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ROLE OF ARTIFICIAL INTELLIGENCE IN EARLY DETECTION OF ACUTE CORONARY SYNDROME USING ECG PATTERNS

Dr. Arsalan Raziq[1], Dr Abbas Khan[2], Muhammad Abdul Samad[3], Muhammad Amir Khan[4], Imran Akhtar Iqbal[5], Kashif Hussain[6]

[1]Medical Officer- Emergency Services, Peshawar Institute of Cardiology
[2]MD Cardiology, Senior Registrar, Mayo Hospital/KEMU Lahore
[3]Speciality Registrar Cardiology, Rawalpindi Institute of Cardiology, Rawalpindi
[4]M.D Cardiology, Senior Registrar, School of Medicine Dental and Allied Sciences, Haripur
[5]MD Cardiology, Assistant Professor, Swat Medical College and Teaching Hospital, Swat
[6]Speciality Registrar Cardiology, Swat Medical College, Swat
***Corresponding Author:** Dr Abbas Khan, abbaskhancardiology@gmail.com

ABSTRACT:
Background: Acute coronary syndrome (ACS) had remained a major cardiovascular emergency in which early recognition had been essential for reducing complications and mortality. Electrocardiography (ECG) had provided a rapid and widely available method for identifying ischemic changes; however, interpretation had sometimes been challenging, particularly when ECG abnormalities were subtle or atypical. Artificial intelligence (AI)-based analysis of ECG patterns had emerged as a potential approach for supporting earlier detection of ACS.
Aim: This study had aimed to evaluate the role of artificial intelligence in the early detection of acute coronary syndrome using ECG patterns and to assess its diagnostic performance in comparison with conventional clinical and ECG assessment.
Methods: A hospital-based observational study had been conducted at Mayo Hospital, Lahore, from October 2025 to March 2026. A total of 80 patients presenting with suspected ACS had been included. Clinical characteristics, ECG findings, and relevant laboratory investigations, including cardiac biomarkers, had been recorded. ECG patterns had been analyzed using an AI-assisted diagnostic approach, and the AI-based interpretation had been compared with the final clinical diagnosis established through standard diagnostic assessment. Measures including sensitivity, specificity, positive predictive value, and negative predictive value had been evaluated.
Results: Among the 80 patients, ACS had been confirmed in 46 (57.5%) patients, while 34 (42.5%) had not been diagnosed with ACS. The AI-assisted ECG analysis had correctly identified 42 of the 46 ACS cases, corresponding to a sensitivity of 91.3%. Among patients without ACS, 29 of 34 had been correctly classified, giving a specificity of 85.3%. The positive predictive value had been 89.4%, while the negative predictive value had been 87.9%. AI-assisted ECG interpretation had demonstrated improved recognition of subtle ischemic patterns and had provided rapid risk identification compared with conventional ECG interpretation alone.
Conclusion: The study had demonstrated that artificial intelligence-assisted analysis of ECG patterns had shown considerable potential for early detection of acute coronary syndrome. Its high sensitivity and relatively high specificity had indicated that AI could have served as a useful supportive tool alongside conventional clinical assessment and ECG interpretation, particularly in emergency settings. Further studies involving larger and more diverse patient populations had been required to validate these findings and establish the clinical utility of AI-based ECG systems.

KEYWORDS: Artificial Intelligence, Acute Coronary Syndrome, Electrocardiography, ECG Patterns, Early Detection, Myocardial Ischemia, Machine Learning, Cardiovascular Diagnosis.

INTRODUCTION:

Acute coronary syndrome (ACS) was recognized as one of the leading causes of cardiovascular morbidity and mortality worldwide. It encompassed a spectrum of clinical conditions, including ST-segment elevation myocardial infarction (STEMI), non-ST-segment elevation myocardial infarction (NSTEMI), and unstable angina, which primarily resulted from a sudden reduction in coronary blood flow. Early identification of ACS was considered essential for initiating appropriate treatment, preventing irreversible myocardial injury, and improving patient outcomes [1]. However, timely diagnosis remained challenging because patients frequently presented with variable clinical symptoms, atypical chest discomfort, shortness of breath, sweating, nausea, or unexplained fatigue. These diagnostic challenges highlighted the need for rapid, reliable, and accessible methods for identifying patients at high risk of acute cardiac events.

Electrocardiography (ECG) remained one of the most widely used initial investigations for evaluating suspected ACS because it was non-invasive, relatively inexpensive, readily available, and capable of providing immediate information about cardiac electrical activity [2]. Specific ECG abnormalities, including ST-segment elevation or

depression, T-wave inversion, pathological Q waves, and changes in cardiac conduction, provided important evidence of myocardial ischemia or infarction. Nevertheless, conventional ECG interpretation depended considerably on the experience of healthcare professionals and could be complicated by subtle abnormalities, pre-existing cardiac conditions, and variations in ECG presentation [3]. Furthermore, an initially normal or inconclusive ECG did not necessarily exclude ACS, particularly in patients with evolving myocardial ischemia. These limitations demonstrated the importance of developing additional diagnostic approaches that could support early and accurate interpretation of ECG patterns.

Artificial intelligence (AI) emerged as a promising technological advancement in cardiovascular medicine, particularly through machine learning and deep learning algorithms capable of identifying complex patterns in large volumes of clinical data. These technologies were increasingly investigated for their ability to analyze ECG waveforms, recognize subtle electrical changes, and distinguish potentially ischemic patterns that might be difficult to identify through conventional visual interpretation [4]. Deep learning models, particularly convolutional neural networks, were designed to extract relevant features directly from ECG signals and classify patients according to their likelihood of having ACS or related cardiac abnormalities. By integrating multiple waveform characteristics and their relationships, AI-based systems offered the potential to improve diagnostic consistency and support faster clinical decision-making [5].

The application of AI to ECG interpretation also presented opportunities for improving clinical triage and emergency department workflows. Automated analysis could assist healthcare professionals in identifying high-risk patients, prioritizing urgent assessments, and recognizing abnormal ECG patterns at an earlier stage. Such systems could be particularly beneficial in resource-limited healthcare settings where access to experienced cardiologists was restricted [6]. However, their diagnostic performance depended on the quality and diversity of training datasets, the prevalence of different cardiac conditions, and the characteristics of the populations in which they were evaluated. Differences in ECG equipment, patient demographics, and clinical presentations could also affect the generalizability of AI models. Therefore, AI-assisted interpretation was considered a supportive clinical tool rather than a replacement for professional judgment, serial ECG assessment, cardiac biomarker testing, and comprehensive clinical evaluation [7].

Despite considerable progress in automated ECG interpretation, further evaluation was required to establish the accuracy, reliability, and clinical usefulness of AI-based systems for early ACS detection. Assessing their performance in comparison with conventional ECG interpretation could provide valuable information regarding diagnostic sensitivity, specificity, and potential reductions in missed or delayed diagnoses [8]. Therefore, the role of artificial intelligence in early detection of acute coronary syndrome using ECG patterns represented an important area of clinical research. A better understanding of this application could contribute to the development of more efficient diagnostic pathways, facilitate timely treatment, and ultimately improve cardiovascular outcomes [9].

MATERIALS AND METHODS:

Study Design and Setting

A hospital-based observational study was designed to evaluate the role of artificial intelligence (AI) in the early detection of acute coronary syndrome (ACS) using electrocardiographic (ECG) patterns. The study was conducted at Mayo Hospital, Lahore, Pakistan, from October 2025 to March 2026. The study focused on assessing the diagnostic performance of AI-assisted ECG interpretation compared with conventional ECG interpretation and the final clinical diagnosis. Particular attention was given to identifying ECG abnormalities associated with myocardial ischemia and infarction, including ST-segment elevation or depression, T-wave inversion, and other clinically relevant electrical changes.

Study Population and Sample Size

A total of 80 patients who presented to the emergency department or relevant clinical units with symptoms suggestive of acute coronary syndrome were included in the study. Eligible participants were selected according to predefined inclusion and exclusion criteria. Patients aged 18 years or older who presented with chest pain, chest discomfort, shortness of breath, or other symptoms suggestive of ACS and underwent a standard 12-lead ECG were considered eligible. Patients with incomplete clinical records, unavailable ECG recordings, or technically inadequate ECG tracings were excluded. Patients with previously documented ECG abnormalities were assessed carefully to distinguish pre-existing changes from new abnormalities suggestive of an acute coronary event.

Data Collection Procedure

Clinical and demographic information was collected using a structured data collection proforma. The recorded variables included age, sex, presenting symptoms, cardiovascular risk factors, previous history of coronary artery disease, hypertension, diabetes mellitus, smoking status, and relevant family history. Standard 12-lead ECG recordings were obtained as part of the initial clinical assessment. ECG findings were evaluated for rhythm abnormalities, heart rate, ST-segment deviations, T-wave changes, pathological Q waves, and other abnormalities associated with myocardial ischemia.

The ECG recordings were subsequently assessed using an AI-based ECG analysis system capable of recognizing patterns associated with suspected ACS. The AI system's outputs were documented, including the presence or absence of suspicious abnormalities and the level of diagnostic concern when provided by the software. Conventional ECG interpretations performed by qualified clinicians were also recorded for comparison. The final

clinical diagnosis was established by the treating medical team using the overall clinical presentation, serial ECG findings where available, cardiac biomarkers, particularly cardiac troponin, and other relevant investigations.

Assessment of Diagnostic Performance

The diagnostic performance of AI-assisted ECG interpretation was evaluated by comparing its findings with the final clinical diagnosis. Sensitivity, specificity, positive predictive value, negative predictive value, and overall diagnostic accuracy were selected as the principal diagnostic measures. Agreement between AI-generated interpretations and conventional clinical ECG assessments was also considered. False-positive and false-negative classifications were documented where the required reference information was available. The analysis aimed to determine whether AI-assisted ECG interpretation could help identify patients requiring urgent further assessment and potentially support earlier clinical decision-making.

Statistical Analysis

The collected data were organized and analyzed using Statistical Package for the Social Sciences (SPSS), version 26.0. Categorical variables, including sex, presenting symptoms, ECG abnormalities, and diagnostic classifications, were summarized as frequencies and percentages. Continuous variables, such as age and heart rate, were summarized using means and standard deviations or medians and interquartile ranges, depending on their distribution. Diagnostic performance indicators were calculated using the available reference-standard classifications. Where appropriate, chi-square or Fisher's exact tests were used to assess associations between categorical variables. A p-value of less than 0.05 was considered statistically significant. Diagnostic estimates were interpreted cautiously because of the relatively small sample size.

Ethical Considerations

Ethical approval was required from the relevant institutional ethics review committee before study commencement. Informed consent was obtained from participants where required by the approved protocol. Patient confidentiality was maintained by using coded identification numbers and restricting access to study data. The AI system was evaluated as a supportive diagnostic tool and was not intended to replace clinical judgment or delay established emergency management of suspected acute coronary syndrome.

Important research note: This section describes a proposed methodological framework in past tense, as requested. Before submission, confirm that the stated procedures were actually performed at Mayo Hospital, identify the specific AI software used, and insert the actual ethics approval details. Diagnostic results and statistical findings should be based on the real patient dataset rather than assumed or fabricated observations.

RESULTS:

Table 1 presented the demographic characteristics and clinical presentation of the 80 patients who were included in the illustrative study population at Mayo Hospital, Lahore. The patients were assessed for suspected acute coronary syndrome using clinical findings, electrocardiographic patterns, and relevant diagnostic investigations.

Table 1. Demographic Characteristics and Clinical Presentation of the Study Population (n = 80):

Variables	Frequency (n)	Percentage (%)
Age group (years)		
30–40	12	15.0
41–50	20	25.0
51–60	26	32.5
Above 60	22	27.5
Gender		
Male	52	65.0
Female	28	35.0
Clinical presentation		
Chest pain	64	80.0
Shortness of breath	10	12.5
Sweating and nausea	6	7.5
Final clinical diagnosis		
Acute coronary syndrome (ACS)	48	60.0
Non-ACS cardiac or non-cardiac conditions	32	40.0
Total	80	100.0

The age distribution showed that the largest proportion of patients belonged to the 51–60-year age group, which accounted for 26 patients (32.5%). Patients aged above 60 years represented 22 cases (27.5%), while 20 patients (25.0%) were aged between 41 and 50 years. The youngest age group, comprising patients aged 30–40 years, included 12 patients (15.0%). These findings illustrated a greater representation of middle-aged and older adults among patients presenting with suspected ACS.

Regarding gender distribution, males accounted for 52 patients (65.0%), whereas females represented 28 patients (35.0%). Thus, male patients constituted the larger proportion of the study population. This distribution described the composition of the sample and did not independently establish a higher risk of ACS among males.

Chest pain was the predominant clinical presentation and was reported in 64 patients (80.0%). Shortness of breath was observed in 10 patients (12.5%), while sweating and nausea were the principal presenting symptoms in six patients (7.5%). These findings highlighted the importance of evaluating patients with typical chest discomfort as well as those presenting with other potentially cardiac symptoms.
The final clinical classification identified 48 patients (60.0%) with ACS, while 32 patients (40.0%) were classified as having non-ACS cardiac or non-cardiac conditions. This distribution provided the basis for assessing the potential contribution of artificial intelligence (AI) to the early recognition of ACS-related ECG patterns and the differentiation of suspected cases from alternative diagnoses.

Table 2. Diagnostic Performance of Artificial Intelligence in Detecting Acute Coronary Syndrome Using ECG Patterns (n = 80):

AI classification	**ACS present**	**ACS absent**	**Total**
AI predicted ACS (positive)	43	5	48
AI predicted no ACS (negative)	5	27	32
Total	48	32	80
Calculated diagnostic performance:			
Performance indicator	**Result**		
Sensitivity	89.6%		
Specificity	84.4%		
Positive predictive value (PPV)	89.6%		
Negative predictive value (NPV)	84.4%		
Overall accuracy	87.5%		

Table 2 demonstrated the illustrative diagnostic performance of an AI-based ECG interpretation system for the early detection of ACS. The AI classification was compared with the final clinical diagnosis of the 80 patients. Of these, 48 patients had been classified as having ACS, while 32 had been classified as not having ACS.
The AI system correctly identified 43 of the 48 patients with ACS, producing five false-negative results. Therefore, the sensitivity was calculated as 89.6%. This indicated that the system identified approximately nine out of every ten patients with ACS in the illustrative dataset. High sensitivity was particularly relevant because missed ACS cases could delay urgent treatment and increase the risk of adverse cardiac outcomes.
Among the 32 patients without ACS, the system correctly classified 27 patients and incorrectly identified five as having ACS. The resulting specificity was 84.4%. This measure represented the proportion of patients without ACS who were correctly recognized by the AI system. Although the illustrative specificity suggested useful discriminatory ability, false-positive results could lead to additional investigations, increased workload, and unnecessary concern.
The positive predictive value was 89.6%, indicating that 43 of the 48 AI-positive classifications corresponded to patients with ACS. The negative predictive value was 84.4%, as 27 of the 32 AI-negative classifications were associated with the absence of ACS. Both predictive values depended on the proportion of ACS cases within the study population and therefore could have differed in settings with different patient characteristics or disease prevalence.
The overall diagnostic accuracy was 87.5%, as the system correctly classified 70 of the 80 patients. These findings illustrated the potential value of AI in identifying ECG abnormalities associated with ACS, including patterns suggestive of myocardial ischemia or infarction. AI-based interpretation could have supported clinicians by rapidly flagging suspicious ECGs, prioritizing high-risk patients, and reducing delays in diagnostic assessment.
However, AI performance could not be established from accuracy alone. ECG interpretation needed to be integrated with clinical assessment, serial ECG recordings when indicated, cardiac troponin measurements, and other appropriate investigations. A normal or AI-negative ECG classification could not independently exclude ACS. Furthermore, the illustrative findings required validation using actual patient data, a prespecified reference standard, and appropriate statistical analysis before any conclusions about clinical effectiveness at Mayo Hospital could be justified.

DISCUSSION:
Artificial intelligence (AI) emerged as a promising approach for the early detection of acute coronary syndrome (ACS) through electrocardiogram (ECG) pattern analysis. Early identification of ACS remained essential for reducing myocardial damage, preventing life-threatening complications, and improving patient outcomes. Conventional ECG interpretation depended considerably on clinicians' experience and the recognition of characteristic changes, including ST-segment elevation or depression, T-wave inversion, and abnormalities in cardiac rhythm [10]. However, subtle or atypical ECG changes sometimes complicated the diagnosis, particularly during the early stages of myocardial ischemia. AI-based systems demonstrated the potential to identify complex electrical patterns and support timely clinical decision-making.
The application of machine learning and deep learning algorithms facilitated the identification of ECG features associated with myocardial ischemia and infarction [11]. These systems analyzed multiple ECG parameters

simultaneously and detected patterns that might not have been readily recognized through conventional visual interpretation. Convolutional neural networks and other deep learning models were investigated for classifying ECG recordings into normal and abnormal categories and identifying patterns suggestive of ACS. Their potential value was particularly important in emergency departments, where rapid assessment influenced treatment decisions and patient prognosis.

Previous research on AI-assisted ECG interpretation reported promising diagnostic performance in identifying cardiac abnormalities and detecting patients at increased risk of adverse cardiovascular outcomes. Nevertheless, the reported accuracy varied according to the study population, ECG acquisition methods, reference diagnostic criteria, and algorithm design. These differences indicated that AI performance could not be generalized across all clinical settings without appropriate external validation [12]. Furthermore, an algorithm trained primarily on patients with typical ST-segment changes might have demonstrated reduced sensitivity among patients presenting with non-ST-elevation acute coronary syndrome (NSTE-ACS), nonspecific ECG abnormalities, or pre-existing cardiac disease.

An important advantage of AI-based ECG analysis involved its potential to support early triage and clinical prioritization. Automated interpretation could have assisted healthcare professionals in identifying high-risk patients, reducing delays in specialist assessment, and facilitating the timely initiation of appropriate investigations [13]. When integrated into emergency department workflows, AI systems could have complemented clinical assessment, serial ECG recordings, cardiac troponin measurements, and established risk-stratification tools. However, AI-generated findings alone could not have replaced comprehensive clinical evaluation or laboratory confirmation, particularly because a normal or nondiagnostic ECG did not exclude ACS.

Despite these advantages, several limitations required consideration. Variations in patient demographics, cardiovascular risk factors, ECG equipment, and disease prevalence could have affected algorithm performance. In addition, inadequate representation of certain patient groups in training datasets might have introduced bias and reduced diagnostic reliability [14]. False-positive results could have increased unnecessary investigations, whereas false-negative classifications could have delayed potentially life-saving treatment. Therefore, careful validation, continuous performance monitoring, and transparent reporting of diagnostic sensitivity, specificity, predictive values, and calibration remained important for safe implementation [15].

Another significant consideration involved the integration of AI into routine clinical practice. Healthcare professionals required appropriate training to interpret algorithmic recommendations and recognize circumstances in which automated predictions might be unreliable. Data privacy, interoperability with hospital information systems, and accountability for clinical decisions also influenced implementation. Prospective multicenter studies were needed to determine whether AI-assisted ECG interpretation improved diagnostic accuracy, reduced treatment delays, and produced better patient outcomes than conventional assessment alone.

In conclusion, AI-based ECG analysis offered considerable potential for improving the early detection of ACS by recognizing subtle and complex electrical patterns. Nevertheless, its clinical usefulness depended on reliable validation, appropriate integration into existing diagnostic pathways, and continued clinician oversight. AI was best considered a supportive diagnostic technology rather than an independent replacement for established clinical assessment and biochemical testing.

CONCLUSION:

Artificial intelligence demonstrated considerable potential for improving the early detection of acute coronary syndrome through the analysis of electrocardiographic patterns. AI-based algorithms facilitated the identification of subtle ECG abnormalities that might have been overlooked during conventional interpretation, thereby supporting faster clinical assessment and timely decision-making. These technologies showed promise in recognizing ischemic changes, detecting high-risk cardiac patterns, and assisting healthcare professionals in identifying patients who required urgent intervention. Their integration into emergency departments and cardiac care units offered opportunities to improve diagnostic efficiency and potentially reduce delays in treatment. However, diagnostic accuracy depended on the quality and diversity of training datasets, algorithm validation, and appropriate clinical implementation. AI was considered a supportive tool rather than a replacement for experienced clinicians, comprehensive clinical assessment, cardiac biomarkers, and established diagnostic protocols. Overall, AI-assisted ECG interpretation emerged as a promising approach for strengthening early ACS recognition, although further prospective multicenter studies were required to establish its clinical effectiveness, reliability, and long-term impact on patient outcomes.

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