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# Global policy perspectives on digital tools for the tuberculosis diagnostic pathway: a qualitative study

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## Abstract

# Objectives.

This study examined how global policy stakeholders view the potential of digital tools for tuberculosis screening and triage. A smartphone-based application using cough audio for triage, which is currently under development, was utilized to inform the discussion and generate insights relevant to the broader adoption of digital health technologies in settings with a high tuberculosis burden.

# Design.

Qualitative, semi-structured interviews were conducted online with fifteen experts involved in tuberculosis screening, triage, and diagnostic evidence and policy at global level. Interviews were transcribed verbatim and analysed thematically.

# Results.

Participants viewed digital tools as having the potential to strengthen the tuberculosis diagnostic pathway by reducing administrative workload, supporting earlier case identification, and offering more discreet and accessible entry points into care. At the same time, they identified persistent barriers to implementation, including limited infrastructure, funding constraints, gaps in digital literacy, and the absence of clear governance frameworks. Participants emphasised the importance of human-centred design, context-specific adaptation, and equitable access.

# Conclusions.

Digital tools hold promise for optimizing the tuberculosis diagnostic pathway in high-burden settings, but their effective integration requires coherent policy guidance, investment in infrastructure and workforce capacity, and design approaches that support usability and equity.

## Introduction

Tuberculosis (TB) causes a significant burden of ill health, particularly in low- and middle-income countries (LMICs) that face persistent resource and health system constraints. Global estimates indicate that TB caused approximately 1.23 million deaths in 2024, making it the most lethal infectious disease[(1)]. Progress toward global TB elimination targets depends on the timely identification of individuals with TB and their rapid linkage to appropriate diagnostic testing[(2)]. In many high-burden settings, however, entering the TB diagnostic pathway still relies on assessing broad clinical symptoms that lack specificity and is recorded using paper-based records. This often leads to missed opportunities

for diagnosis and inefficient use of limited diagnostic capacity, particularly in over-burdened primary care facilities where confirmatory tests may be expensive or unavailable[3–5].

In response to these challenges, there is growing interest in screening approaches that can strengthen case finding in settings with constrained resources. One emerging method involves the analysis of cough audio to identify individuals who should proceed to confirmatory testing. The Cough Audio Triage for Tuberculosis (CAGE-TB) consortium has collected cough recordings and clinical information from people with and without TB in South Africa and Uganda to develop a cough audio-based classifier, which is intended to indicate a presumptive TB infection[6]. A complementary smartphone application is under development using a user-centred approach to ensure relevance and usability in diverse settings. This strategy builds on evidence suggesting that cough audio analysis may be most informative among individuals who already have an elevated pre-test probability of TB, such as those presenting with a prolonged cough or those seeking care[7–9].

For digital screening and triage tools, such as a smart phone-based application using cough audio for TB triage, to deliver meaningful impact, they must fit into existing healthcare systems, align with policy, and work within everyday clinical routines. In parallel with the classifier development, the CAGE-TB consortium is therefore considering policy and system factors that may influence its future introduction and implementation, particularly in settings with a high burden of TB.

This study drew on in-depth interviews with global level policy stakeholders to examine current challenges, priorities, and opportunities related to the TB diagnostic pathway and the potential role of digital tools. The aim was to explore the feasibility of implementing digital tools for screening and triage, particularly smart phone-based TB screening using cough audio in high TB burden settings and to identify the conditions necessary for effective and equitable integration into routine TB care.

## Methods

# Approach

This qualitative cross-sectional study examined the perspectives of global policy stakeholders on the integration of digital tools for TB screening, with particular attention to cough audio-based triage technologies in high-burden settings. Participants were individuals involved in shaping, advising, or guiding TB policy at the global level. The study was between February and July 2024.

## Sampling strategy and recruitment

Participants were identified through professional networks associated with the CAGE-TB consortium and through targeted online searches (using terms such as TB and diagnostic/screening/triage or mobile/m-health). Professionals involved in TB screening, triage, and diagnostic policy at a global level were invited to participate, defined in terms of their direct involvement with the development of policy/guidance at

supranational organizations, participation in expert technical meetings or contribution of evidence to policy development. These included individuals working at the World Health Organization (WHO), the Stop TB Partnership, universities, research institutes, and other non-governmental organizations. Invitations were sent by email together with an information sheet and consent form.

## Data collection

Data were collected through in-depth interviews conducted in English via Microsoft Teams. Interviews were led by a researcher trained in qualitative interviewing and a background in international public health. Sessions lasted between thirty and forty-five minutes and followed a semi-structured guide. The interviews included questions on their professional backgrounds and the factors that influence the TB diagnostic pathway as well as emerging digital approaches, with the CAGE-TB smartphone-based application as an example. To this end, the participants were provided with a brief description of the CAGE-TB application and its intended use, though with no further information on usability, sensitivity/specificity or cost-effectiveness.

## Data processing and analysis

Audio recordings were transcribed verbatim in Microsoft Teams with participants' consent. Transcripts were analyzed in ATLAS.ti using a combination of inductive and deductive coding. Open, axial, and selective coding were applied using an initial codebook that was refined as new insights emerged. Codes reflected themes related to TB care, screening practices, and the implementation of mobile health innovations, with policy, governance, and technical considerations added during analysis. Notes on tone and relevant non-verbal cues were recorded to support interpretation.

## Ethical review

An ethics self-assessment was conducted using a tool provided by the Vrije Universiteit, Amsterdam, which concluded that the data collection does not fall under the scope of the Dutch Medical Research Involving Human Subjects Act and no further ethical approval was therefore sought. Written informed consent was obtained from all participants, who were briefed on the objectives of the study, its voluntary nature, and the procedures for data management. Anonymity was maintained, and all data were stored on encrypted drives accessible only to the research team.

## Results

# Participants

Fifteen experts were interviewed, with participants based in Canada, Indonesia, Nigeria, the Netherlands, South Africa, Switzerland, the United States, and Zimbabwe. Participants were affiliated with global

health agencies, academic institutions, non-profit organizations, and international development organizations. Their professional backgrounds reflected a broad spectrum of expertise relevant to the study objectives. Table 1 summarizes the primary fields of work represented in the sample.

Table 1
Participant roles and field of work, n = 15

| Participant | Field of work |
|---|---|
| Assistant professor 1 | Digital health implementation in LMICs |
| Clinician 1 | Infectious diseases in LMICs |
| Epidemiologist 1 | TB epidemiology and quality of care |
| Epidemiologist 2 | Global TB policy development |
| Epidemiologist 3 | TB policy development in LMICs |
| Epidemiologist 4 | Global TB control implementation strategies |
| Physician 1 | TB epidemiology and diagnostics |
| Physician 2 | TB control in LMICs |
| Physician 3 | Global TB policy development |
| Professor | Infectious diseases in LMICs |
| Pulmonologist 1 | Digital health implementation in LMICs |
| Researcher 1 | TB diagnostics implementation in LMICs |
| Researcher 2 | Inclusive digital healthcare implementation |
| Technical advisor 1 | TB digital health solutions |
| Technical advisor 2 | Digital health solutions for TB control |

The analysis highlighted several key issues that are relevant to the implementation of digital tools in the TB diagnostic cascade. These were related to the adoption of novel TB screening and diagnostic technologies as well as the digital tools more generally in TB programmes.

## Factors shaping the adoption of novel tools for TB screening and diagnostics

Participants raised the availability and accessibility of TB screening and diagnostic tools as a central concern, particularly at the point of care. They identified system-level barriers that constrain the adoption of novel approaches to TB screening and diagnosis. Overwhelmed healthcare systems, particularly in terms of limited workforce capacity and uncertainty in decision-making, were consistently described as key obstacles to the effective implementation of new tools. Moreover, participants noted that the recent

increase in screening and diagnostic options has placed additional strain on health systems. Shifting from a single-option model to multiple tools was viewed as creating uncertainty about prioritization and use.

*“This is very novel to us, suddenly having too many tools… health systems are overwhelmed… moving from a paradigm of one option to a paradigm of a menu of options… countries are needing more guidance… It’s difficult… countries are hitting a bit of a wall in terms of being able to quickly make these kinds of decisions…”* (Epidemiologist 2)

Concerns regarding the accuracy of tools (particularly novel approaches) for screening and diagnosis also featured prominently. Participants emphasized that false positives and false negatives could undermine the credibility of screening and diagnostic algorithms as well as trust in broader TB programmes. Diagnostic and screening tools were not viewed in isolation and clear follow-up procedures and defined post-triage pathways were viewed as essential to the translation of effective diagnostic and screening results into appropriate care.

*"Otherwise, you're just moving patients around and providing results, and it's not leading to appropriate management."* (Physician 1)

Despite these challenges, participants expressed optimism about the potential of more cost-effective screening tools to strengthen TB programme performance. This sense of possibility shaped how participants approached emerging digital tools, which they viewed as offering additional opportunities to improve TB management. However, they also emphasized the importance of effective marketing and dissemination strategies to support investment in new screening and diagnostic technologies. Without clearly articulated pathways to adoption, they cautioned that promising innovations may struggle to progress beyond the development stage. Structured support was therefore viewed as essential to narrowing the gap between research and implementation.

# Potential contribution of digital tools for TB management

Participants viewed digital health as a promising strategy for strengthening TB management in settings with high disease burden and limited resources. They described how digital tools could ease pressure on overstretched systems by automating administrative tasks, simplifying reporting, improving data flow, and reducing the time spent on manual work. Self-screening (using digital tools) was also viewed as a way to lessen front-line workload. These efficiencies were seen as creating more space for direct patient care.

*“At the end of the day, you need to look at what value [the digital tool] adds to your day-to-day life.”* (Assistant professor 1)

Digital tools were described as potentially supporting self-management and reducing the stigma associated with TB. For example, embedding TB care within broader digital health platforms was seen

as making services more discreet and accessible, offering a more comfortable entry point into care and helping reduce stigma-related avoidance. Participants noted that TB clinics are often secluded within health facilities and that being seen in these areas can carry significant stigma, which digital platforms may help patients avoid.

# Implementing digital health tools in routine TB care

Alongside their recognition of digital health's potential, participants identified several obstacles that need to be addressed for digital tools to be successfully integrated into routine TB care. Participants noted gaps in medical technology regulation, particularly in mobile health applications, along with the need for stronger infrastructure, comprehensive training for healthcare workers, and clear safeguards to protect patient privacy. Participants affiliated with the WHO noted that the organization is establishing a dedicated department to strengthen policies and management systems for the rapidly evolving digital health landscape.

*"It's important that digital testing is conducted in a way that ensures the dignity of the patients and protects their privacy."* (Assistant Professor 1)

Infrastructure constraints were also viewed as a significant barrier to sustainable implementation. Participants highlighted limited internet access, poor system interoperability, and the need for offline functionality, particularly for community health workers operating in remote areas. Epidemiologist 2 suggested piloting various delivery models, including clinic-based platforms, patient-owned devices, and outreach services, to assess their relative effectiveness.

The importance of inclusivity and accessibility in digital health, and particularly artificial intelligence, development was a recurring theme. Participants emphasized the need for diverse datasets in algorithm design to ensure that digital tools perform consistently across populations.

*"...if you're developing an algorithm, ensuring that a diverse data set is used in the training and development of the model so that they are representative of a broader population."* (Clinician 1)

Concerns regarding digital equity were also prominent. Participants observed that commonly used effectiveness metrics often overlook the experiences of individuals with limited digital literacy.

*"When we think about digital inclusion and digital equity, we need to consider what patients need to use this, what developers need to create inclusive technology, and what policymakers need to support this inclusivity."* (Researcher 2)

Ensuring adoption and sustained use was seen as requiring meaningful engagement with healthcare providers, policymakers, and community leaders to ensure that digital tools align with local needs and contexts. User-friendliness was identified as a critical determinant to promote/ensure uptake and sustainability. Participants stressed the need for intuitive interfaces and readily available support for troubleshooting.

*"If they have questions regarding it, there needs to be help available where they can go and ask questions, and it needs to be quite a low threshold help. So, it needs to be very quickly accessible and not require too much time."* (Technical advisor 1)

While acknowledging these barriers, participants remained optimistic about the potential of digital tools and emphasised the need for continued refinement to maximise their impact.

# Discussion

This study explored expert perspectives on novel approaches to the TB diagnostic cascade, in particular digital tools, and their potential implementation in high burden settings. The participants recognized several potential contributions of digital tools, but also described substantial barriers to their adoption and important challenges that could limit their effective implementation. The results point to issues specific to TB screening and diagnostics and more broadly to digital tools in TB programmes.

Global level stakeholders in TB screening and diagnostics from diverse backgrounds highlighted a need for improved access to the TB diagnostic cascade. Digital screening and diagnostic tools were seen as offering great potential to address the current limitation of current approaches. Advantages of these tools included reducing administrative workload, improving data flow, and offering individuals a more discreet and accessible route into TB care. The potential for such tools to reduce the impact of stigma related to care seeking for TB-related symptoms is a novel finding.

Limited health system capacity was seen as a central barrier to the implementation of digital tools, specifically gaps in infrastructure, workforce readiness, and training. These observations are consistent with studies showing that resource constraints and insufficient organisational capacity hinder the introduction of new TB screening tools in high-burden settings[10, 11]. Furthermore, the interviewed experts noted uncertainty about how to assess and prioritise multiple emerging tools for screening and diagnostics and this aligns with research that has highlighted the difficulty of transitioning from a single screening pathway to a more diverse set of tools[12]. To achieve the potential of digital tools for TB screening and diagnosis, participants highlighted how they need to accommodate varied levels of digital literacy. These concerns underscore the need for usability, in terms of language accessibility and offline functionality [19] and engaging stakeholders in user-centred design [20].

The opportunities were described in the context of significant and more generalized barriers to the implementation of digital tools in TB programmes. Weak connectivity, limited device availability, and poor interoperability were common concerns, aligning with researcher on the digital divide and the disproportionate impact on under-resourced regions [15, 16]. Participants also described gaps in the regulatory environment for digital tools, reflecting observations from recent work that financial constraints and fragmented systems limit the adoption of digital technologies in high-burden countries [17]. Privacy and dignity were viewed as essential considerations, consistent with research showing that trust in digital systems depends on strong safeguards, particularly in resource-constrained settings [18].

The findings have direct implications for digital tools, such as the proposed CAGE-TB application, intended to triage for TB based on cough audio. The emphasis on usability, simplicity, and alignment with workflow provides concrete guidance for implementation. The study also highlights an important structural gap noted by several experts, namely the absence of clear frameworks to guide how mobile tools should be integrated into TB programmes. Although global initiatives aim to strengthen governance, these pathways remain incompletely defined, indicating an area where further policy development is needed.

# Strengths and limitations

A strength of this study is the inclusion of participants working across multiple areas of TB care and policy, including epidemiology, clinical practice, digital health, and global TB governance. This diversity, which spanned organizations, such as the WHO, academic institutions, and international partnerships, provided a broad view of the system-level factors that shape the adoption of digital screening and triage tools. The use of in-depth, semi-structured interviews enabled exploration of complex issues and allowed participants to describe challenges and opportunities relevant to their roles and settings. The purposive sampling strategy ensured representation from different regions and institutional backgrounds, which strengthened the breadth of insights captured.

Although the study included clinicians and other technical experts, it did not capture perspectives from patients or community members, whose experiences are essential for understanding usability and day-to-day implementation. Future research would benefit from incorporating the views of people affected by TB, including people affected by TB and community members, to complement the policy and programme-level perspectives described by the interviewed experts.

## Conclusion

This study examined expert perspectives on novel digital tools for the TB diagnostic cascade, using the example of a smartphone-based tool that uses cough sounds for triage. Several advantages of digital tools were identified were, including more discreet entry points into the TB diagnostic cascade. These benefits will however only be realized if persistent barriers, including limited infrastructure, variable digital literacy, and the lack of clear frameworks to guide the integration of mobile tools into TB programmes, are addressed. Novel digital tools for screening and diagnosis, such as a smartphone-based application using cough sounds, are most likely to be effective when they align with existing workflows, reduce user burden, and prioritize equity and usability. Strengthened policy guidance, investment in workforce capacity, and ongoing attention to the enabling environment are essential for sustainable implementation. Overall, the study highlights both the promise and the complexity of digital screening in TB care and underscores the need for further effort to evaluate digital triage tools in real-world settings and to identify strategies that support their equitable and effective integration into routine services.

## Declarations

# Conflict of interest

No potential conflict of interest relevant to this article was reported.

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# Author contributions:

CO, FC, HM, JNK, LM, KZ, TN, DN, GT and CP have made substantial contributions to the conception or design of the work; or to the acquisition, analysis, or interpretation of data for the work; drafted the work or revised it critically for important intellectual content; approved the final version to be published; and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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