



Artificial Intelligence in Detecting Subclinical Cardiovascular Disease: A New Frontier in Preventive Cardiology

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ABSTRACT

Introduction: The condition commonly referred to as subclinical cardiovascular disease (SCVD) presents in most instances when the disease is not easily diagnosed and tends to progress to a more severe phase. Early detection has become one of the most promising trends in cardiology using AI technologies.

Objective: To determine the usefulness of artificial intelligence in identifying subclinical cardiovascular disease and its usefulness in early diagnosis and prevention in tertiary care. **Materials and Methods:** A survey was conducted on 200 patients visiting the Department of Cardiology, Hayatabad Medical Complex Peshawar, Pakistan. Information from ECGs, echocardiograms, and biomarkers was analyzed using AI algorithms to establish signs of early cardiovascular disease. This was done to compare it with the traditional diagnosing technique.

Results: AI models are highly accurate in identifying early signs of left ventricular dysfunction, arterial stiffness, and endothelial dysfunction in asymptomatic persons. It was found that the overall detection rate of AI was 85%, which was higher than the traditional approaches to diagnosis. **Conclusion:** AI presents an early and accurate approach towards identifying SCVD, especially for use in preventive cardiology, especially in low-resource environments.

INTRODUCTION

Technology has newly introduced the world to artificial intelligence (AI), which has affected many fields and is regarded as the next big thing in the healthcare sector. Today, the use of AI in CVD diagnosis and management has attracted increasing research attention, especially in SCVD. They are subclinical forms of cardiovascular diseases that include causal conditions that have not developed outward signs but can lead to poor outcomes if not prevented. Regular diagnostic techniques seem to provide little help in unraveling these trends, which is why new methods for the early recognition of risk-based changes are necessary. AI can bring a solution to make diagnostic evaluations more effective, faster, and capable of processing more information and observing details beyond human visibility (1).

CVD remains the leading cause of death, and the death rate is still rising due to such factors as advanced

age, inactivity, and bad diets. While early detection is a crucial tool in addressing this burden, subclinical manifestations go unrecognized because these changes in the brain cannot be detected using conventional imaging or biomolecular techniques. This challenge can be solved with the help of artificial intelligence, machine learning, and deep learning to discover latent and anticipate disease markers and model them (2). AI is implemented in cardiology for various uses, including ECG and echocardiogram analysis, genomics, and wearables. These systems can stitch together numerous approaches and gain a far better understanding of cardiovascular health so that the clinician can intervene before the disease progresses (3).

AI technology research indicates that combining, for instance, medical imaging technology with genetics and ultrasound could mean the difference between accurate

and preventive medicine. For example, combining radiomics with molecular biomarker analysis may demonstrate that tissue structure and function changes precede clinical episodes, which is a solid rationale for early diagnosis (4). This goes with diagnosing SCVD since other diagnostic techniques might not help detect early pathological changes. The disease situations are well detected by these ICTs with high sensitivity and specificity (5). Another important branch of AI application is to apply AI in the diagnosis of cardiovascular disease, and because women stakeholders have less specific symptoms or nonspecific symptoms, gendered inequality in medical care.

Therefore, by implementing specific methods, such as machine learning, AI-based applications for screening can be modified according to individual risk factors and exclude bias (6). Other non-supervised ML approaches are essential in finding patterns within the data and differentiating between diseases. This is particularly so where there is scarce labelled data or when getting the labelled data may be challenging (7). Moreover, technologies for bone density examination, including DEXA, utilize AI to predict subclinical cardiovascular disease using vascular calcifications and arterial health indicators (8). AI demonstrates its versatility through its ability to transform existing clinical tools for expansion into broader diagnostic utilization domains.

Medical advancements in cardiology result from multimodal imaging system integration with molecular diagnostic tools to screen for cardio-toxic effects before cancer treatment or non-cardiac procedures. AI is the overarching system that completes data integration across various sources while performing complete risk evaluation and monitoring (9). Emerging techniques utilize AI algorithms to process data from proteomics and metabolomics sources so scientists can better identify cardiovascular risk markers and track concealed disease indicators that lead to clinical manifestations. The approaches deliver insights about cardiovascular metabolism and show how to prevent heart problems (10). Recent research demonstrates that Pakistan and other local countries assess AI applications through studies that show feasibility and clinical benefit in detecting and managing CVD while optimizing resource-limited healthcare systems (11).

AI applications in cardiovascular medicine undergo current research validation and real-world system deployment experiments. AI serves as a fundamental tool for cardiology practitioners throughout the world because it provides guidance for medical decisions while also automatically interpreting images (12). The implementation of AI detection systems has propelled breast arterial calcifications into SCVD diagnosis through the identification of their cardiovascular risk potential, although these biomarkers were previously dismissed (13). By improving electrocardiographic data

with AI models, doctors can detect left ventricular systolic dysfunction while accurately predicting patient mortality risk to achieve better medical outcomes (14). Through ongoing unsupervised learning, researchers verify AI's potential to expand cardiovascular diagnostic capabilities. AI reveals hidden patterns and clusters within clinical data that make it possible to switch from a crisis-oriented approach to integrated cardio care (15). AI in detecting SCVD is not just a technological advancement but a revolution in the approach to preventive cardiology that can revolutionize preventive cardiovascular medicine and substantially alleviate the global cardiovascular disease burden.

Objective

This study aimed to assess AI technologies for screening asymptomatic CV disease to determine whether the technology can help improve early diagnosis and preventive measures in cardiology.

MATERIALS AND METHODS

Design: Cross-sectional Study.

Study setting: This study was done at the Department of Cardiology, Hayatabad Medical Complex Peshawar, Pakistan

Duration: This study was conducted prospectively and took six months, in the period defined from January, 2024 to June, 2024.

Inclusion Criteria

The target audience for the study was comprised the outpatient adult population of 30 years and above who meet clinical study criteria, including hypertension, diabetes, or dyslipidemia, but have no clinical cardiovascular disease history. These patients was identified from cardiology outpatient clinics, where they undergo a regular cardiovascular evaluation. The study got permission from the respondents, and assent was sought from all participants.

Exclusion Criteria

Any patient with a history of myocardial infarction, stroke, or documented coronary artery disease was excluded. Furthermore, subjects with other severe comorbid illnesses, such as cancer or renal failure that affect cardiovascular risk estimation, was not included. Pregnant women, along with participants who cannot give informed consent because of cognitive limitations, was not included in this research.

Methods

The investigation applies multiple data detection methods informed by artificial intelligence to assess subclinical CVD manifestations. The people in the study was gone through cardiovascular diagnostic tests, such as ECG, echocardiography, and blood tests of cholesterol and C-reactive protein. These data sets was

analyzed through AI algorithms and markers or predictors of SCVD, including early markers of left ventricular dysfunction, arterial stiffness, and endothelial dysfunction. Machine learning and deep learning type AI models was given a partial dataset to understand the mapping of clinical measurements to subtle cardiovascular pathophysiologic changes. Echocardiogram images and other modalities are acquired by aided image-recognition machines since the cardiovascular changes that inaccessible to human eye. A statistical investigation analyzed AI diagnostic accuracy through comparisons between AI results, clinical outcomes, and traditional diagnostic approaches.

RESULTS

This study assessed AI technology's performance in identifying asymptomatic cardiovascular disease among patients visiting the cardiology department at Department of Cardiology, Hayatabad Medical Complex Peshawar, Pakistan. Two hundred patients fulfilled study criteria, allowing their enrollment. Each participant received an extensive cardiovascular analysis, including ECG testing, echocardiography, and blood work examination. The collected data underwent analysis by AI-based algorithms, which searched for signs indicating subclinical cardiovascular disease.

Table 1
Demographic Characteristics of Study Participants

Demographic Factor	Frequency (n = 200)	Percentage (%)
Age (years)		
30-40	45	22.5
41-50	70	35
51-60	55	27.5
61+	30	15
Gender		
Male	120	60
Female	80	40
Risk Factors		
Hypertension	140	70
Diabetes Mellitus	100	50
Dyslipidemia	90	45

AI assessment detected SCVD signs in patients showing no clinical symptoms of the disease. AI-based models identified a direct link between known cardiovascular risk factors, particularly hypertension, diabetes, and dyslipidemia, and subclinical cardiovascular function abnormalities. The AI system detected early-stage left ventricular dysfunction in patients with hypertension by combining echocardiographic image assessment with ECG data analysis.

Table 2
Prevalence of Subclinical Cardiovascular Abnormalities Detected by AI

Cardiovascular Abnormality	Detected by AI (n = 200)	Percentage (%)
Left Ventricular Dysfunction	40	20

Arterial Stiffness	60	30
Endothelial Dysfunction	45	22.5
Subclinical Coronary Artery Disease	30	15
No Abnormality Detected	25	12.5

The AI-based echocardiographic analysis indicated that left ventricular dysfunction existed in 40% of participants, together with arterial stiffness affecting another 30% of participants. AI detection revealed preclinical abnormalities that standard medical evaluation methods failed to identify. The capability of AI models to detect inactive disease conditions became clear through their detection of 45% endothelial dysfunction alongside 30% coronary artery variations in examined patients.

AI models achieved high precision in detecting SCVD through diagnostic methods that outperformed standard clinical diagnostic tools. The AI system achieved an accuracy of 85% for detecting SCVD when evaluated through comparative clinical assessments, whose results validated an 80% specificity and 90% sensitivity.

Table 3
Performance of AI in Detecting SCVD Compared to Traditional Methods

Diagnostic Method	Sensitivity (%)	Specificity (%)	Accuracy (%)
AI-based System	90	80	85
Traditional Methods	70	75	72.5

An AI-based system demonstrated higher performance than conventional methods regarding sensitivity and specificity, which proves its potential value as an early detection tool for SCVD. Standard cardiovascular screening must include AI integration as an essential measure because it provides vital high-risk assessments for individuals before clinical symptoms surface.

DISCUSSION

Artificial intelligence (AI) technologies enable improved detection and treatment of both cardiovascular diseases (CVD) and subclinical cardiovascular disease (SCVD). Studies examined AI systems for detecting subclinical cardiovascular disease within the patient population at the ²Department of Cardiology, Hayatabad Medical Complex Peshawar, Pakistan. Research demonstrates how artificial intelligence can find cardiovascular conditions that standard diagnostic procedures usually fail to identify. The research shows artificial intelligence has the potential to both enhance preventive cardiology infrastructure and discover diseases early in situations where health resources are limited, such as Pakistan. Medical detection of early cardiovascular diseases holds key importance because asymptomatic pathologies progress until cardiac arrest occurs, as either heart failure or myocardial infarction. Standard diagnostic approaches involving ECG tests,

echocardiograms, and blood tests have proven essential but show limited ability when detecting subclinical cardiovascular disease in asymptomatic individuals.

This is where AI comes in as a highly advanced way of analyzing a large amount of data and providing much more accurate results than standard human analysis (1). The AI models in this study offered excellent predictive values for differentiation between SCVD and non-SCVD patients in terms of left ventricular dysfunction, arterial stiffness, and endothelial dysfunction. These outcomes explain how diagnostic tools are limited and how AI will enhance early detection. One of the most valuable findings of the current study was to prove the AI capability for assessing left ventricular dysfunction in 20% of the patients without any clinical signs of such dysfunction. Left ventricular dysfunction is a significant predictor of heart failure, and it is generally challenging to identify at an early stage. This may be because detecting this condition before it manifests into symptoms may lead to early management through changing behavior, or using medications that are likely to arrest the expected progression of heart function decline.

An analysis of how AI sees the images and data that cannot be seen in echocardiographic images and ECG data supports the ability of machine learning algorithms to make more accurate diagnoses (2). Such research findings align with earlier studies. AI can effectively diagnose LVD with high sensitivity and specificity during the first stages of cardiovascular risk assessment, comparable to previous study results. Besides LV dysfunction, AS was identified in 30% of participants and is a proven predictor of cardiovascular disease. It may not cause symptoms in the early stage and presents itself when additional problems, such as hypertension or stroke, occur. AI models in study were able to predict arterial stiffness in asymptomatic patients, which means that AI could potentially be used to monitor patients' cardiovascular risk (4).

The detection of arterial stiffness also correlates with the study finding where AI was reported to enhance arterial health assessment in patients predisposed to conditions such as diabetes, hypertension, and dyslipidemia (5). The study results support an AI system for detecting high-risk patients even before their medical conditions manifest symptoms. Researchers detected cardiovascular risk through endothelial dysfunction in 22.5% of the participants selected for the study. Endothelial cells operate diverse vital vascular health capabilities, yet an impaired endothelium signals early cardiovascular disease development (6). AI analysis can identify endothelial dysfunction among asymptomatic patients during the early stages, resulting in better opportunities to begin cardiovascular interventions and manage disease progression. The detection of endothelial dysfunction as a clinical outcome

demonstrates AI's remarkable effectiveness through biomarkers and imaging scans, making it a powerful tool for cardiovascular prevention (7).

The AI system correctly identified subclinical coronary artery disease occurrences among the studied participants in 15% of cases. However, CAD remains undiagnosed until patients develop advanced clinical disease stages, leading to myocardial infarction or angina. The early detection of coronary artery disease is critical because medical interventions become possible through doctors' timely diagnosis of complications. AI detection of early-stage CAD fundamentally changes preventive healthcare by creating individualized treatment methods, including statin medication programs and lifestyle changes for disease progression reduction (8). Many research papers show that AI systems are skillful at identifying hidden inflammatory lesions within imaging scans using advanced analytic methods through standard reading approaches (9). According to this study's primary outcome, AI diagnostic techniques produced superior results compared to regular diagnostic procedures. Table 3 demonstrates that AI diagnostic tools outperform traditional diagnostic techniques because of improved detection capability, resulting in an 85% accurate assessment.

Research findings that AI surpasses conventional diagnostic testing demonstrate how AI complements other established methods to detect cardiovascular health conditions more accurately. The high diagnostic capabilities of AI for SCVD detection represent an essential tool to stop cardiovascular conditions from advancing into more serious conditions. The ability of AI systems to evaluate massive datasets while spotting unclear patient patterns is a primary benefit for early disease identification (10). The study's outcomes hold immediate practical value for Pakistani healthcare facilities because cardiovascular conditions act as significant contributors to mortality and disability in this resource-constrained environment. Early SCVD screening through AI technology addresses healthcare accessibility challenges because it serves communities that lack access to advanced diagnostic technologies.

AI diagnostic tools built for regular cardiovascular screening services help providers find developing diseases and start treatment immediately in locations with minimal healthcare funding (11). AI makes healthcare professionals' lives easier through automated diagnosis and data interpretation, which enables them to focus on essential patient care tasks and executive functions. The outcomes from this research hold promise, yet multiple constraints warrant attention. The results from this research only apply to a specific tertiary care hospital population, which limits their broader applicability. Future analysis should enlarge sample diversity by testing healthcare participants from various

geographical backgrounds across risk groups. AI demonstrates adequate sensitivity and specificity, but its implementation in clinical practice needs additional validation based on broader testing with real-world data (12).

Healthcare AI deployment needs attention to ethical points, such as protecting patient data privacy while maintaining clear algorithm transparency (13). This study shows that AI has significant potential to detect cardiovascular disease before it becomes clinical and enhance early disease recognition. Combining AI algorithms and multimodal data analysis allows healthcare providers to detect at-risk individuals before their medical symptoms appear. These study results show AI working with standard screening procedures to improve preventive cardiology methods, specifically for resource-constrained areas. Further research and model validation will determine how AI models can achieve their best clinical potential while improving patient health outcomes.

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CONCLUSION

This research shows how artificial intelligence technology is promising for finding subclinical cardiovascular disease early in tertiary care patients. AI systems detected cardiovascular abnormalities with low detection rates during routine testing because they identified subtle conditions like left ventricular dysfunction, arterial stiffness, and endothelial dysfunction, even in patients showing no symptoms. AI models demonstrate high accuracy rates in detecting subclinical cardio-vascular disease SCVD, which proves their effectiveness in initiating prompt cardiovascular risk evaluation procedures. The diagnostic gap in Pakistan's resource-constrained healthcare system could benefit from artificial intelligence, which offers medical providers effective screening methods for vulnerable patients. Additional confirmation from large population-wide trials alongside various racial groups will be vital for achieving standard clinical AI adoption. Preventive cardiology will experience revolutionary change because AI technologies enable early diagnosis and individualized treatment protocols.

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