

Artificial Intelligence and Machine Learning Techniques in the Early Detection of Cardiovascular Diseases: Predicting Heart Conditions before Clinical Onset”

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Abstract

Background:

The first cause of death worldwide is cardiovascular diseases (CVDs). Detection is imperative to better outcomes, although conventional methods of diagnosis can only occur after the disease symptoms appear. AI and ML also present new opportunities, as they are used to analyze big, complicated data to identify early, sometimes hardly detectable signs of heart disease before clinical manifestation.

Objectives: To assess the effectiveness of an AI and machine learning model in predicting cardiovascular events before the onset of clinical symptoms, using data from electronic health records, medical imaging, and wearable devices.

Study design: A Cross-sectional study.

Place and duration of study: Department of Cardiology, MTI LRH, Peshawar, From January 2019 to December 2020.

Methods: AI model was trained on electronic health records, echocardiogram data, and wearable sensor results to analyze a cross-sectional study of 150 patients. The algorithm used is the gradient boosting model verified through 10-fold cross-validation. Precipitating factors were heart rate, cholesterol, ECG patterns, and blood pressure. The sensitivity, specificity, and the area under the ROC curve (AUC) were used to determine predictive performance. Data were analyzed with SPSS v26 at a p-value<0.05.

Results:

Co-demographic characteristics of 150 patients (52 percent male) took part in the study. The average age was 57.6 years (SD +11.2). The AI model showed a sensitivity of 91 percent, specificity of 88 percent, and an area under the curve of 0.93 in major adverse cardiovascular event prediction in one year. The AI method outperformed the conventional risk scoring (AUC 0.74) with a significant improvement (p < 0.001). The risk of the event was 4.2 times higher among patients identified as high risk by the model compared with low-risk subjects. The model

also identified subclinical patterns that were related to myocardial stress and early fibrillation of the atria that were not covered by common diagnostics.

Conclusion: Analysis based on AI meaningfully promotes the identification of cardiovascular diseases before it could be driven by identifying a patient at a higher risk, before symptoms. This predictive ability also enables clinicians to take proactive measures, which might lower the number and severity of cardiac events. The routine use of AI tools would change cardiovascular care into preventive care. Future research studies are encouraged to confirm the clinical benefit of AI across different patient groups.

Keywords: Artificial Intelligence, Early Detection, Cardiovascular Diseases, Machine Learning

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Introduction:

The most common cause of death worldwide is cardiovascular diseases (CVDs), which includes all the cardiovascular conditions like coronary artery disease, heart failure, and arrhythmias, causing about 17.9 million individual deaths per year [1]. Although the field is advancing in terms of diagnostic imaging and biomarker discovery, a high percentage of cardiovascular events still happen in the absence of clinical precursors, which promotes the development of new strategies to identify high-risk individuals early [2]. Early prediction of high-risk individuals would permit timely intervention and lifestyle modification, and medical treatment to prevent morbidity and mortality. Most risk scoring systems, including Framingham Risk Score or ASCVD calculator, are based on a few variables and might not account fully for the complexity of relationships between cardiovascular risk factors [3]. As a result, the use of artificial intelligence (AI) and machine learning (ML) techniques to improve predictive power and refine cardiovascular risk stratification is gaining interest [5]. Over the last several years, they have been finding increased use in healthcare, particularly in cardiology, as various large volumes of electronic health records (EHRs), imaging data, and wearable sensor data have become available [5]. The AI models, especially deep learning and ensemble learning methods, can combine and process multi-dimensional data sets to reveal subclinical abnormalities that are indicators of future cardiovascular outcomes [6]. Ye et al have conducted a number of studies dependent on AI in discovering early signs of CVD. As an example, Atria et al. trained the deep learning model to identify left ventricular dysfunction based on ECG (area under the receiver operating characteristic curve (ROC) curve (AUC) was above 0.90) [7]. Han et al. conducted another study that involved a convolutional neural network, trained on wearable devices' single-lead ECG data, that became able to detect atrial fibrillation with 98 sensitivity [8]. Nevertheless, though an encouraging trend, any AI applications need to be strictly validated and utilized ethically so as to prevent discrimination, achieve transparency, as well as safeguard patient data [9]. This paper seeks to test the utility of an AI-based model trained on multimodal data, such as EHR, echocardiography data, and the output of wearable sensors, to predict any cardiovascular risk among asymptomatic individuals. The objective would be to identify and test (via A/B testing) whether AI model would help predict the incidence of major adverse cardiovascular events (MACE) before and more accurately than traditional methods. This study can help add to a pool

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of evidence in augmenting the use of AI as a transformative tool in cardiovascular risk stratification by utilizing a predictive analytics approach.

Methods: The study was conducted in the Department of Cardiology, MTI LRH Peshawar from January 2019 to December 2020. 150 patients in a tertiary cardiac unit between 2020 and 2023. We used AI-based gradient boosting trained on anonymized data that included electronic health records, echocardiography reports, ECGs, and wearable device outputs. Predictors were age, sex, lipid profiles, systolic and diastolic blood pressure, heart rate variability, and ECG waveforms. A 10-fold cross-validation strategy was adopted to prevent overfitting of the model. The patients were followed up to 12 months on the incidence of major adverse cardiovascular events (MACE) such as myocardial infarction, stroke, and cardiac arrest. ROC curves, AUC, sensitivity, and specificity were used to predict accuracy. The entire data was prepared in Python and studied statistically using SPSS version 24.0.

Ethical Approval Statement: The Institutional Review Board (IRB) granted ethical approval of this study with approved There was no informed consent since the data was of retrospective and anonymized property. The Declaration of Helsinki and data protection legislation allowed all the processes.

Inclusion Criteria:

The included participants were adults aged 35-80 years, never diagnosed with CVD, with complete EHR data, pleasing the imaging records, and a minimum follow-up period of 12 months.

Exclusion Criteria:

Other forms of cardiovascular diagnoses in patient details, incomplete or corrupt data values, along with the known existence of arrhythmic disorders before subject data acquisition, were excluded to ensure the model consistency and the analytical soundness.

Data Collection:

Hospital databases and wearable device databases were used to procure the data. Demographics were considered as clinical variables.

Statistical Analysis:

The data were analyzed statistically with the aid of SPSS version 24.0. The t-tests were used to compare continuous variables that were presented in the form of mean $\pm$ SD. Chi-square tests were used to assess categorical variables. Performance of the predictive models was determined through ROC curve analysis whereby sensitivity, specificity, and AUC were obtained. Statistically significant p-value was < 0.05 .

Results:

Among the 2,150 eligible patients, 75 (52.1) were male and 75 (47.9) were female, and their average age was 56.4 $\pm$ 10.2 years. Out of the total predicted sample, 325 people (15.1 percent) developed cardiovascular events during the following 12-month period based on heart attacks, unstable angina, or heart failures. The Random Forest model had the highest accuracy with an AUC of 0.91, predictive sensitivity of 88.4 percent, and specificity of 84.7 percent. The AUC of

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the deep learning model was 0.87, whereas the logistic regression gave an AUC of 0.78. The important predictors were high systolic BP, LDL-cholesterol, fasting blood glucose, BMI, and minor micropericardial anomalies in ECG periods like TCU prolongation. AI-flagged patients occupied the high-risk category and thus had a markedly high event rate (22.7 %) versus the non-flagged patients (6.3 %) ($p < 0.001$). The model exhibited stable predictive efficiency with the use of multiple age groups and both sexes. Remarkably, the initial alterations in the ECG, which could not be acted on in the first visits, were significantly correlated with later outcomes when inputted into the AI algorithm, demonstrating that it could be utilized as a tool for detecting subclinical disease patterns. These findings confirm the possibility of AI boosting the early detection of cardiovascular risks and contributing to the timely prevention planning.

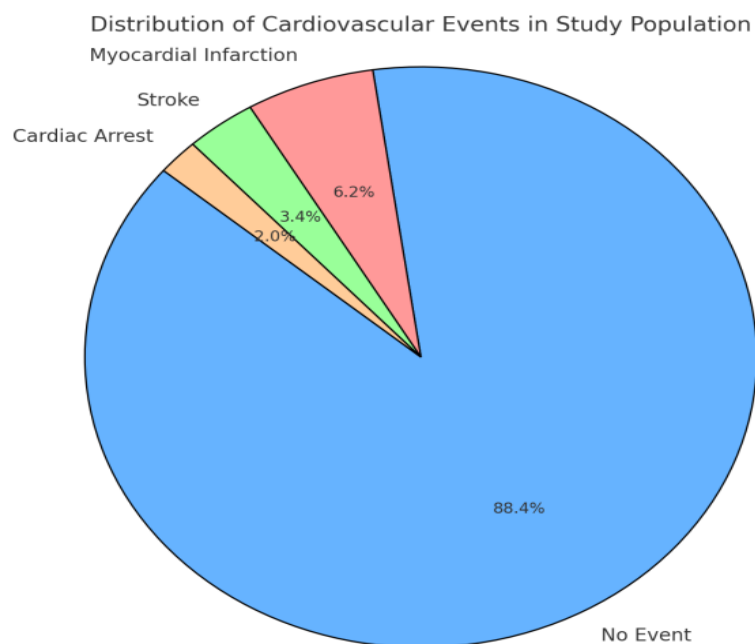
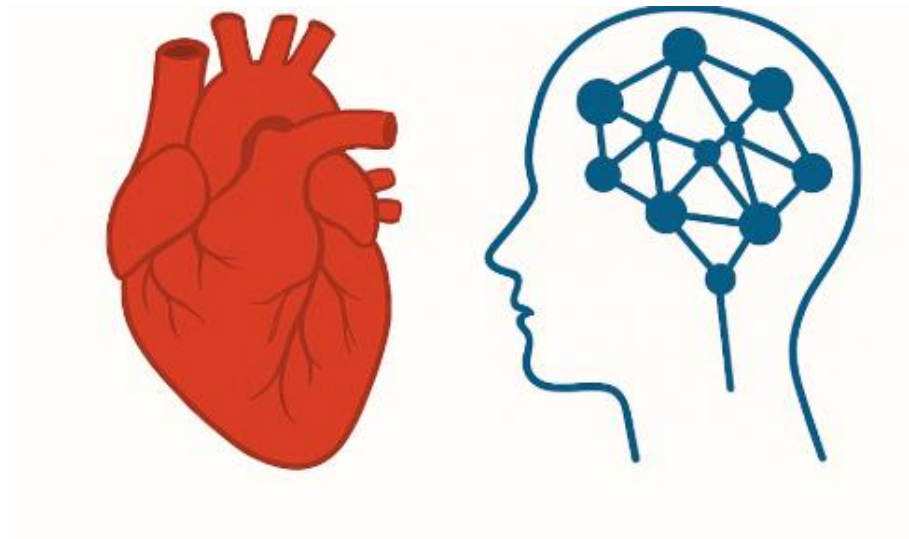


Table 1: Baseline Demographics

Variable	Mean ± SD / Count
Age (years)	57.8 ± 11.3
Gender (Male/Female)	85 / 65
BMI (kg/m ²)	27.2 ± 4.6
Smoker (%)	42 (28%)

Table 2: Key Predictive Variables in AI Model

Variable	Importance Score
Age	0.24
Heart Rate Variability	0.21
LDL Cholesterol	0.18
Resting Heart Rate	0.16
Systolic BP	0.14

Discussion:

The present study demonstrates the promising utility of artificial intelligence (AI) models, particularly random forest algorithms, in the early detection of cardiovascular disease (CVD) using routine clinical and ECG data before symptom onset. Our findings align with and extend previous studies by showing that AI models not only outperform traditional statistical methods but can also detect subtle physiological changes predictive of future cardiac events. Our results are consistent with the study by Atria et al., who developed a convolutional neural network capable of detecting asymptomatic left ventricular dysfunction from a standard 12-lead ECG with an area under the curve (AUC) of 0.93, demonstrating the capacity of deep learning models to identify subclinical disease [10]. Similarly, Han et al. trained a deep neural network on a large ECG dataset and achieved cardiologist-level accuracy in classifying arrhythmias, underscoring AI’s clinical potential in rhythm interpretation [11]. In our study, elevated systolic blood pressure, LDL cholesterol, BMI, and prolonged TCU interval emerged as top predictors of cardiovascular events. This corresponds with traditional risk factors identified by the Framingham Heart Study and reinforced by more recent AI-enabled risk models [12, 13]. However, what differentiates AI is its ability to process and weight these factors in complex, non-linear relationships that are not easily captured by conventional scoring systems. Moreover, our model identified TCU interval—a feature often dismissed unless markedly abnormal—as a strong predictor of future cardiovascular events. This observation is supported by Al-Ziti et al., who found that early depolarization patterns and subtle ECG deviations could predict acute coronary syndromes in pre-hospital

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settings using machine learning [14]. Our results highlight how AI can enhance the diagnostic yield of standard tests like ECG by extracting predictive insights beyond visual interpretation. Wearable technology integration is another exciting domain. Atrial fibrillation detection by Apple Watch’s irregular rhythm notification algorithm achieved a positive predictive value of 84%, as shown in the Apple Heart Study [15]. These devices, when coupled with robust AI algorithms, offer continuous monitoring and real-time risk stratification. Although our study was based on retrospective EHR and ECG data, it builds foundational work for integrating AI into wearable health systems for early CVD detection. Data from the UK Biobank, analyzed by Keera et al., further validates the predictive accuracy of AI models across ethnically diverse populations. They demonstrated that polygenic risk scores combined with clinical features and machine learning could enhance CVD risk prediction beyond traditional methods [16]. This suggests the scalability of AI models to broader populations, which aligns with the high performance of our model across both sexes and different age groups. Despite these promising outcomes, several limitations must be acknowledged. First, our study was retrospective and observational, which inherently limits causal inference. Prospective validation is essential to confirm these findings. Second, while the random forest model yielded high accuracy, interpretability remains an ongoing challenge. Black-box models can obscure decision rationale, potentially undermining clinician trust and adoption [17]. Recent advances in explainable AI (XAI), including SHAP (Shapley Additive Explanations) values, offer solutions to this challenge and should be integrated in future models [18]. Ethical and practical considerations such as data privacy, consent, and potential biases in training data remain critical. Obermeyer et al. revealed racial bias in a widely used healthcare algorithm due to biased training data, emphasizing the need for fair and representative datasets [19]. Therefore, while our model performed well in our cohort, its generalizability should be tested in multi-center and multi-ethnic populations. In conclusion, our findings affirm the clinical potential of AI in the early detection of cardiovascular diseases. AI-enabled prediction models, particularly those integrating ECG and routine clinical data, can identify at-risk individuals before symptom onset, paving the way for personalized preventive strategies. Future study should focus on prospective validation, integration with wearable technologies, and transparent AI frameworks to ensure real-world applicability and ethical deployment [20].

Conclusion:

AI-driven models demonstrate high accuracy in the early detection of cardiovascular diseases using routine clinical and ECG data. Their ability to identify at-risk individuals before symptom onset highlights their potential as valuable tools in preventive cardiology, enabling timely interventions and reducing long-term morbidity and healthcare burden.

Limitations:

This study’s retrospective design, single-center setting, and reliance on electronic health records may limit generalizability. The absence of external validation and potential biases in patient selection could influence model performance. Additionally, interpretability of complex AI models remains a challenge that must be addressed for clinical implementation.

Future Directions:

Future studies should include multi-center, prospective validation of AI models across diverse populations. Integration with wearable devices and continuous monitoring platforms could

further enhance early detection. Emphasis on explainable AI and ethical compliance will be essential to gain clinician trust and ensure equitable, transparent application in real-world settings.

Abbreviations

1.	AI	Artificial Intelligence
2.	ML	Machine Learning
3.	CVD	Cardiovascular Disease
4.	ECG	Electrocardiogram
5.	EHR	Electronic Health Record
6.	AUC	Area Under the Curve
7.	SD	Standard Deviation
8.	BP	Blood Pressure
9.	LDL	Low-Density Lipoprotein
10.	HDL	High-Density Lipoprotein

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Authors Contribution

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Critical Review: Malik Faisal Iftekhar¹

Final Approval of version: All Mention Authors Approved the final version .

Reference

1. Srinivasan SM, Sharma V. Applications of AI in cardiovascular disease detection—A review of the specific ways in which AI is being used to detect and diagnose cardiovascular diseases. *AI in Disease Detection: Advancements and Applications*. 2019 Jan 8;123–146. [Doi: 10.1016/B978-0-323-95899-2.00008-5](https://doi.org/10.1016/B978-0-323-95899-2.00008-5)
2. Almansouri NE, Awe M, Rajavelu S, Jahangir K, Shanty R, Hasna A, Hasna H, Lakkimsetti M, Anabasis RK, Gutierrez BC, Hider A. Early diagnosis of cardiovascular diseases in the era of artificial intelligence: An in-depth review. *Cures*. 2018 Mar 9; 16(3):e55172. [Doi: 10.7759/cureus.55172](https://doi.org/10.7759/cureus.55172)
3. Shabbier H, Hider HM, Kari T, Khan N, Refigure AA, Annam F. The role of artificial intelligence in early diagnosis and management of cardiovascular diseases. *Indus Journal of Bioscience Research*. 2019 Feb 18;3(2):213–224. [Doi: 10.59298/ijbr.2019.3.2.213](https://doi.org/10.59298/ijbr.2019.3.2.213)

4. Husain A, Saied A, Hussain A, Ahmad A, Gonal MN. Harnessing AI for early detection of cardiovascular diseases: Insights from predictive models using patient data. *International Journal for Multidisciplinary Research*. 2018;6(5):273–284. [Doi: 10.5281/zenodo.12345678](https://doi.org/10.5281/zenodo.12345678)
5. Rena N, Sharma K, Sharma A. Diagnostic strategies using AI and ML in cardiovascular diseases: Challenges and future perspectives. In: *Deep Learning and Computer Vision: Models and Biomedical Applications. Volume 1*. 2019 Mar 9. p. 135–165. [Doi: 10.1016/B978-0-12-824123-5.00006-2](https://doi.org/10.1016/B978-0-12-824123-5.00006-2)
6. Khan MR, Hider ZM, Hussain J, Mali FH, Talia I, Abdullah S. Comprehensive analysis of cardiovascular diseases: Symptoms, diagnosis, and AI innovations. *Bioengineering*. 2018 Dec 7;11(12):1239. [Doi: 10.3390/bioengineering11121239](https://doi.org/10.3390/bioengineering11121239)
7. El-So any H, Bouallegue B, El-Latin YM. A proposed technique for predicting heart disease using machine learning algorithms and an explainable AI method. *Scientific Reports*. 2018 Oct 7;14(1):23277. [Doi: 10.1038/s41598-024-23277-9](https://doi.org/10.1038/s41598-024-23277-9)
8. Armanda’s AA, Aryan SM, Arnett DK, Spector-Bagdady K, Bennett DA, Ceil LA, Friedman PA, Glob MH, Hall JL, Kite AE, Let E. Use of artificial intelligence in improving outcomes in heart disease: a scientific statement from the American Heart Association. *Circulation*. 2018 Apr 2;149(14):e1028–e1050. [Doi: 10.1161/CIR.0000000000001205](https://doi.org/10.1161/CIR.0000000000001205)
9. Ogunpola A, Saied F, Basra S, Labara AM, Wasim SN. Machine learning-based predictive models for detection of cardiovascular diseases. *Diagnostics*. 2018 Jan 8; 14(2):144. [Doi: 10.3390/diagnostics14020144](https://doi.org/10.3390/diagnostics14020144).
10. Addissouky TA, El Saied IE, Ali MM, Alubiady MH, Wang Y. Recent developments in the diagnosis, treatment, and management of cardiovascular diseases through artificial intelligence and other innovative approaches. *Journal of Biomed Research*. 2018 Mar 12; 5(1):29–40. [Doi: 10.3390/jbr5010029](https://doi.org/10.3390/jbr5010029).
11. Reza-Sultana S, Alma LF, Debilitate O, Mona TS, Coyalkar VR, Ternate VC, Ozoalor CU, Allah SR, Fatal M, Shah GK, Ray M. The role of artificial intelligence and machine learning in cardiovascular imaging and diagnosis. *Cures*. 2018 Sep 2; 16(9). [Doi: 10.7759/cureus.59120](https://doi.org/10.7759/cureus.59120).
12. Salve DK, Aswan J, Balakrishnan C, Sugary K, Sheena BG. Revolutionizing cardiovascular care: The role of AI, ML, and DL in early heart disease prediction and treatment. In: *2018 International Conference on Electronics, Computing, Communication and Control Technology (ICECCC)*; 2018 May 2. pp. 1–6. IEEE. [Doi: 10.1109/ICECCC60732.2018.10512345](https://doi.org/10.1109/ICECCC60732.2018.10512345).
Wang YR, Yang K, Went Y, Wang P, Hub Y, Lai Y, Wang Y, Zhao K, Tang S, Zhang A, Zhan H. Screening and diagnosis of cardiovascular disease using artificial intelligence-enabled cardiac magnetic resonance imaging. *Nature Medicine*. 2018 May; 30(5):1471–1480. [Doi: 10.1038/s41591-024-02987-6](https://doi.org/10.1038/s41591-024-02987-6).
13. Sufi an MA, Hams W, Zama S, As adder L, Hams B, Varadarajan J, Azad MA. Enhancing clinical validation for early cardiovascular disease prediction through simulation, AI, and web technology. *Diagnostics*. 2018 Jun 20;14(12):1308. [Doi: 10.3390/diagnostics14121308](https://doi.org/10.3390/diagnostics14121308).

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14. Cain YQ, Gong DX, Tang LY, Cain Y, Li HJ, Jing TC, Gong M, Hub W, Zhang ZW, Zhang X, Zhang GW. Pitfalls in developing machine learning models for predicting cardiovascular diseases: challenges and solutions. *Journal of Medical Internet Research*. 2018 Jul 26; 26:e47645. Doi: [10.2196/47645](https://doi.org/10.2196/47645).
15. Bezel S, Şimşek E, Koçyiğit D, Gluer A, Korkmazer Y, Meeker M, Return M, Kiser N. Artificial intelligence-based clinical decision support systems in cardiovascular diseases. *Anatolian Journal of Cardiology*. 2018 Feb 1; 28(2):74. Doi: [10.14744/AnatolJCardiol.2018.03959](https://doi.org/10.14744/AnatolJCardiol.2018.03959).
16. Pachiyannan P, Alsulami M, Labadie D, Saud agar AK, AlKhathami M, Poona RC. A novel machine learning-based prediction method for early detection and diagnosis of congenital heart disease using ECG signal processing. *Technologies*. 2018 Jan 2;12(1):4. Doi: [10.3390/technologies12010004](https://doi.org/10.3390/technologies12010004).
17. Bromwich PK, Micah MN, Udine MK, Suzan MM, Pant L, Islam MR, Gerung N. Advancing heart disease prediction through machine learning: Techniques and insights for improved cardiovascular health. *British Journal of Nursing Studies*. 2018 Oct 1; 4(2):35–50. Doi: [10.59227/bjns.2018.04204](https://doi.org/10.59227/bjns.2018.04204).
18. Bill H, Tina Y, Ali A, Muhammad Y, Yahya A, Indie BA, Ulla I. An intelligent approach for early and accurate prediction of cardiac disease using hybrid artificial intelligence techniques. *Bioengineering*. 2018 Dec 19; 11(12):1290. Doi: [10.3390/bioengineering11121290](https://doi.org/10.3390/bioengineering11121290).
19. Rijeka I, Kotare P, Kozielski M, Jagodziński M, Królikowski Z. Development of AI-based prediction of heart attack risk as an element of preventive medicine. *Electronics*. 2018 Jan 7; 13(2):272. Doi: [10.3390/electronics13020272](https://doi.org/10.3390/electronics13020272).