Digital Stethoscope in the Era of Artificial Intelligence: A Comprehensive Review in the Era of Evidence-Based Clinical Studies

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ABSTRACT

The conventional stethoscope, though a clinical mainstay, is limited by subjectivity. Digital stethoscopes integrated with Artificial Intelligence (AI) offer a transformative solution, converting acoustic signals into objective electronic data for automated classification and predictive analytics. This review synthesizes evidence demonstrating that AI-enhanced auscultation significantly boosts diagnostic accuracy and scalability. Studies highlight improved classification of pediatric heart murmurs (AUC up to 0.92), reliable detection of valvular heart disease (e.g., 93.2% sensitivity for aortic stenosis), and identification of lung pathology (wheezes, crackles, pneumonia). Furthermore, these devices proved valuable in screening for left ventricular dysfunction and facilitating triage during the COVID-19 pandemic. Future integration of multimodal sensing (ECG), wearable sensors, and Internet-of-Medical-Things (IoMT) will enable continuous, personalized monitoring. Successful implementation hinges on regulatory oversight and standardization across diverse populations. AI-powered digital stethoscopes are poised to democratize access and advance precision medicine globally.

Keywords: Digital Stethoscope; Artificial Intelligence; Machine Learning; Auscultation; Heart Murmur; Diagnostic Accuracy; Telemedicine; Precision Medicine

INTRODUCTION

Since its invention in 1816, the stethoscope has remained an enduring symbol of clinical practice and a cornerstone of bedside diagnosis. Conventional auscultation, however, is inherently dependent on clinician skill, auditory acuity, and experience, introducing subjectivity that can result in misclassification of heart murmurs, delayed recognition of pulmonary pathology, and missed early signs of cardiovascular compromise [1]. Digital stethoscopes have emerged as a technological evolution, converting acoustic signals into electronic data that can be amplified, filtered, and visualized. When coupled with artificial intelligence (AI), these devices enable automated sound classification, predictive analytics, and continuous monitoring. AI algorithms have the capacity to detect subtle acoustic patterns beyond human perception, offering objective assessments that may enhance diagnostic accuracy and improve patient outcomes [2]. Evidence increasingly supports the clinical utility of AI-enhanced digital stethoscopes. Multiple studies have demonstrated improved detection of pediatric heart murmurs, neonatal respiratory distress, valvular heart disease, and chronic pulmonary conditions. Furthermore, these devices provide cost-effective, non-invasive solutions suitable for telemedicine and resource-limited settings [3].

This review synthesizes current clinical evidence, technological innovations, and future directions for AI-integrated digital stethoscopes.

MATERIALS AND METHODS

A literature review was conducted using PubMed, Scopus, and Web of Science for publications from 2010 to 2025. Search terms included "digital stethoscope," "artificial intelligence," "machine learning," "heart murmur," and "respiratory auscultation," with reference lists of relevant articles screened for additional studies. Eligible studies included prospective, comparative, and randomized clinical trials evaluating digital stethoscopes, with or without AI integration. Studies were included if they focused on cardiology, pulmonology, or pediatric populations, and reported objective diagnostic outcomes, including sensitivity, specificity, accuracy, or area under the receiver operating characteristic curve (AUC). Data extracted comprised study population characteristics, technological specifications, clinical focus, and diagnostic performance. Two independent reviewers performed data extraction, with discrepancies resolved by consensus. Findings were synthesized narratively and presented in tabular form, highlighting the comparative performance of AI-assisted versus conventional auscultation.

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Clinical Utility and Evidence of AI-Enhanced Digital Stethoscopes

Digital stethoscopes convert mechanical vibrations into electronic signals using microphones or piezoelectric sensors, which can be amplified, filtered, and visualized in real time. Integration with artificial intelligence (AI) enhances their functionality, enabling automated classification of heart and lung sounds, predictive modeling, and longitudinal monitoring [4]. Signal processing techniques reduce noise and improve waveform fidelity, while deep learning algorithms, including convolutional neural networks (CNNs) and long short-term memory (LSTM) networks, support multi-class sound classification and early detection of physiological abnormalities. Connectivity with mobile devices, cloud platforms, and electronic health records facilitates telemedicine, remote consultation, and continuous patient monitoring. By transforming auscultation from a subjective skill into an objective and reproducible diagnostic process, AI-powered digital stethoscopes are particularly advantageous in populations where subtle physiological variations are clinically significant, such as neonates, pediatric patients, and critically ill adults.

Clinical evidence supports their utility across cardiology, pediatrics, and pulmonology. In children, heart murmurs are common and often benign, yet traditional auscultation is prone to misclassification. Zhou et al. [5] demonstrated that deep learning applied to digital stethoscope recordings achieved AUC values of 0.92, 0.83, and 0.88 for normal heart sounds, innocent murmurs, and pathological murmurs, respectively, enabling objective assessment and early intervention. For pediatric respiratory conditions, digital auscultation improved detection of wheezes, crackles, and stridor relative to conventional methods; Kevat et al. [6] reported higher sensitivity for wheezes and 100% concordance for crackles, while the PERCH study [7] confirmed reliable identification of abnormal lung sounds in children with pneumonia in low-resource settings. In neonates, AI-assisted digital stethoscopes facilitated early recognition of respiratory distress, with Grooby et al. [8] reporting 85% specificity and 66.7% sensitivity. In adult cardiology, AI-enhanced auscultation improved detection of valvular heart disease, with Chorba et al. [9] achieving 76.3% sensitivity and 91.4% specificity for murmurs, reaching 93.2% sensitivity for moderate-to-severe aortic stenosis and 94.6%

specificity for mitral regurgitation. AI-guided screening in peripartum women nearly doubled detection of left ventricular systolic dysfunction compared with conventional assessment (4.1% vs. 2.0%) in a trial by Adedinsewo et al. [10], while integration with single-lead ECGs further enhanced early detection of asymptomatic left ventricular dysfunction (AUC 0.85; sensitivity 77.5%; specificity 78.3%) [11]. In pulmonology, AI-assisted auscultation improved diagnosis and monitoring of chronic respiratory diseases, including interstitial lung disease and chronic obstructive pulmonary disease, with deep learning models achieving AUC >80% when combined with lung imaging [12]. During the COVID-19 pandemic, digital stethoscopes facilitated rapid triage and severity prediction based on lung sounds, enhancing patient management in resource-limited and telemedicine settings [13]. Collectively, these findings demonstrate that AI-integrated digital stethoscopes provide objective, reproducible, and scalable assessments, enhancing early detection, clinical decision-making, and accessibility across diverse patient populations.

Discussion and Meta-Analysis of AI-Enhanced Digital Stethoscope Studies

Across pediatric, cardiac, and pulmonary populations, AI-assisted digital stethoscopes consistently enhance diagnostic accuracy, objectivity, and early detection. In pediatrics, these devices improve heart murmur classification [5], respiratory sound detection [5, 6], and pneumonia identification in low-resource settings [7], while supporting timely intervention for neonatal respiratory distress [8]. In adult cardiology, AI-guided auscultation enables reliable detection of valvular heart disease [9], peripartum cardiomyopathy [10], and asymptomatic left ventricular systolic dysfunction [11], providing scalable, non-invasive screening that can reduce reliance on echocardiography. In pulmonology, deep learning applied to lung sounds, alone or combined with imaging modalities, achieves high accuracy for chronic respiratory diseases such as interstitial lung disease and chronic obstructive pulmonary disease (Table 1) [12], and facilitates rapid assessment of infectious conditions including COVID-19 [13]. Collectively, AI-powered digital auscultation decreases inter-observer variability, standardizes measurements, and supports timely clinical decision-making, offering particular advantages in pediatric populations and resource-limited environments.

Condition / Focus	Technology Used	Outcome Metrics	Key Findings	Study
Pediatric heart murmurs	Deep learning algorithm + digital stethoscope	AUC: Normal 0.92, Innocent Murmurs 0.83, Pathologic 0.88	Multi-class classification of pediatric heart sounds (normal, innocent murmurs, pathologic murmurs)	Zhou et al., 2024
Pediatric respiratory conditions	Digital stethoscope	Sensitivity: 100% for crackle detection; improved wheeze detection	Higher sensitivity than clinician auscultation in detecting wheezes; 100% concordance for crackle detection	Kevat et al., 2017
Pediatric respiratory sounds	Digital stethoscope	Sensitivity for wheeze: higher than traditional auscultation	Enhanced detection of wheezes, crackles, and	Zhou et al., 2024

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		stridor vs traditional auscultation		
Pediatric pneumonia diagnosis	Digital stethoscope	Diagnostic value in low-resource settings; more prevalent in severe cases	Captured crackles and wheezes; higher prevalence in severe pneumonia	PERCH Study, 2019
Neonatal respiratory distress	Digital stethoscope + RUSBoost classifier	Specificity: 85%; Sensitivity: 66.7%; Accuracy: 81.8%	Early prediction of respiratory distress in term newborns	Grooby et al., 2022
Cardiac murmurs and valvular disease	Deep learning + digital stethoscope	Sensitivity: 93.2% (Aortic Stenosis); Specificity: 94.6% (Mitral Regurgitation)	High sensitivity and specificity for detecting murmurs, moderate-to-severe aortic stenosis, and mitral regurgitation	Chorba et al., 2021
Peripartum cardiomyopathy	AI-guided digital stethoscope	Detection rate: 4.1% AI group; 2.0% control group	Improved detection of LVSD in peripartum women, doubling detection rates	Adedinsewo et al., 2024
Left ventricular systolic dysfunction	Digital stethoscope + ECG	AUC: 0.85; Sensitivity: 77.5%; Specificity: 78.3%	Early detection of asymptomatic LVSD using CNN model	Guo et al., 2025
Pulmonary diseases (ILD, COPD, COVID-19)	Deep learning + digital stethoscope	AUC: >80% for chronic lung diseases	AI-assisted analysis of lung sounds for diagnosis and prognosis	Glangetas et al., 2021
Chronic lung conditions (ILD, COPD)	Deep learning + digital stethoscope	AUC: >80% in diagnosing ILD and COPD	Digital stethoscopes with AI models offer an alternative to traditional diagnostic techniques	Siebert et al., 2023
COVID-19 diagnosis and prognosis	AI-powered digital stethoscope	Fast and consistent diagnoses; beneficial for telemedicine	AI-driven analysis enabled rapid, consistent diagnosis and severity assessment	Glangetas et al., 2021

Table 1: Recent Studies on Digital Stethoscopes in Cardiology, Pulmonology, and Pediatrics

AI-enhanced stethoscopes represent a paradigm shift, transforming a traditionally subjective skill into an objective diagnostic process. Evidence-based studies confirm their superiority for detecting pediatric murmurs, neonatal respiratory distress, valvular heart disease, and chronic pulmonary conditions (Table 2), with benefits including improved diagnostic accuracy, earlier interventions, reduced healthcare costs, and increased access in low-resource and telemedicine contexts. Nevertheless, challenges persist: clinician training, integration into clinical workflows, and standardization of AI models across diverse populations remain essential. Trust in algorithmic outputs, regulatory approval, and ongoing performance validation across age groups, comorbidities, and ethnicities are critical for safe implementation. Data privacy, security, and interoperability must also be addressed, particularly in telehealth and Internet-of-Medical-Things (IoMT)–enabled systems [3].

Population / Condition	AI Performance	Clinical Interpretation	Significance for Practice	Study
Pediatric Heart Murmur	AUC 0.92 / 0.83 / 0.88	Accurate classification; reduces misdiagnosis	Supports early detection, standardized evaluation, clinician confidence	Zhou et al., 2024
Pediatric Respiratory Sounds	High sensitivity; crackle 100% concordance	Objective detection of wheezes, crackles, stridor	Early intervention, reduces subjective variability	Kevat et al., 2017 & Zhou et al., 2024
Pediatric Pneumonia	>1,000 lung recordings; abnormal sounds prevalent	Identifies severe pneumonia	Cost-effective, non-invasive diagnosis in low-resource settings	PERCH Study, 2017
Neonatal Respiratory Distress	RUSBoost: 85% specificity, 66.7%	Detects early respiratory compromise	Enables timely NICU intervention	Grooby et al., 2022

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	sensitivity, 81.8% accuracy			
Valvular Heart Disease	Sensitivity 76.3%, specificity 91.4%; aortic stenosis 93.2%, mitral regurgitation 94.6%	Accurate murmur and valve detection	Non-invasive screening, reduces echocardiography dependence	Chorba et al., 2021
Peripartum Cardiomyopathy	AI doubled LVSD detection (4.1% vs 2.0%)	Early identification in obstetric population	Facilitates timely management where echo is limited	Adedinsewo et al., 2025
Asymptomatic LVSD	AUC 0.85, sensitivity 77.5%, specificity 78.3%	Detects subclinical LV dysfunction	Scalable, non-invasive screening for early intervention	Guo et al., 2024

Table 2: Clinical Interpretation and Significance of evidence-based clinical studies in the era of artificial intelligence digital stethoscope

The COVID-19 pandemic further highlighted the utility of AI-integrated digital stethoscopes in decentralized care. Algorithms facilitated rapid triage and disease severity assessment, underscoring their potential in telehealth, pandemic preparedness, and low-resource settings. As clinical datasets expand, AI models are expected to become increasingly sophisticated, potentially integrating multimodal signals such as electrocardiography, pulse oximetry, and respiratory rate—to deliver holistic, patient-specific diagnostic outputs. These advances position AI-enhanced auscultation as a cornerstone of precision, accessible, and data-driven healthcare.

Future Technological Perspectives, Limitations, and Directions

Emerging digital stethoscope technologies are set to transform auscultation through continuous, non-invasive, and context-aware monitoring. Flexible and wearable devices, such as epidermal acoustic sensors and soft polymer piezoelectric systems, enable high-fidelity sound acquisition without tubing interference, improved chest conformity, and wireless transmission to mobile and cloud platforms, making them especially suitable for pediatric, neonatal, and long-term care applications [14,15]. Integration of heart and lung sound analysis with complementary signals including electrocardiography, pulse oximetry, respiratory rate sensors, and motion detectors permits multimodal diagnostics, allowing AI algorithms to detect compound pathologies, such as heart failure exacerbations, by analyzing synchronous physiologic data [16]. AI can also establish individualized acoustic baselines, improving sensitivity, reducing false positives, and supporting early intervention in chronic conditions such as heart failure and asthma [16]. Augmented reality and workflow integration enable clinicians to visualize auscultation data and AI-guided diagnostic suggestions in real time, enhancing efficiency, standardization, and documentation within electronic health records [17].
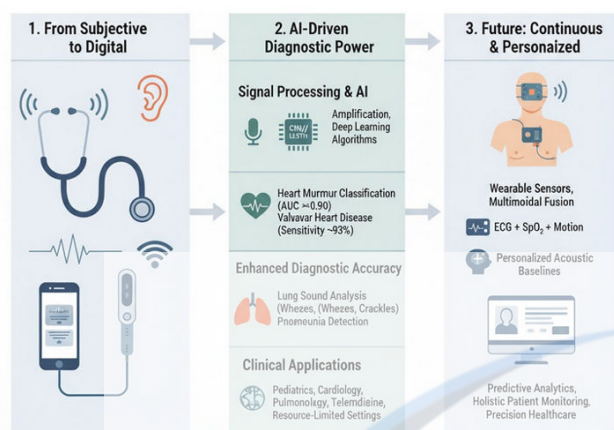
Future digital stethoscopes will increasingly leverage interoperability standards, including FHIR, HL7, DICOM-WAVE, and IEEE 11073, enabling secure data exchange, real-time streaming, and integration with telehealth platforms, hospital systems, and predictive analytics frameworks for population health management and AI-assisted triage [18]. Despite these advances, significant challenges remain. High-quality annotated datasets are essential for robust algorithm training, yet variability in recording environments, patient movement, and background noise may compromise model performance. Many studies remain single-center or region-specific, limiting generalizability and emphasizing the need for multicenter validation. Regulatory and ethical considerations—including compliance with medical device regulations, data privacy, and algorithm transparency—are critical to build clinician trust. Cost and accessibility may restrict deployment, particularly in low-income regions, and successful integration requires alignment with clinical workflows and acceptance by healthcare teams. Collaborative efforts among engineers, clinicians, data scientists, and policymakers are essential for safe, effective, and equitable implementation.

Looking forward, next-generation AI-integrated digital stethoscopes will combine wearable technologies, multimodal sensing, and advanced analytics to enable continuous monitoring, personalized diagnostics, and augmented clinical decision support. IoMT-enabled devices will facilitate remote consultations and longitudinal tracking of patient-specific acoustic profiles, enhancing early detection of pathophysiological changes. Multi-modal fusion of heart and lung sounds with ECG, pulse oximetry, respiratory rate, and motion data will allow comprehensive cardiopulmonary assessment, while predictive AI algorithms may forecast disease progression, hospital readmissions, and acute exacerbations, guiding proactive interventions. These innovations promise to improve diagnostic precision, democratize access to care, and transform patient management across diverse clinical settings (Figure 1) [3].

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Note: AI-Enhanced Digital Auscultation. This figure illustrates the evolution and application of digital stethoscopes integrated with Artificial Intelligence (AI), representing a paradigm shift toward precision medicine. The schematic is divided into three interconnected columns detailing the transformation from traditional methods to continuous, personalized diagnostics.

Figure 1: AI-Integrated Digital Stethoscope: Transforming Auscultation into Precision Diagnostics.

CONCLUSION

In conclusion, AI-enhanced digital stethoscopes represent a transformative evolution in evidence-based medicine. By improving diagnostic accuracy, reducing inter-observer variability, and enabling early detection of cardiac, pulmonary, and neonatal conditions, they offer substantial clinical benefits. Current evidence supports their utility in pediatric heart murmur classification, neonatal respiratory distress, peripartum cardiomyopathy, chronic pulmonary diseases, and COVID-19 management. Continued technological innovation including wearable devices, sensor fusion, personalized acoustic profiling, and telemedicine integration alongside robust datasets, regulatory oversight, and clinician training, will be crucial for widespread adoption. As these systems mature, AI-powered digital stethoscopes are poised to become indispensable tools for precision, patient-centered care, expanding access, and improving outcomes globally.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest directly related to the content of this manuscript. Professor E. Andrès has conducted fundamental and clinical research under institutional contracts with Alcatel-Lucent and the French National Technology Agency

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