Commentary

AI-powered digital stethoscopes: A new opportunity in tuberculosis screening?

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Tuberculosis screening faces challenges of under-detection, costly approaches, and inequitable access. AI-enabled digital stethoscopes have demonstrated promising accuracy and feasibility for detecting lung and cardiovascular abnormalities, with promising results in early TB studies. Training and validation in diverse, high-burden settings are essential to explore the potential of this tool further.

Tuberculosis (TB) remains the deadliest infectious cause of deaths globally, claiming 1.25 million lives in 2023.[1] Despite recent advancements in screening and diagnostic tools, an estimated 2.7 million people with TB were missed by current screening programs.[1] Growing awareness about the vast numbers of people with asymptomatic or subclinical TB, missed by routine symptom screening, led to renewed interest in chest radiography which, more recently, saw the WHO recommendation of several artificial intelligence (AI)-powered computer-aided detection (CAD) software to facilitate the detection of TB cases.[2]

Despite advancements in the form of CAD as well as ultra-portable radiography hardware, radiology remains costly for TB programs, with high upfront hardware and operating costs, and is not feasible to implement in all settings (e.g., primary care) or all people (e.g., pregnant women) due to radiation concerns as well as the requirement of infrastructure and trained equipment operators.[3,4] We must look beyond radiology to further enhance access to care and take TB screening into homes and communities.

Acoustic biomarkers for disease detection

AI holds significant potential for screening, including applications beyond CAD of TB from radiographs. One application of AI for disease screening is to interpret acoustic (sound) biomarkers of disease, with potential to identify sounds that appear non-specific or are inaudible to the human ear. Given the role of coughs in traditional TB screening methods, there has been particular interest in utilizing AI to detect and interpret cough biomarkers to enhance disease detection. However, significant challenges persist in translating cough sound AI algorithms into clinically meaningful tools. A recent scoping review highlighted several key limitations in utilizing coughs as an acoustic biomarker.[5] First, the non-specific nature of coughing (present in various conditions, from upper respiratory infections to TB) limits its value for differential diagnosis based on acoustic features alone, as not all diseases present distinct cough patterns. Technical barriers also persist, including device- and setting-dependent performance variability, as current algorithms struggle to distinguish between individuals in crowded or shared environments, resulting in contaminated recordings that affect outputs. Usability issues also hinder user acceptance, with studies reporting burdensome external microphones on portable monitors, excessive smartphone battery consumption, and patient privacy concerns.[5]

AI-powered lung auscultation may be able to overcome some of the challenges associated with AI cough-based TB screening. Although not typically recommended as a TB screening tool, lung auscultation, which uses a stethoscope placed in multiple locations over the lungs to analyze breath sounds, could offer a more direct route to detection of abnormal lung sounds as a rapid, initial screen, which could prompt further testing for TB. Advancements in stethoscope technology have renewed interest in its potential as a screening tool. Although traditional stethoscopes are widely used in primary care settings, sensitivity has historically been limited due to acoustic limitations (inability to transmit subtle, low amplitude sounds) as well as operator- and context-dependent factors, with effectiveness varying with experience, technique, and consultation time.[6]

In recent years, digital stethoscopes have overcome some of these challenges by using high-fidelity digital sensors, noise filtering, and sound amplification (up to 8-fold better than analog).[7] Low-cost digital stethoscopes have recently been approved by the U.S. Food and Drug Administration (FDA) for home-based personal health monitoring. Digitalization has led to sound wave visualization, recording for consultation, compatibility with telehealth providers, and ultimately, AI acoustic analysis (Figure 1 shows an example). Therefore, despite the limitations of traditional stethoscopes for TB detection, digital technology combined with AI could transform these devices into potentially powerful screening tools by enabling the detection and characterization of subtle pathological lung sounds that may be imperceptible or non-specific to the human ear during manual auscultation procedures and thereby inform screening and triage for specific lung diseases. This capability reduces reliance on operator

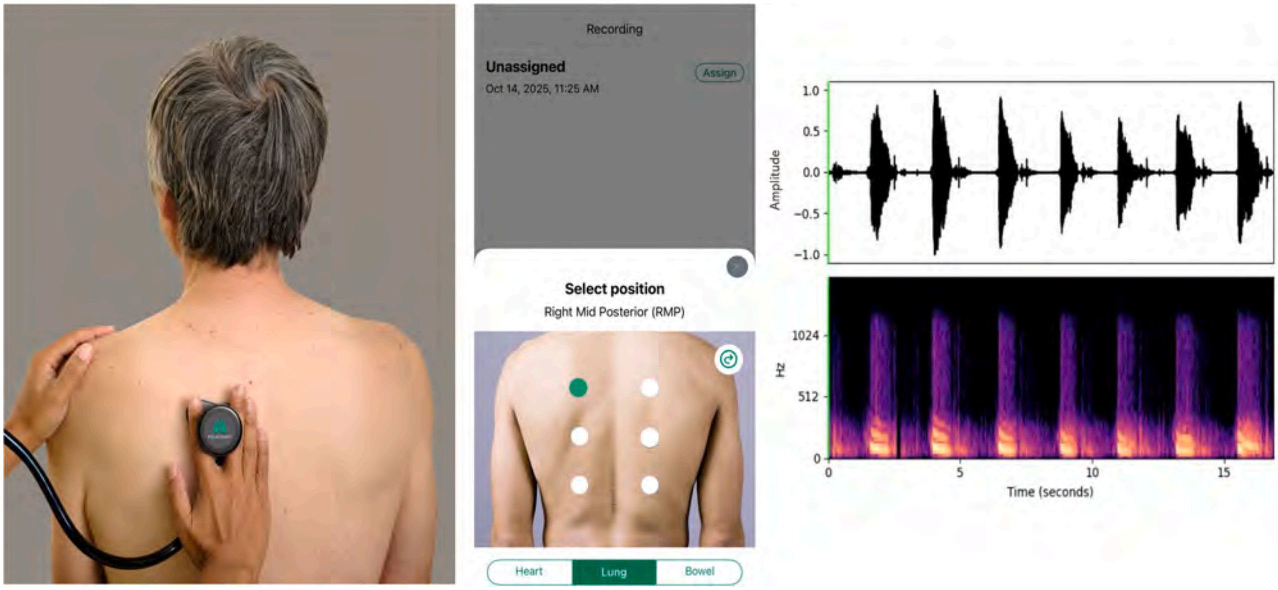

Figure 1. CORE 500 digital stethoscope

CORE 500 digital stethoscope in pulmonary mode (left); initiating pulmonary capture in app (center); lung signal capture (right), (reproduced with permission from Eko Health, Inc, California, USA).

skill and subjectivity, allowing standardized and reproducible interpretation across diverse settings and representing a major advance in the application of AI to acoustic biomarkers.

Recent clinical validations have shown that auscultation-based acoustic biomarkers, when analyzed with AI, can reliably detect complex pathological conditions with clinically meaningful accuracy. AI interpretation of heart sounds is particularly gaining traction as growing evidence supports its diagnostic utility. A landmark study assessing AI interpretation of ECGs recorded using the Eko DUO digital stethoscope (Eko Health) in the UK identified an AUROC of 0.85 (0.81–0.89), sensitivity of 82.7%, and specificity of 79.9% for detecting signs of heart failure.[8] Similarly, a 2024 randomized trial in Nigeria involving 1,232 pregnant and postpartum women demonstrated that AI-enabled auscultation almost doubled the number of women with pregnancy-related cardiomyopathy identified in routine procedures and demonstrated 95.7% sensitivity when detecting left ventricular systolic dysfunction.[9] AI algorithms for heart failure detection are increasingly approved by stringent regulatory authorities, including the FDA, underscoring the growing clinical acceptance of acoustic biomarkers.

As compared to AI analyses of heart sounds, there is less evidence on AI-based detection of lung sounds. A 2023 scoping review identified numerous early studies, which often developed and validated auscultation AI algorithms utilizing publicly available datasets, that demonstrated high AI accuracy for identifying abnormal lung sounds (such as crackle, wheeze, and rhonchi), and/or classifying the presence or absence of diseases including asthma, COPD, and pneumonia.[7] For example, when tested on the ICBHI 2017 dataset, one algorithm obtained 84.5% sensitivity and 84.9% specificity for distinguishing normal lung sounds, crackle, wheeze, and crackle and wheeze co-occurrence.[7] The same review identified several studies demonstrating AI's ability to identify COPD from healthy lung sounds, with sensitivity and specificity both exceeding 90%.[7] External validations similarly highlight AI's potential for detecting and classifying adventitious lung sounds. In Shanghai Children's Medical Center, the ability of AI to detect adventitious lung sounds in children recorded using a digital stethoscope (Yunting Model II) surpassed that of pediatricians, with highest accuracy among those younger than 12 months[10] Meanwhile, in Malawi, a prototype AI-enhanced digital stethoscope, tested in children hospitalized with severe pneumonia, demonstrated 96.3% sensitivity and 66.7% specificity for detecting abnormal lung sounds compared to a panel of certified physicians.[11]

Only two studies to date have evaluated AI-enabled digital auscultation for TB detection. The AID.TB algorithm (AI Diagnostics) demonstrated high sensitivity (89.9%) and moderate specificity (50.4%) against an Xpert Ultra molecular reference standard in a South African cohort—outperforming 3 out of the 12 CAD software evaluated separately in a similar study population.[12] Subsequently, in a mixed cohort from four high-TB burden countries (Peru, South Africa, Uganda, and Vietnam), the same AI stethoscope showed somewhat lower sensitivity of 76.7% (65.1–85.2%) and 50.0% (43.0–56.9%) specificity.[13] These findings highlight that AI-enabled auscultation could hold promise as a TB screening and triage tool.

Importantly, this technology may be particularly suitable for vulnerable populations, such as children, where screening is challenging due to atypical clinical presentation, the limitations of chest radiography in this population, and the exemption of children under 15 years old from the WHO's recommendation on CAD.[2] Similarly, pregnant women, where radiation exposure is a concern, could

Table 1. Comparison of key features of AI with digital CXR, for cough classification and with digital stethoscope

	Digital CXR + CAD/AI	Cough detection and classification	Digital stethoscope + AI
WHO endorsed for TB screening	yes	no	no
Type of technology	imaging	acoustic	acoustic
Hardware cost	21,505 to 56,560 USD (ultra-portable radiography)[a]	100-200 USD for smartphone (for recording)	~50 to 500 USD (plus 100–200 USD if smartphone required for operation)
Software cost (license only)	8,975 to 11,000 USD (perpetual)[a]	not available	
Radiation risk	minor	none	none
Infrastructure requirements and typical setting where used	moderate, district level or higher	none, home, primary care or higher	none, home, primary care or higher
Personnel requirements	specialists required for X-ray operation.	community health worker, nurse, general practitioner	community health worker, nurse, general practitioner
Potential for home use or use by community health workers	none	high	high
Use in pediatric populations	Moderate. Not recommended by WHO for children <15 years in absence of radiologist.	Easy-to-moderate, equiring cooperation, ability to cough when solicited.	Easy to use in pediatric population.

CXR, chest X-ray; CAD, computer-aided detection; AI, artificial intelligence.
[a]Global Access Prices from Stop TB Partnership's Global Drug Facility (GDF) Catalog: https://www.stoptb.org/sites/default/files/documents/2025.08.21%20GDF_Diag%20and%20MD_catalog.pdf.

benefit from non-radiative auscultation-based screening methods. While traditional lung auscultation presents unique challenges in children due to anatomical and physiological differences as well as challenges in patient cooperation, AI-enabled auscultation systems have demonstrated high diagnostic value for other pulmonary diseases in this population, suggesting digital technology combined with AI can compensate for the complexities of pediatric lung sounds.[10,11] Rigorous, high-quality studies are necessary to further assess diagnostic accuracy for TB in general populations, while ensuring that AI-powered auscultation effectively meets the screening needs across diverse and vulnerable populations.

A key potential advantage of AI digital stethoscopes is their potential for quick uptake by community health workers in resource-limited contexts that are already trained in basic clinical assessment and can be rapidly upskilled for AI-assisted auscultation. In India, feedback from health workers testing a prototype AI-enabled stethoscope in both urban and rural healthcare settings indicated it was easy to use and that they would like to incorporate it into their practice.[14] On the System Usability Scale, scores ranged from 67.5 (Community Health Officer) to 82.5 (Auxiliary Nurse Midwife and Doctor both) out of 100, indicating positive usability ratings.[14] In Sylhet, Bangladesh, community health care providers received 3 days of initial training, followed by two on1-day refresher trainings, to deploy a prototype AI-enabled digital stethoscope for screening pediatric pneumonia.[15] After 1.5 years of experience with the prototype, applying it to an average two to three children daily, community health care workers preferred the digital, AI-enabled prototype to their previous traditional stethoscopes, particularly citing the sound interpretation feature. However, healthcare workers noted some challenges with background noise, availability of electricity to charge the device, and necessity to transport the device to and from the clinic due to lack of secure storage.[15] Meanwhile, parents of children screened with the stethoscope reported that health workers appeared confident during utilization and children showed no fear of the devices. With multiple microphones and noise suppression algorithms reducing the need for precise chest placement and interpretation, digital stethoscopes demonstrate high feasibility for use by healthcare workers with minimal clinical experience to capture recordings of sufficient for reliable AI interpretation, without extensive auscultation skills. Considering this alongside their portability, affordability, and freedom from radiation (Table 1), AI digital stethoscopes may become useful alternatives to imaging-based approaches for TB screening, with the potential to democratize access to care for populations underserved by radiography.

The path forward

Coordinated action is required to realize the potential of AI-enabled stethoscopes for TB screening. First, pilot implementation of AI-enabled digital stethoscopes for TB in high-burden settings should be coupled with robust evaluation protocols to assesstheir integration into existing screening algorithms to validate AI, determine impact on TB screening, and user acceptability in contexts without radiography. It will be particularly helpful to conduct non-inferiority studies to test whether AI-enabled stethoscopes can provide similar performance to CAD-enabled digital X-rays for TB screening. The question here is are both technologies roughly equivalent in their ability to detect those with abnormal lungs that require additional, confirmatory testing for TB?

Second, like the initiatives already undertaken for cough sounds, collaborative efforts are needed to develop high-quality, labeled auscultation datasets of lung sounds, along with clinical and microbiological results, for TB model training to catalyze further product development. While such datasets remain scarce, they can be generated using low-cost devices in field settings, allowing high-burden communities to directly contribute to AI development—ensuring algorithms learn from the real-world diversity in presentations, comorbidities, and environmental conditions. Furthermore, this creates an opportunity to develop local algorithms that are trained and validated specifically within and for the needs of high-burden countries.

As the world advances toward TB elimination, AI-enabled digital stethoscopes hold potential to fill critical screening gaps for populations underserved by current approaches: children under 15 (for whom CAD is not WHO-recommended, especially younger children where CXR is often unfeasible), pregnant women (who need to avoid radiation exposure), rural communities (lacking routine access to imaging infrastructure),[4] and home-based care for individuals with limited mobility. The global TB response demands innovation that is not only technologically advanced but also accessible and equitable. AI digital stethoscopes embody these principles, offering a scalable, low-cost, and person-centered tool that could bring us closer to reaching TB case finding goals.

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