The Role of Artificial Intelligence in Early Detection of Cardiovascular Diseases

Dr Sabahat Ali Sheikh[1], Dr Asif Khan[2*], Dr Khadija Sarwat Farooqui[3], Dr Zainab Rauf[4], Dr Moazama Shakeel Ahmed[5], Dr Kashif Zia[6]

[1]*University of Lahore Sargodha Campus, Pakistan*
[2]*Medical Officer, Department of Cardiology, Peshawar Institute of Cardiology, Pakistan*
[3]*Cardiologist, Cardiac Emergency, NICVD Karachi, Pakistan*
[4,5]*House Officer, Department of Internal Medicine, King Edward Medical University/ Mayo Hospital Lahore, Pakistan*
[6]*Assistant Professor, Cardiac Surgery Department, Sindh Institute of Cardiovascular Diseases (SICVD), Larkana, Pakistan*

***Corresponding author:** Dr. Asif Khan, Email: asif2k18@gmail.com*

KEYWORDS

ECG, echocardiography, machine learning, cardiovascular disorders, early detection, artificial intelligence, and risk assessment.

ABSTRACT

Introduction: Cardiovascular diseases (CVDs) are a leading cause of morbidity and mortality worldwide. Early diagnosis is crucial for better patient outcomes and effective care. Artificial intelligence (AI) has emerged as a viable method in cardiology that enhances risk assessment and diagnostic accuracy..
Objectives: This study compares the accuracy, sensitivity, and specificity of AI-assisted diagnostics with conventional techniques in order to assess the usefulness of AI in the early diagnosis of CVDs.
Materials and Methods: From January to June 2024, an observational study was carried out at NICVD Karachi Pakistan. 500 patients' ECG and echocardiogram data were examined using AI algorithms, and the results were compared to evaluations made by cardiologists.
Results: AI performed better than conventional diagnostic techniques, showing increased sensitivity (94.2%) and specificity (91.5%). 20.8% of preclinical anomalies were successfully identified by AI, resulting in earlier actions..
Conclusion: Early CVD detection is much improved by AI, which also increases diagnostic accuracy. For wider clinical adoption, data bias, ethical issues, and implementation hurdles must be addressed.

INTRODUCTION

AI has emerged as a cutting-edge clinically beneficial technology that has proven successful in the diagnosis of heart conditions. Healthcare managers have a good chance to use artificial intelligence in patient diagnosis and treatment due to the increase in heart disease cases worldwide, which will improve overall wellness (1). Early heart illness identification and coverage of mortality rates associated with CVD within a given time frame have been made possible by the application of AI in ECG and other diagnostic procedures (2). Over the years, there has been the development of other models of deep learning machine learning in relation to illness prediction as well as risk assessment among patients with cardiovascular diseases in the past decade (3). Independent Early Risk Detection systems have new definitions due to Artificial Intelligence in imaging systems, wearable technology, and screening means. This makes it possible for practitioners and doctors to identify people who could possibly be suffering from the disease at a stage before complications start manifesting themselves (4).

ECG, which was earlier considered to be less accurate than the new approaches in diagnosing atrial fibrillation, heart failure and other diseases (1). It is demonstrated that these AI-based algorithms capture ECG signals with better accuracy in comparison with the traditional methods or define the changes that may indicate a cardiovascular disease (5). For example, technologies such as automated detection of echocardiograms have high sensitivity and specificity in discovering patients with severe CAD without requiring cardiologists to interpret the images (6). In addition,

based on wearable sensing data, AI has been able to ascertain continuous cardiac activity and signs of early HF, arrhythmias, and MI (4). This list-based real-time monitoring helps in improved patient management as the physicians can attend to patients at the right time thus preventing further complications and improving their long-term outcomes (7).

AI's capacity to analyze many data types, such as imaging, genetic, and patient history data, to produce a thorough risk report is an additional benefit in the diagnosis of cardiovascular diseases (8).. Machine learning algorithms that take into account lifestyle decisions, medical history, and molecular markers can effectively predict the risk of CVDs (7).. As these models draw from the mass of data, they improve their accuracy in predicting the risk probabilities of such people (9). As one example, explainable AI in the diagnostic imaging area that looks specifically at SPECT imaging has enabled clinicians to increase the diagnostic accuracies of coronary artery disease by providing them with insights into disease dynamics and patterns (9). The explainability aspect of AI models will also guarantee accountability, whereby the provider of the AI-generated prediction will have the capacity to understand and incorporate it in developing the treatment pattern (10).

However, there are problems with using AI in clinical settings for cardiovascular disease diagnosis. The quality and diversity of the training data set, which occasionally has limited coverage, are what give an AI model its credibility in generalization (11). This picture includes important means that have to do with patient rights to privacy and their data, data security, and the problematic issue of algorithm bias, as well as other concerns that limit the implementation of AI systems across healthcare practices (12). Besides, AI integration in clinical practice, it is crucial to note that it requires a brainstorming effort from data scientists, cardiologists, and healthcare policymakers to guarantee their safety in using AI-driven tools (13). Additionally, the roles of AI are also constantly changing in the field of medicine, and there should be strict regulation of AI-based solutions to ensure they meet the required regulatory standards for their validation and approval for using them in clinics (14).

AI applications in early CVD screening are not limited to diagnosis but are actively involved in therapy and treatment. Artificial Intelligence Decision Supporting Systems in turn help doctors identify the best course of action that is suited to a specific patient and subsequently improve the overall outcomes (15). For instance, the automated interpretation of the ultrasound images of the heart especially using echocardiography has aided in the detection of early symptoms of not only heart failure but also valvular diseases (15). Additionally, telemedicine has been given a boost from applications of artificial intelligence because patients in most remote areas consult with cardiologists without the need to physically present themselves for an appointment (14). Using AI chatbots and virtual health assistants, patients can get suggestions of lifestyle changes or medication compliance promptly, thus relieving pressure off the healthcare facilities and improving the patients' activation in disease prevention (13).

Lastly, the application of AI has strengthened, improved, and expedited the early detection of cardiovascular illnesses. Therefore, enhancing the use of artificial intelligence in wearable technology, cardiovascular imaging, ECG interpretation, and cardiovascular disease diagnosis has improved patient outcomes and decreased the prevalence of cardiovascular disorders worldwide. (12). However, there are issues with the privacy of information used, biased algorithms, and regulatory policies that should be solved to enhance the use of AI in clinical practice (11). , which would be a breakthrough shortly due to the continuous advancement in research and technology (22) in the field of AI that augurs well for the better management and diagnosis of cardiovascular diseases early enough (8).

Objective: This study aims to assess artificial intelligence's contribution to cardiovascular disease early detection, with particular attention to the technology's predictive power, diagnostic precision, and influence on clinical judgment.

MATERIALS AND METHODS

Study Design: This hospital-based observational study aims to assess the potential utility of artificial intelligence (AI) in early cardiovascular disease (CVD) diagnosis. It combines real-time AI-assisted diagnostic tools with retrospective data analysis to evaluate their accuracy and reliability in contrast to traditional diagnostic procedures.

Study setting: The study was carried out NICVD Karachi Pakistan.

Duration of the study: The study was carried out between January and June of 2024, a period of six months.

Inclusion Criteria

The participants included patients 40 years and above with hypertension, diabetes, hyperlipidemia, obesity, or a family history of CVD. High-risk cardiac patients and patients having normal cardiac health screening were also included in the study, along with the clients who complained of slight or moderate cardiac disorder, chest pain or palpitation in particular. The retention of a high degree of AI coverage was made possible by confining the study patients to those who had both ECG and echocardiographic data to be used in the study.

Exclusion Criteria

The patients with risk factors of congenital heart disease, severe heart failure, or prior cardiovascular operation such as bypass surgery or stent insertion were thus excluded. In this study, several factors that could affect cardiovascular evaluation results, such as end-stage renal diseases/terminal cancer, were also excluded. These patients either had no documented clinical notes or refused to be part of the diagnostic system to increase the validity of the data to work on the paradigm.

Methods

The data from this research were collected through a process entailing analysis of past medical records and real-time AI diagnostic methods to determine the efficiency of AI in diagnosing cardiovascular diseases (CVDs). Recorded data of ECG, echocardiography and clinical profiles of the patients were retrieved from the admitted patients of the NICVD Karachi Pakistan for the period of study from January 2024 to June 2024. Relationships with cardiovascular risk variables were calculated using machine learning and deep learning approaches. In clinical practice, the diagnostic software was integrated into standard testing for real-time analysis.. They analyzed ECG and echocardiographic information and found out that the patient had arrhythmias, ischemic heart disease, and LV dysfunction. The results were compared with those of conventional cardiology evaluation to audit the levels of agreement with the proposed AI diagnostics. To evaluate the performance of assessments made by the AI system, sensitiveness, specificities, and predictability were estimated. Since the study involved human participants, it was approved ethically and all the participants consented to be in the study. The results were then statistically analyzed to ascertain the effectiveness of AI diagnostic acumen.

RESULTS

500 participants who met the study's inclusion criteria at NICVD Karachi Pakistan were evaluated between January and June of 2024. The average age of the participants was 58.6 ± 10.4 years, with 35% of them being female and 65% being male. AI-assisted diagnostic tools were used to assess ECG and echocardiography data, and their accuracy was contrasted with that of conventional cardiologist evaluations..

AI Diagnostic Performance vs. Traditional Methods

When compared to cardiologists' manual interpretations, the AI model showed **greater sensitivity (94.2%) and specificity (91.5%)** in identifying cardiovascular illnesses. AI found a**nomalies in 87.3%** of patients with early-stage heart disease, while conventional techniques found anomalies in 76.5% of patients. AI demonstrated significantly higher accuracy in **identifying arrhythmias, ischemic heart disease**, and left ventricular failure.

Table 1: Diagnostic Accuracy of AI vs. Cardiologist Assessment

Diagnostic Parameter	AI Accuracy (%)	Cardiologist Accuracy (%)
Sensitivity	94.2	87.8
Specificity	91.5	85.2
Arrhythmia Detection	92.8	83.4
Ischemic Heart Disease	89.3	81.6
Left Ventricular Dysfunction	93.1	84.7

AI-Based Risk Stratification and Predictive Analysis

Low, moderate and high-risk patients were identified with the help of clinical history, echocardiogram patterns and ECG ratings established by using AI models, and it was seen that 88.5% of high-risk patients were diagnosed with the help of AI, while it was 76.9% of conventional techniques.

Table 2: AI-Based Risk Stratification vs. Traditional Methods

Risk Category	AI Correct Prediction (%)	Traditional Prediction (%)
Low Risk	96.2	89.4
Moderate Risk	91.8	84.7
High Risk	88.5	76.9

AI-Driven Early Detection and Intervention

In 104 cases (20.8%), AI helped the clinician diagnose cardiac issues in the preclinical stages that were not detected by the previous diagnostic methods. This led to early interventions as regards this, reducing the potentiality for other cardiovascular issues.

Table 3: Early Detection Rate by AI vs. Traditional Methods

ɛtection Parameter	AI Detection (%)	Traditional Detection (%)
Preclinical Abnormalities	20.8	12.4
Early-Stage Ischemia	23.5	15.7
Asymptomatic Arrhythmias	18.9	10.2

From these outcomes, it is clear that AI is superior to conventional approaches in diagnosing CVDs earlier and with better precision, thus benefiting the patient and allowing for timely treatments.

DISCUSSION

The research discussed within the framework of this paper reveals the applicability of artificial intelligence in the early diagnosis of cardiovascular diseases. This paper examines the importance of accurate diagnosis of CVDs since they are affecting the global population at an alarming rate, thereby requiring timely intervention in order to minimize the risk of fatality. Diagnostic devices have also been proven to be more efficient in diagnosing any form of cardiac problems than other conventional methods at an advanced stage. However, AI has some benefits, such as the capacity to process vast amounts of information, identifying patterns in echocardiogram and ECG results, and correctly predicting the likelihood of a disease (1). At the same time, it is necessary to state that the results of this study showed that the use of AI could be useful in the diagnosis and, in particular, in early identification since this approach allowed to achieve higher sensitivity and specificity in the diagnosis of various diseases, including arrhythmia, ischemic heart disease and dysfunction of the left ventricle (2).

It can be used to enhance the concept of risk stratification in the following ways. The extant methods are not AI-based, so they could be nonstandard, hence the discrepancies in the measurements produced by different clinicians. AI systems employed for this work were also useful in identifying the group of pathogens in the patient's system with low, moderate, and high risk more effectively than other alternatives. This led to early intervention because the improved

risk categorization also enabled physicians to prevent the worsening of the disease (3). This capability corresponds with the findings of prior studies, which showed that the AI-based models improve the effectiveness of the treatment as it is different for each patient depending on their cardiovascular conditions. Thus, risk assessment based on AI has the highest application in Primary care facilities because it can help to identify the at-risk groups to offload the burden faced by Tertiary care facilities and enhance patient outcomes (5).

Another important conclusion of this study is the fact that AI outperforms clinicians in the identification of preclinical changes. This situation means that the conventional diagnostic modalities are inadequate in diagnosing yet unidentified cardiac diseases, especially those that are dormant. Nevertheless, AI had higher sensitivity compared to the conventional methods of diagnosing by identifying subclinical changes in 20.8% of patients (6). It was important for the early detection of sudden cardiac events as they may occur in persons who do not present any form of symptoms. It does this through processing large volumes of data, finding the patterns that could remain obscure to human practitioners and presenting the findings to clinicians (7). The usage of AI in wearable devices improves the continuous monitoring process and helps in the early identification of heart rhythm disturbances and risk of life-threatening issues (8).

There are still a few noteworthy obstacles, though, and they are all related to the therapeutic use of AI in cardiovascular diagnostics. This is a serious issue because AI models must be trusted everywhere or else there could be terrible results. As a result, the quality of the training sets and the variety of the data used for training determine the quality of the parameters that an AI system utilizes for projection. The predictions made by AI algorithms will also be less accurate in certain demographic segments if the datasets used for AI training do not include all of them (9). It is crucial to use data from other ethnicities and other economic brackets for the training of AI models to increase their clinical usefulness and equity (10). This makes it even more crucial that ethical considerations play a big role in the application of AI in the medical field. Other parties or persons must not have access to or use patient data, especially for illegal purposes. As with most diagnosis models that are dependent on patients' data, AI diagnosis raises questions about privacy and appropriateness in handling a patient's data (11). These are the issues that could be addressed by achieving improved data security, adherence to the regulation norms, and including the explanation of AI techniques in the process (12). Further, currently, there is a requirement for validation and testing for AI algorithms to be used more frequently in clinical practice (13).

Another issue is the current healthcare system's embrace and integration of AI. The diagnostic using AI can only be done in advanced hospitals and clinics that have the IT support and infrastructure to enable the process. Some limitations of the deployment of artificial intelligence include cost may include the costs of acquiring the hardware, and software as well as the costs incurred in training a new team of workers to work under the new system (14). Solving these problems presupposes the cooperation of healthcare organizations, information technologists and policymakers to implement cost-effective solutions that can be easily incorporated into clinical practice (15). AI is not only confined to early diagnosis but also delivers value regarding disease treatment as well. The decision support system is an artificial intelligence technology that enables doctors to make decisions on the best treatment approaches to use depending on the situation with the patient. For instance, echocardiographic imaging can be used to diagnose and estimate the change in cardiac function or suggest treatment (14). Also, AI has increasingly integrated into telemedicine and bridged the gap when it comes to access to cardiovascular health care in rural areas. Wearable technology accompanied by the use of artificial intelligence in the monitoring of patients promotes a more efficient way of patient assessment as opposed to conventional frequent hospital administration (13).

It is also significant to know how expertise works in AI-supported diagnosis. However, AI can applied to improve the discrimination of acute kidney injury and also should not act as a substitute for clinical decision-making. On the contrary, AI should remain an auxiliary process aimed at providing doctors and other healthcare workers with relevant information. Such programs remain indispensable to prepare clinicians for the role of deciphering AI-generating insights and to

incorporate the information into care delivery to ensure the optimal application of AI in cardiology (12). AI should be considered as an assistant technology which accelerates the diagnostic process and does not replace an expert's knowledge (11). Finally, there is a growing use of AI in CVD diagnosis, improving real-time tracking, risk distinction, and test accuracy. The conclusions of this study provide the support that is needed to agree with the capability of AI in identifying cardiovascular diseases at an early stage that will result in improved patient outcomes. Nevertheless, some threats need to be discussed, namely, data bias, ethical issues, and infrastructural issues to consider for the integration of AI into daily practice.

CONCLUSION

This study demonstrates how artificial intelligence (AI) can improve patient monitoring, risk assessment, and diagnostic accuracy, thereby contributing to the early diagnosis of cardiovascular diseases (CVDs). It was found that using AI-based models increased sensitivity and specificity when it came to identifying cardiac abnormalities, which in turn reduced the effects of such complications. AI is highly effective in the interpretation of detailed clinical data, echocardiography of the heart, and electrocardiograms (ECGs), which in turn translates to timely intervention and improved patient outcomes. It is still necessary to address some shortcomings, such as data bias, ethical concerns, and integration challenges, to ensure the broader application of the model in medical practices. To balance the approaches to properly utilize AI-enhanced diagnostics in practice while protecting the patients and their information, it is necessary to involve lawmakers, developers, and clinicians. Therefore, it can be safely assumed that with further advancements in AI in treating CVDs, the identification of the ailment in its early stages will become cheaper, faster, and far-reaching, in turn lessening the weight of CVDs on humanity.

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