnostic tests performed following a positive symptom screen produce negative results. One benefit of screening symptomatic individuals using CXR is that it can divide people into groups with a higher or lower probability of having TB, so that programme implementers can prioritize the use of follow-on diagnostic tests that are more sensitive but more expensive than AFB smear. If an individual has one or more TB symptoms (e.g. fever and unexplained weight loss) but a truly clear/normal CXR, the likelihood that this individual will have TB disease is low. In many settings, such individuals can be screened out of follow-on diagnostic testing with minimal reductions in overall TB detection (18).

A note on costs: Diagnostic testing was not a pressing financial issue in the era of AFB smear microscopy, as the test is inexpensive and has minimal infrastructure requirements. However, with expensive molecular assays beginning to replace smear microscopy as the first diagnostic test for people with TB symptoms, there has been a substantial increase in the cost of diagnostic testing for TB. The current generation of molecular assays are 5 to 10 times more expensive than smear tests and require equally expensive machines, robust maintenance programs and climate-controlled work stations (see the field guide on laboratories to read more about laboratory systems). Ideally, everyone with TB symptoms would be tested using a molecular assay. However, the costs associated with this algorithm may limit the number of people reached in resource-limited settings.

While procurement of a radiography system might seem unrealistic due to its relatively high upfront costs, the cost savings from triaging follow-on molecular tests will compensate for the system procurement well within the radiography system's functional lifespan. Eventually, this diagnostic approach will represent outright cost savings, which programmes can use to increase the reach and coverage of their screening and testing services to improve TB detection rates.



3. PLANNING FOR CHEST X-RAY SCREENING

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This field guide highlights recent CXR screening implementation experiences. It is important to note that these examples do not represent prescriptive guidelines, nor do they cover every scenario in which CXR might be used by TB programmes. When planning CXR screening interventions, implementers will need to assess the population that will be receiving services, the structure and capacity of the current health system, and the overall purpose of the CXR screening. Based on this assessment and the anticipated impact of employing CXR, decisions can be made about the procurement and utilization of this tool.

3.1 Radiography systems and procurement

Types of radiography systems

There are currently three broad categories of radiography systems available for procurement:

- Analogue systems that require film processing;
- Indirect digital systems that use computer radiology (CR) cassettes and readers to replace film processing; and
- Direct digital systems.

Each type of system is then available in a:

- Fixed/stationary set-up that can be installed in a health facility or a mobile truck; or
- A portable unit that can travel and be set up temporarily in screening locations.

Each system has its strengths and weaknesses. These should be carefully considered in the context of how the system will be used before planning any procurement.

Selecting and procuring a radiography system

There are several factors to consider when selecting a radiography system. Table 2 is adapted from WHO's Chest radiography in tuberculosis detection (19) and Tuberculosis prevalence surveys: a handbook (15). When resources are available and consistently high workloads are expected, a direct digital system is ideal.

Table 2.	Considerations for the selection of a radiography system

Setting	Stationary radiography systems are ideal for health facilities. For mobile CXR, programmes could choose to procure a stationary radiography system installed in a truck or container, or a portable unit depending on the accessibility of field sites, the country's radiation regulations, the climate (temperature) and required hourly throughput capacity. For mobile X-ray systems, it is important to opt for proven shock resistance designs, components and/or provisions to ensure safe transport.
Cost	The market for radiography systems in many high TB burden countries is well developed, with multiple manufacturers and models being sold at various price points. It is important to consider procurement and service costs over the entire lifespan of the radiography system. Digital systems have higher initial investment costs, but, since no films or chemicals have to be procured, they offer significant savings on consumables and human resources from day one of operation.
Maintenance	Radiography systems have components (e.g. X-ray tubes) that can break easily, rendering the system unusable. If a manufacturer does not have presence in a country or has a limited service footprint, or its service and maintenance is contracted to a non-specialized third party, there may be delays with the provision and installation of replacement parts and long periods when the radiography system is not functional. Maintenance can significantly increase the operating costs of CXR screening, but it may be possible to bundle maintenance into upfront procurement costs. Manufacturers and recipients can also mutually agree on turnaround times for service and maintenance in procurement contracts.
Importation	Programmes should carefully review a country's existing procurement legislation and regulations before deciding on a radiography system. If a manufacturer or specific model is not registered in the country, the system may get stuck in customs or require a hefty tax that could add significantly to overall costs. Production and delivery lead times should be considered if a large number of units are to be procured at one time.
Throughput capacity	If a consistently high workload is anticipated and adequate funds are available, a direct digital radiography system is the ideal choice, as processing times are the shortest and variable costs are the lowest. Analogue radiography systems are economical to procure, but may be a more cumbersome alternative, with some compromise on quality and higher recurring costs. Indirect digital systems, which provide digital images at lower efficiency than direct digital systems, have mid-range throughput and the cassettes may have to be renewed after a certain number of images.
Personnel	It is important to consider whether skilled personnel will be available in the setting to conduct CXR examinations, read the results and maintain the equipment. Direct digital systems are more user-friendly and require less manpower, while indirect digital and analogue systems are more labour-intensive and time-consuming. The number and type of personnel required will also depend on country regulations.
Field conditions	Direct digital systems are heavy and require good transportation facilities if they are to be installed as mobile units. In addition, the more powerful the radiography system, the greater are its power requirements. Such systems need more powerful and larger (heavier) generators that must be transported along with the radiography system if it is mobile. Direct digital systems that can operate for 8 hours or more on car batteries in combination with a small generator, and an overnight charging station while parked are options to consider. If it is stationary, considerations must be made for a continuous power source and earthing at the health facility; otherwise, an expensive machine will stand idle or be damaged. Implementers in some settings have utilized solar-powered generators and machines for clinics.
Duration of use	Although a radiography system may be procured for TB case-finding activities, programmes should consider its general use over a longer time period (minimum of 5 years; average system lifespan exceeds 10 years). This is particularly true if funds are only available for TB case-finding for a short period of time. Therefore, radiography systems that are multifunctional may provide a wider diagnostic imaging impact for the health system beyond TB.
Radation exposure	Latest generation digital X-ray systems require very small doses of radiation, so radiation exposure should not be a primary concern when selecting a system. Direct digital systems are associated with less radiation exposure than indirect digital or analogue systems.

Renting a system: Programmes may choose to rent an X-ray system for mobile screening instead of procuring one outright. In many high-burden urban settings, X-ray trucks operated by private companies are available to rent. These trucks come with all the staff necessary to operate the truck, including a radiologist. This option may be ideal for short-term campaigns or for evaluating the protocols or effectiveness of mobile CXR screening in a setting before committing significant funds to the approach. Rental options also eliminate the need to maintain a radiography system and truck. However, over the long term, rental options will prove to be more expensive than outright procurement and will require the TB programme to think carefully through quality assurance measures and methods for data collection, sharing and storage.

Stationary vs. mobile radiography systems

The decision to procure and use a stationary or mobile radiography system will be context-specific. Historically, programmes have favoured the procurement of stationary radiography systems for installation in health facilities. This choice was largely driven by the fact that radiography systems can be used by the health facility to provide many different services. However, many radiography systems at health facilities remain underutilized. Access to stationary systems is limited by their location in the community or within a large health facility, and by the operating hours of the health facility. For example, many X-ray services at government health facilities are only open on weekday mornings. Radiography systems installed on trucks offer many advantages that should be carefully considered. X-ray trucks can be parked at a health facility during clinic hours in order to meet the needs of facility-based TB screening services. The truck can even be moved around the hospital so that patient flow/management is more efficient in cases where systematic TB screening is conducted by different services and clinics, thereby reducing loss to follow-up. An X-ray truck can also visit multiple health facilities with no stationary radiography systems on a known schedule. This approach enables people to access X-ray services where they initially seek care, rather than being referred from one health facility to another. In addition, once clinic hours at a health facility are over, the X-ray truck can be taken into the community to provide additional screening services. Although an X-ray truck is more complex to manage, operate and maintain than a stationary radiography system, it provides TB programmes with an immense amount of flexibility to meet the ever-changing needs of the programme, as well as TB screening and detection targets.

Programmes may consider buying prefabricated X-ray trucks or X-ray containers, especially when only a few trucks are being procured. If the plan is to procure a fleet of several X-ray trucks, there may be significant cost savings by bringing fabrication and customization in-house should the programme have the requisite expertise and capacity.

Procurement of additional items

To operationalize a radiography system, it is necessary to procure additional items, such as lead aprons and barriers, abdominal shields for pregnant women, radiation meters, and internet connectivity solutions for cloud-hosted reading. For mobile screening initiatives, programmes should consider purchasing tents or dividers so that there can be some modicum of privacy for the people being screened. In most high TB burden countries, it is not easy to share digital CXR images because clinics and/or doctors do not have easy access to computers or tablets. Programmes may then need to buy film and a film printer so that X-ray images from selected people (particularly those who feel sick, but are not diagnosed with TB) can be printed and distributed back to patients and doctors. However, as 4G/internet connectivity and smartphone/tablets become more commonplace, the sharing of X-ray images will become far easier and cheaper.

Following local radiation regulations

In most settings, the use of X-rays is regulated by a government body. It is essential for TB programmes to understand local radiation regulations and to engage radiation regulatory bodies at the time of mobile X-ray truck procurement/assembly and before planning mobile events. Copies of the standard operating procedures (SOPs) and radiography system specifications may be requested in order to issue a permit or grant approval to host mobile X-ray screening events. Some regulatory bodies may even request that radiography systems undergo inspection to check for radiation leakage. If mobile X-ray screening events are organized without prior approval, programmes may be fined and/or might be denied a permit or approval for future screening events.

3.2 Personnel considerations

Screening with stationary radiography systems

Programmes are unlikely to need many additional personnel to increase CXR screening within facilities, given that X-ray technicians, doctors, nurses and health workers will most likely be already in place for routine facility-based screening and treatment services. Although a project coordinator/manager and possibly project officers may be needed to coordinate enhanced referral activities and data management, these roles could potentially be filled by interested individuals from among existing staff. Additional personnel will need to be recruited as programmes connect community-based screening with stationary radiography systems, but unlike with mobile CXR screening, the core personnel needed to perform and read CXR likely already exist. If workloads are to increase significantly, however, then implementers might need to consider incentives, shift rotations to ensure higher throughput and occupational safety, and other measures.

Mobile chest X-ray screening

The personnel requirements for mobile CXR screening will vary widely depending on the set-up of stations, operations and infrastructure. There are no clear-cut, standardized recommendations for staffing X-ray events. However, implementation experiences have yielded many practical observations that are worth sharing.

The total number of people required to operationalize a CXR screening event primarily depends on **how long** the truck will be operational and **how frequently** events will be conducted. X-ray screening events are demanding on personnel because of the high volumes and long shifts. Therefore, conducting frequent screening events using the same personnel is not advisable.

Preparatory work: Programmes should not underestimate the preparatory work needed in the days leading up to a screening event (especially on the morning of the screening event) or the travel time of personnel to the screening site. If preparatory work is not done in advance of people arriving, the time available for screening may be shorter than expected.

Number of staff: A typical CXR screening event will attempt to control patient flow by setting up several stations. The following basic stations should be considered:

- Intake (registration and screening)
- CXR screening
- Waiting area/sputum collection

Each station of a mobile X-ray screening event should be staffed by at least one person. Depending on the expected volumes, however, these numbers can increase.

- Intake – Registration and verbal screening takes the greatest amount of time. Since every person attending the event will pass through this station, it is advisable to have several people running this station.
- CXR screening – The management of CXR can be divided into two functions: operation and interpretation (15). At least two to three people should be in charge of operationalizing the X-ray station, including the set-up and break down of the radiography system, performance of CXR screening, ensuring the quality of captured X-ray images, troubleshooting the Picture Archive & Communication System (PACS), etc. One of the individuals at this station should work with the participants to explain the CXR procedures before they position themselves in front of the radiography system. This should speed up image capture. CXR images can be interpreted on the spot by a medical officer who has been instructed to over-read the images. Additional information on CXR interpretation can be found in Section 4.3 of this field guide.
- Real-time maintenance and support – A driver can be made responsible for maintaining the electricity generator, ensuring fuel supply and assisting the X-ray team. The drivers of mobile X-ray units may need to be involved in a range of activities related to maintenance and team support, among others, and so should be hired with care.
- Results – A special area needs to be set up for people to wait for their CXR results. This area could be maintained by the mobile X-ray team or by a collaborative team of community health workers or NGO/faith-based workers at the site.

Programmes should consider building a dedicated team to collect sputum samples from people who were unable to provide spot samples at the X-ray event and to ensure linkage to treatment for people who are diagnosed with TB. The need for such a team is greatest in cases where community-based screening is being conducted in an area that is not clearly associated with a TB treatment facility or located far from the nearest TB treatment site. These teams can be comprised of individuals from civil society organizations who have good access to community members even after the mobile CXR team has moved on to another location.

Managing radiation exposure and infection risks

Exposure to radiation is an occupational hazard for the personnel running and managing X-ray services. Staff should be issued a radiation badge to measure their personal exposure to radiation. These badges should be read regularly and, whenever radiation limits are reached, personnel should be given time off work or reassigned to roles with no radiation exposure. In a lead-shielded X-ray room with lead glass, occupational hazards from radiation will be negligible. However, X-ray techs should implement airborne infection control measures, such as ensuring air turnover, wearing a mask and installing an ultraviolet light, to avoid becoming infected with TB in poorly ventilated work spaces.


How to Wash
MOXEOUE
ACINET
LOOBID
TRIAXON

4. CONDUCTING CHEST X-RAY SCREENING

4. CONDUCTING CHEST X-RAY SCREENING

4.1 Chest X-ray screening with fixed radiography systems

Facility-based CXR screening can serve multiple purposes. However, given the limitations of fixed radiography systems with respect to access and throughput, facility-based screening is best positioned to aid in clinical diagnosis and for triaging follow-on diagnostic testing. Many high-volume TB and MDR-TB treatment facilities already house a dedicated radiography system. At these sites, there will be few operational challenges in increasing the number of people referred for X-ray.

Access challenges for X-ray referrals

The vast majority of TB treatment sites in high-burden settings must refer people to either another unit within the hospital or to an entirely different health facility for CXR. In rural settings, the nearest radiography system may be very far away. Even in certain urban settings, it may take 1–2 hours to travel between health facilities. Government-run X-ray services are often operational for only a few hours each day, which can lead to an additional day of health care seeking.

Cost to patients

In most high TB burden countries, people are charged for CXR screening. Even in countries with national health insurance schemes, people are often required to pay for CXR screening services; if CXR costs are reimbursable, they are rarely covered in full. For people who otherwise feel healthy, the perceived benefits of CXR screening may not outweigh the cost and access barriers, resulting in low uptake of screening services. TB programmes may be able to negotiate a reduced rate for CXR screening for TB by eliminating the need for detailed radiology reports (e.g. output of normal/clear or any abnormality) and film print-outs, thereby making cost less of a barrier.

Referral voucher schemes

Paper referral vouchers can be used to track CXR uptake and minimize loss to follow-up. Vouchers can be distributed to patients, and lists of people referred on the sending and receiving ends can be reconciled on a regular basis in order to follow up on referrals that did not materialize. Vouchers could also be used to encourage referrals to materialize, e.g. by offering a reduced-rate or free CXR if redeemed within a certain time period. Such voucher schemes can even incorporate both public and private providers in order to reduce access barriers. In India, the Resource Group for Education and Advocacy for Community Health (REACH) provided referral vouchers to all household contacts of index patients on treatment at government-run health facilities. These vouchers could be used at private radiology centres with dozens of branches across the city. Referral vouchers were collected at the radiology centre and the project paid the radiology centre on a monthly basis. Because the private radiology centres were more numerous (closer to home or work) and had more convenient hours, access barriers were virtually eliminated and participation among contacts was extremely high.

Throughput capacity constraints

Many hospitals have centralized radiography services that are used by all clinical services and departments. Establishing any form of systematic CXR screening for TB will result in more X-rays being performed. Given that many radiography services are likely operating at or near their capacity limits, it may be impossible to scale up TB screening services using the existing infrastructure. In such cases, systematic CXR screening for TB may require the procurement of additional radiography systems.

FACILITY-BASED CXR SCREENING TO IDENTIFY PEOPLE FOR DIAGNOSTIC TESTING IN CAMEROON

The Bamenda Regional Hospital receives patients from across Cameroon's Northwest region and has an imaging centre equipped with a Carestream Direct View Classic CR digital radiography system. In 2015–2016, adults presenting at the outpatient department of the hospital each morning were verbally screened for TB symptoms and sent for CXR screening at the imaging centre. Because X-ray screening was conducted using the hospital's radiography system, the imaging centre's existing workloads confined the capacity for TB screening to only 20–25 people per day. CXR images were read on the spot by a trained radiologist. The images were not printed on film and the project paid a reduced rate for capturing the CXR images. Anyone with one or more symptoms and/or an abnormal CXR was referred for free smear microscopy, Xpert MTB/RIF and culture testing. People diagnosed with TB were also tested for HIV in line with national guidelines and initiated on TB treatment at the hospital's TB clinic.

Between September 2015 and April 2016, 2,051 hospital outpatients were screened for TB symptoms and by CXR. Of those screened, 1,137 people (55.4%) reported one or more TB symptoms, including 867 people (42.3%) with current cough and 341 people (16.6%) with cough lasting over 2 weeks. In total, 1,255 people were eligible for diagnostic testing: 872 people (69.5% of those eligible) were able to provide sputum samples and completed the diagnostic work-up, resulting in the detection of 31 people with bacteriologically-confirmed TB (3.5% of those tested). Among those screened, the prevalence of bacteriologically-confirmed TB was 1,511 per 100,000 – 7.4 times higher than Cameroon's estimated TB incidence (11). CXR screening increased the number of people indicated for follow-on diagnostic testing by 10.4% above and beyond symptom screening and increased bacteriologically-positive TB detection by 14.8%. However, 45.1% of bacteriologically-confirmed TB was detected by culture only, while 88.2% of people with Xpert-positive results reported one or more TB symptoms.

Considerations: The existing workload of the hospital's radiography system severely limited the number of people who could be screened by CXR each day. Although this approach detected very high rates of TB, it would not be possible to scale up coverage to all outpatients without procuring additional radiography systems. CXR screening added only modestly to case detection because so many individuals screened positive on the TB symptoms questionnaire. The cost and complexity of implementing this screening approach must be judged against the gains of additional case detection. Finally, this approach and results definitively show the need for clinical diagnosis, even when molecular assay results are negative and even when Xpert tests are employed.

4.2 Mobile chest X-ray screening

Mobile CXR screening can serve multiple purposes, including the identification of additional people for diagnostic testing, triaging follow-on diagnostics tests and/or adding clinical diagnoses. However, this approach is best suited for finding additional people in need of diagnostic testing because mobile events allow for a large number of people to be screened. Furthermore, their roving nature means that access barriers for the target population are decreased or removed entirely. Community-based screening efforts have the potential to identify people very early in their disease course and to substantially increase TB detection rates. A more detailed discussion on community-based TB screening programmes and the role CXR can play can be found in the field guide on community screening in this series.

Selecting screening sites

The selection of screening sites is an important step to ensure the success of mobile CXR screening events. When choosing the location for a screening event, TB programmes should coordinate with the nearby health facilities, local governments and councils, and civil society organizations representing the population to be screened. Mobile CXR events can be held regularly at health or correctional facilities, sites of worship (e.g. pagodas, temples, churches, mosques, etc.), schools, sports fields, and even on neighbourhood streets. Programmes may choose to place mobile X-ray trucks in front of health facilities that already have functioning radiography systems. This strategy is acceptable if there is a throughput issue with the facility-based radiography system, which is resulting in loss to follow-up. In conjunction with mobile screening, programmes should also consider ways to improve throughput with existing radiography systems, such as allocating additional staff and expanding operating hours.

It is a good idea to scout the site of future screening events in order to make sure that there is sufficient space to accommodate the X-ray truck and all the associated screening stations, and that the X-ray truck can actually drive onto the screening site.

Quick site assessment: Are the roads leading up to the screening site capable of handling the weight of an X-ray truck? Are the roads sufficiently wide? Are there any overhead barriers or bridges under which the X-ray truck cannot fit? Can people in the community access the site on foot? Is there enough space to accommodate a crowd and manage a line?

Even though a location may be ideal for screening in terms of space and target population access, a different screening site will need to be selected if the X-ray truck cannot actually reach the site. If the route to the screening site is not mapped out in advance and the X-ray truck encounters challenges en route, the start of screening may be delayed or the entire screening event may need to be cancelled at the last minute. While these considerations may seem common sense, many TB programmes have reported such issues when launching their first-ever mobile X-ray screening event because they did not take these factors into account during the planning phase.

Mobilizing people and communities

Programmatic mobile CXR screening is not meant to measure disease prevalence and thus screening events do not need to follow a strict cluster and/or participant selection/invitation design. Outreach to and mobilization of higher risk populations is encouraged because this can reduce the number needed to screen (NNS) to find a person with TB and make the screening approach more cost-effective.

Mobile X-ray event dates should be decided well in advance and communicated to stakeholders. Civil society organizations can take advantage of their links with their respective communities to sensitize people with respect to TB and X-ray services in the weeks and days before screening events are hosted. This sensitization could be done via door-to-door community canvassing, but also by engaging key influencers (such as pastors, imams, teachers, tribal leaders, etc.) to speak about X-ray screening events at community gatherings. On the day of the screening event, community volunteers can mobilize people and actively assist those facing transportation issues in order to ensure high turnout. In settings with strong government systems, official invitation letters could be sent by local councils or health facilities or events could be discussed at community council meetings. TB sensitization and screening event dates could also be disseminated through local mass media – via radio and cable spots, posters, banners or billboards – or announced on speakers at markets. Branding the X-ray trucks and extending that branding in the mass media outreach is a way to make screening services instantly recognizable. Experience shows that community screening events held on weekends have the greatest turnout because more people are off work and have the time to attend.

HOW TO ENGAGE – REFERRALS AND ENTERTAINMENT:

During a TB REACH project in Pakistan, mobile X-ray event dates were communicated to a large network of private providers who, in turn, referred their patients for screening. Patient turnout was high because they were pre-screened and referred by their clinician. The private providers felt that being able to offer their patients access to a free CXR service in the vicinity strengthened the perception of their practice in the surrounding community. In another TB REACH project in Tanzania, movies were projected onto the side of the truck to create a fun community gathering and ensure turnout. While this particular truck did not house a mobile X-ray system, this method of community engagement is highly relevant.

Flow of people for TB screening

The movement of people through stations at mobile CXR screening events must be carefully thought out and modified in line with the realities of each screening site and the expected turnout. Certain stations at screening events take longer than others (rate limiting), and excessive wait times at specific stations can result in people walking away from screening events before completing the diagnostic work-up. As discussed earlier, it is useful to have at least three stations that people move through, ideally in a linear fashion: 1) registration and recording of presentation complaints or referral, 2) CXR screening and 3) waiting area/sputum collection. Additional stations can easily be added based on the needs of the programme and space available at the screening site.

Participant registration and verbal symptom screening activities are often the most time-consuming part of the screening event. It is very important to collect accurate address and contact details so that participants can be followed up if necessary. In addition, informed consent will be obtained at this station, if required. A large number of people will likely show up right as the screening event starts, creating a backlog of individuals who need to be registered and screened. Crowds and wait times need to be carefully managed and monitored to ensure that people do not walk away in frustration. Programmes should consider implementing a 'Take-A-Number' system so that participants have some idea of wait times and can choose to leave and come back at a later time. It is nice to have chairs and a shaded area where people can wait to be registered, particularly if the screening event is targeting a key population such as the elderly. It may be possible to set up a television or projector to show health videos, or to have someone at the event educating people about TB and other health issues as they wait. Multiple health workers should be simultaneously registering and screening so that wait times are kept as short as possible. However, people should be promoted on to the CXR screening station based on the throughput capacity of the radiography system and station set up. If everyone who shows up to the event is registered and screened for symptoms rapidly, but then the CXR station cannot cope with the volumes, the bottleneck simply shifts from one station to the next.

In Cambodia, the Cambodia Anti-TB Association (CATA) have run hundreds of mobile CXR screening events with support from the Stop TB Partnership's TB REACH initiative. They have procured over a dozen digital CR cassettes to ensure that the wait times for taking a CXR are not dependent on a digital cassette being scanned and cleared; after a CXR is captured, participants then move to a distinct waiting area where they wait for their CXR results before being directed on to a sputum collection station.

Screening for other diseases

One approach for ensuring the acceptability of X-ray screening services and to avoid stigma could be to brand the screening event a "fast-track" health check-up, rather than solely a TB screening, and to offer additional disease screening and testing services. HIV test and treat programmes are a natural partner for TB disease and infection screening services. In certain settings, offering screening for other co-morbid diseases (e.g. diabetes, chronic obstructive pulmonary disease or COPD) may be appropriate, while in other settings, malaria testing and general wellness check-ups may be better suited to the needs of the target population. The integration of services opens up opportunities for cost-sharing across disease programmes and reflects the Sustainable Development Goal aim of moving away from vertical, disease-specific programmes.

Data management

Keep the order: Programmes may find it useful to devise a unique identifier that is assigned to each participant during registration. This identifier will facilitate data collection and tracking at every station of the event. Using participant names to track data can be problematic due to spelling mistakes on forms and registers and due to the commonality of certain names. Without unique identifiers, it can be very time-consuming to match data across stations.

The linear movement of participants through each station at screening events is desirable. While event coordinators may be tempted to send people for a CXR before registration and symptom screening in order to reduce crowd sizes and wait times at the registration station, people may leave the screening event after receiving their CXR result without being registered or screened for symptoms. Keeping the participant flow simple and linear also helps event coordinators and health workers to manage participant flow through the stations of the event. Otherwise, it can be confusing and time-consuming for event personnel to accurately direct participants to where they need to go and the chances of mistakes increase.

Ensure backup: Some digital radiography systems have a hard drive to temporarily store the X-ray image files. However, this hard drive has a finite memory and, when the memory is full, it may begin deleting the oldest X-ray images in order to make room for newer ones. Therefore, regular backups are encouraged, especially in high throughput sites, to ensure that no digital X-ray images files are lost. An intact X-ray image archive is essential for quality assurance programmes. If there is internet connectivity, compacted (~1MB) digital CXR images and patient data can be sent to a remote central database or to a cloud hosting service.

Incentives for participants

Programmes could consider providing non-monetary incentives to encourage people to attend screening events and to complete the diagnostic work-up. In Cambodia, sachets of soap were given to everyone who visited all of the stations at mobile X-ray screening events. This could be an opportunity to approach the corporate social responsibility (CSR) programmes of large companies, such as Procter & Gamble and Unilever, for donation of their products. Although it is a small gesture, it is nice to compensate people for their time and reward good health care-seeking behaviour.

4.3 Chest X-ray image quality and interpretation

Chest X-ray image quality

For CXR screening to be effective, the quality of the X-ray images must be high and consistent. However, the high volumes and rapid throughputs common in CXR screening can easily result in poor-quality images being captured. Common issues during mobile CXR screening events include incorrect positioning of people on X-ray plates (e.g. so that the lungs are not fully captured) and participants not being sufficiently instructed to breathe in and hold their breath while the image is being captured. When the pace of screening increases, so do the chances of incorrect collimation and poor alignment between the X-ray beam, the person being screened and the X-ray detector. These issues and many more are discussed in the Tuberculosis Coalition for Technical Assistance's handbook on X-ray quality assurance (20).

Human reader interpretation

The interpretation of CXR images is subjective. Although some CXR abnormalities are indicative of TB (e.g. cavities), many of the lung abnormalities seen in people with TB are common in other lung diseases. CXR image interpretation can suffer from a high rates of inter- and intra-reader variability (21). This is particularly true for less experienced readers, who are often responsible for providing the initial reads in the field that are then used to decide whether a follow-on diagnostic test is indicated (22).

When CXRs are being used as a screening tool, rather than as a diagnostic aide, a practical way to classify images is either as **normal/clear** or as having *any* **abnormality**. More classification categories may lead to more frequent discrepancies between readers. In addition, a simple binary classification makes the management of follow-on testing very straightforward for health care workers. X-ray readers should 'intentionally overread' CXR images for screening purposes. This means that if the reader is not sure whether an image is normal/clear or abnormal – or whether the abnormality is related to TB – he/she should always classify it as abnormal. Over-reading ensures that no person with the possibility of having TB is screened out of follow-on diagnostic testing. X-ray images can be reread at a later date by more experienced radiologists using standardized CXR reading and recording systems (CRRS) to classify images into more detailed groups for analytical purposes (15). TB programmes may decide to reread the abnormal CXR images from people whose follow-on test results were negative and to provide a detailed radiology report in order to facilitate the care provided by other lung health services.

Getting initial readers to over-read X-ray images is often a challenge, however, as this is likely not their normal way of dealing with individual patients and writing radiology reports for clinicians. But, being overly strict in interpreting CXR images can result in people with TB being screened out of follow-on diagnostic testing. This not only reduces case detection, but also makes the screening approach less cost-effective. If TB programmes do not have enough Xpert MTB/RIF assays to test all people with any abnormality on their CXR, the programme may need to prioritize follow-on testing by choosing a stricter image classification, such as significant abnormality consistent with TB. In the DetecTB project in the Philippines, the project team opted for a stricter criterion for sputum testing (active or activity-undetermined TB lesion on CXR or cough for ≥2 weeks) after initial sample numbers overwhelmed testing capacity and produced low yields. Alternatively, the reader can be instructed to declare a maximum fixed percentage of daily reads as abnormal.

CXR abnormalities in children can be more subtle and do not always follow the patterns that are typical in adults (23). Please refer to the field guide on childhood TB in these series to learn more about the role radiography can play in childhood TB screening and diagnosis.

Computer-aided reading (CAR)

In many settings, the availability of trained radiologists or even readers is limited. This shortage, combined with the variability in image interpretation, led researchers to develop computer software that can analsze radiography images to identify abnormalities. Such software was developed for mammography screening programmes nearly 20 years ago and is now commonplace in screening programmes in high-income countries (24,25). Although computer-aided reading (CAR) is still a nascent field in TB, several software packages are now commercially available.

CAD4TB

Computer-Aided Detection for Tuberculosis (CAD4TB, distributed by Delft Imaging Systems in the Netherlands, and CE-certified by Dutch authorities) is the most rigorously evaluated and used CAR software currently available for TB (26). The software first processes CXR images to correct for exposure, contrast and other factors. The software then identifies anatomical structures, including the lungs, clavicles and ribs. Finally, the lungs are analysed for their shape, symmetry and texture (27). In less than one minute, the software produces a quality assessment of the image, a heat map highlighting possible abnormal areas and a score between 0 and 100 indicating the likelihood of the X-ray image being abnormal (28). Users must select a cut-off score, above which a CXR image will be declared abnormal and the subject indicated for follow-on diagnostic testing. The CAD4TB team provides a standardized verification procedure that can be used to choose the optimal cut-off score for each population and setting, taking into consideration the desired sensitivity and specificity and the prevalence of TB in the population being screened.

CAD4TB software can be used reliably with most digital radiography systems. Users usually send 10–20 CXR images to the CAD4TB team before procuring a bundle of reads in order to ensure compatibility with the radiography system. In addition, another set of images (up to 200) may be requested to further improve the accuracy of the software on that specific system. The cost of using the CAD4TB software varies depending on screening volumes. The newest version of CAD4TB software (v6 at the time of writing) requires images to be uploaded to a secure cloud. This means that screening sites must cost out wifi or mobile data plans. In areas where connectivity is an issue, programmes can procure a CAD4TB box that works offline.

The published literature has shown that older versions of the CAD4TB software perform as well as field readers for identifying abnormal CXRs, but not as well as expert readers (18,29–32). New software versions are regularly released with reported speed and sensitivity and specificity gains, but these versions have not yet been independently evaluated. A complete and up-to-date list of scientific publications on CAD4TB can be found at the Radboud University site: http://www.diagnijmegen.nl/index.php/CAD4TB.

Other CAR software

CAR software alternatives to CAD4TB are now emerging, including Qure.ai and SemanticMD. However, at the time of writing, these software programmes had not been independently evaluated and their programmatic costs were not known. More data on these and other products should be available in the coming months and years.

4.4 Diagnosing TB

Laboratory testing

It is ideal to use a highly sensitive and specific molecular assay (e.g. Xpert MTB/RIF [Ultra]) and/or culture as a follow-on diagnostic test during active case-finding in order to maximize the yield of true-positive results and limit the number of false-positive results (33). Mobile CXR events will likely collect a large number of sputum samples for diagnostic testing in a short amount of time. This can easily overwhelm laboratory technicians and exceed testing capacity, resulting in delayed results or samples not being tested. Strategies to strengthen laboratory diagnostic services are discussed in the field guide on laboratories in this series.

Because mobile CXR events will likely identify people early in their disease course, sputum production may be an issue for people indicated for diagnostic testing. It is important to consider the environment in which people are asked to produce a sample. In many settings, it is not considered proper for females to cough up sputum, let alone do so in public. Designating a sputum collection area that provides privacy could make it more acceptable for people to provide samples on the spot. Research has shown that simple verbal instructions on how to produce a sample can improve the number of samples being submitted, the quality of samples (fewer rejections by lab), and TB detection among women (34). In light of these findings, animated instructional aides in poster and video format have been made for dozens of

high TB burden settings. Programmes may also consider the use of nebulizers or mucolator sachets to induce sputum if people cannot produce a sample of sufficient quality and size after instruction. It may still not be possible to collect a sample from some participants at a mobile CXR event and so programmes should consider investing in a team and/or infrastructure to follow up with people to collect samples coughed up first thing in the morning. People often find it is easier to produce samples in the morning and these samples are likely to contain a higher amount of TB bacteria, which can improve testing positivity rates.

Clinical diagnoses

Clinical diagnoses should contribute to TB detection at mobile CXR screening events. The current Xpert MTB/RIF assay is only 67% sensitive in smear-negative samples (35). While there is hope that the new Xpert MTB/RIF Ultra assay will be better able to detect TB in these samples, early evaluations of its performance show that sensitivity ranges from 63% to 79%, depending on the population being tested (36,37). Furthermore, in active case-finding, many people with TB will be paucibacillary, making the performance of molecular assays lower than what has been reported from passive case-finding evaluations. Programmes must think carefully about how clinical diagnoses will be made with respect to when laboratory test results and final CXR classifications become available. Mobile events are temporary in nature, but there may be missed opportunities for clinical TB detection if diagnostic test results are available after a 1–2 day delay, while the human capacity to make clinical diagnoses has moved on to another screening site. The Centre for Infectious Disease Research in Zambia refers all CXR abnormal individuals with negative Xpert results to a health facility for clinical evaluation. Although not every person is able to make it to the clinic, this practice has led to a substantial increase in clinical TB diagnoses.

4.5 Treating people with TB

It is essential for programmes to map out where TB patients will be treated and notified. For facility-based CXR screening, this will likely not be an issue. For mobile CXR screening events, however, this can be a major challenge, particularly when implemented in rural areas. If people with TB are not systematically linked to treatment, the effort that went into community mobilization, screening and testing will be wasted. In areas with limited health infrastructure, programmes may need to consider training and/or hiring local health and/or community workers to monitor treatment, providing enablers to help patients travel to far away health facilities or implementing remote adherence monitoring technologies (38).

5. MONITORING & EVALUATION

5. MONITORING & EVALUATION

There are multiple ways to evaluate the progress and impact of CXR screening. This section describes in more detail a pragmatic approach for evaluating TB case-finding projects (39). This framework can easily be tailored to monitor the progress and impact of CXR screening initiatives.

5.1 Measuring progress of activities

The activities of TB projects should be measured by their outputs (e.g. number of X-ray systems procured, number radiologists attending trainings on CXR reading, etc.) and the movement of people through the TB care cascade from screening to treatment success. Regular monitoring of the TB care cascade is particularly important to ensure that CXR screening has a population-level impact, as this will enable programmes to identify and fix bottlenecks and thus to maximize case detection. If a project is working across multiple sites, the analysis of disaggregated data is highly encouraged.

Suggested indicators for triaging follow-on diagnostic testing

A. Number of people eligible for CXR screening
This may be all people belonging to a specific population (e.g. prisoners or household contacts) or people screened positive on a prior screening test (e.g. TB symptoms questionnaire).

B. Number of people examined by CXR
The proportion of people accepting X-ray services can be calculated as follows: B/A
If this proportion is low, the programme could begin offering transport enablers in order to ensure that referrals materialize, or it could host mobile X-ray events to ensure X-ray screening occurs.

C. Number of people with abnormal CXRs
The proportion of people with an abnormal CXR can be calculated as follows: C/B
In certain sites, this proportion may be unusually high or low, indicating that retraining of personnel may be needed or that the population of people being screened by CXR is truly different from other sites.

D. Number of people submitting sputum samples
The sputum submission rate can be calculated as follows: D/C
The ways to improve low sputum submission rates are discussed under the laboratory testing header in Section 3.3 of this field guide

E. Number of people tested
The proportion of samples tested among those submitted (E/D) should be as near to 100% as possible. If a laboratory is rejecting samples, there are either issues with the quality of the samples or the capacity of the laboratory for testing.

F. Number of people with bacteriologically-confirmed TB
The test positivity rate can be calculated as follows: F/E

G. Number of bacteriologically-confirmed TB patients started on treatment
Pre-treatment loss to follow-up can be calculated as follows: G/F

Suggested indicators for the identification of people with suspected TB

A1. Number of people verbally screened for TB symptoms

A2. Number of people screened by CXR

B. Number of people indicated for follow-on diagnostic testing
This indicator, and ideally all downstream indicators, should be disaggregated into the following cohorts/groups based on screening results:

- Symptom positive and CXR normal
- Symptom positive and CXR abnormal
- Symptom positive and no CXR performed
- Symptom negative and CXR abnormal – most important screening cohort/group for evaluating this strategy
- Symptom negative and CXR normal – usually screened out of follow-on testing

C. Number of people submitting sputum samples
Sputum submission rates may be low in specific screening cohorts/groups. For example, people who have fever alone and a normal CXR may naturally find it very hard to provide a sputum sample. In such instances, there may be little that can be done to increase collection rates.

D. Number of people tested

E. Number of people with bacteriologically-confirmed TB
Test positivity rates may be lower in specific screening cohorts/groups, especially depending on the diagnostic test used. For example, if someone with a normal CXR has TB, he/she will likely be paucibacilliary and have a high chance of being missed by smear microscopy and possibly even molecular assays.

F. Number of bacteriologically-confirmed TB patients started on treatment

5.2 Measuring Impact

Contribution of CXR screening in detection of TB

One way to show the impact of CXR screening is through the analysis of data related to the intervention. In most settings, TB programmes do not routinely test and treat people who do not have TB symptoms. When a CXR screening intervention detects TB in someone with no symptoms but an abnormal CXR, it can be stated with relative confidence that such patients are found earlier in their disease course and/or would not have been treated in the absence of the CXR screening efforts. If the purpose of CXR screening is to triage follow-on diagnostic tests, intervention data could be analysed to determine how many follow-on diagnostic tests were ruled out and how this translates into cost savings.

Impact on population-level TB treatment rates

The pragmatic evaluation framework described in this field guide can be used to evaluate the population-level impact of most facility-based CXR screening projects, whether focused on the detection of people with suspected TB or on triaging follow-on diagnostic tests, with little modification. However, the evaluation of mobile CXR screening events often requires this framework to be tailored to accommodate their roving design. It would be best to either implement mobile X-ray screening camps with consistent intensity across intervention areas for a defined period of time (e.g. a calendar year), or to organize many screening events in a small number of districts for one quarter, then moving on to another set of districts in the next quarter and so on. The latter approach will allow the mobile X-ray screening intervention to achieve a high level of coverage (saturation) in the populations receiving the ser-

vices. The concentration of case-finding activities is often key to showing impact in TB case notification data. When activities for each intervention district are concentrated into a single quarter, it is possible to standardize the active case-finding quarter across all districts into a single time point in order to provide a summary estimate of impact for the entire coverage area. In the summary measurement, the quarters before and after active case-finding will no longer correspond to calendar dates, but instead are relative to when case-finding activities were implemented in each district (40). Figures 2 and 3 illustrate this example.

Figure 2. Impact of mobile CXR screening on TB case notifications in four district

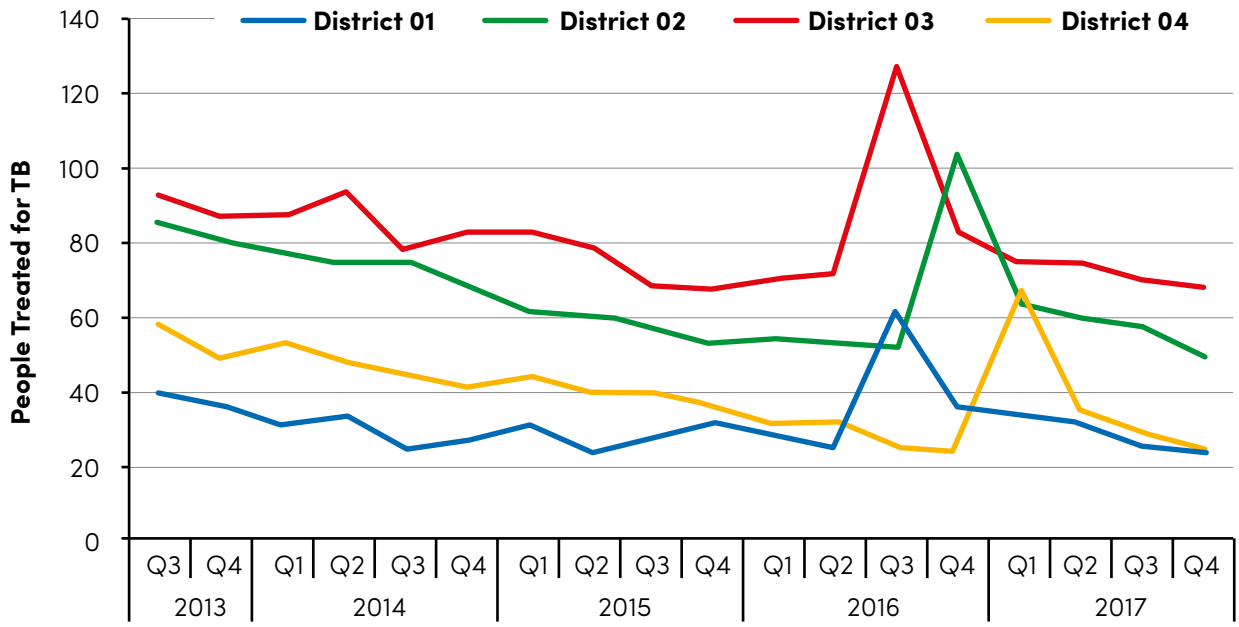
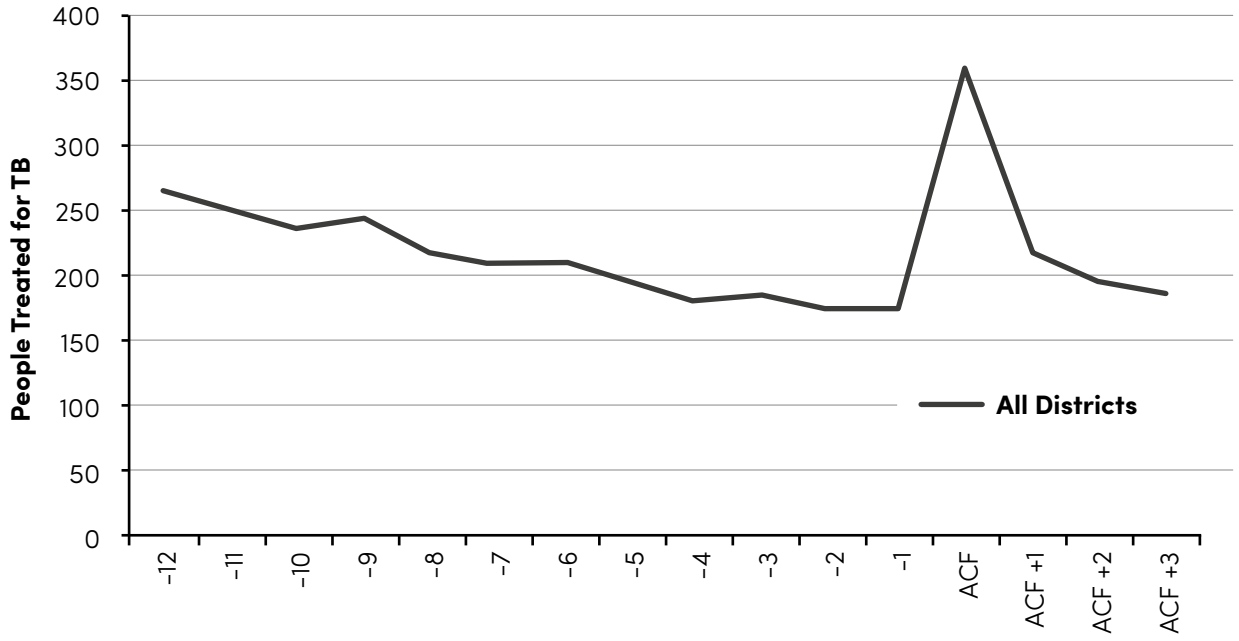


Figure 3. Summary impact of mobile CXR screening for four districts with active case-finding activities standardized into a single quarter



Health-seeking behaviour surveys

Standardized health-seeking behaviour surveys are available for TB patients (15). If mobile CXR events are held in the community, it is likely that people with TB will be found earlier in their disease course than those detected through passive case-finding. This difference can be shown by administering health-seeking behaviour surveys to a group of people with TB detected at the mobile X-ray screening events and then to a second group found passively in health facilities. A simple comparison of these groups in terms of the median numbers of health system interactions or duration of symptoms, when combined with analysis of project data (especially case detection in the asymptomatic screening cohort/group) and improvement in TB case notifications, could reveal the true impact of this screening approach.

Costing and cost-effectiveness

CXR screening has larger upfront costs than other screening approaches and thus is often deemed too costly for TB programmes. However, as the pressure to scale up molecular testing increases, the long-term cost savings of CXR screening become attractive. In addition to analysing routine project data, dedicated costing studies could be implemented to more accurately measure the savings from triaging follow-on diagnostic tests. These findings could be modelled at the national level and used to influence TB investment strategies with governments, international donors and the private sector. Mobile CXR screening, in particular, has high upfront and operational costs. However, it also has the potential to find many people who are missed by health services, particularly the group of people who have no symptoms, yet still have infectious TB. The reductions in TB transmission related to detecting and treating these individuals may be great and have a large impact on a community's long-term TB burden. The necessary duration and intensity of mobile CXR screening to reduce TB incidence will vary across settings based on TB prevalence, the proportion of people with TB who are currently missed by health services, and the proportion of household (or other) contacts that receive preventive therapy. A cost-effectiveness analysis of mobile X-ray screening targeting neighbourhood contacts of index TB patients in Cambodia showed this to be a highly cost-effective approach (41). Cost-effectiveness modelling of mobile X-ray screening is likely to be the final component of impact measurement to help TB programmes advocate for the inclusion of this higher cost, but high impact approach in national investment plans. Mobile screening also has the potential to significantly reduce the rate of catastrophic costs that patients and their families face. Programmes could compare TB-related costs in cohorts of actively and passively found patients to assess whether mobile screening lowered the financial burden of actively found patients.

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This document is one in a series of 11 field guides produced by Stop TB Partnership in collaboration with the Global Fund to Fight AIDS, Tuberculosis and Malaria, Interactive Research and Development Global (IRD), KIT Royal Tropical Institute, and multiple global experts and implementation partners. The field guides rely on practical experiences and expertise of implementers and are meant to help national TB programmes and other TB programme managers to identify the best strategies for finding people with TB who are missed by routine health services.

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