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ORIGINAL ARTICLE

Enhanced Diagnostic Accuracy of Electrocardiogram Using Additional ECG Markers for Detecting Acute Coronary Occlusion in Myocardial Infarction

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ABSTRACT

Objective: The aim of this study was to evaluate the diagnostic accuracy of using additional electrocardiographic markers alongside traditional ST-segment elevation (STE) in the detection of acute coronary occlusion (ACO) in patients presenting with myocardial infarction taking angiographic evidence of coronary artery occlusion as the gold standard.

Methodology: This cross-sectional study was conducted from 11 August, 2025 to 11 November, 2025 at Army Cardiac Hospital.

Results: In this study the mean age of the cases was 60.80 ± 8.40. There were 105 (70%) male and 45 (30%) females found in this study. The comparison of ECG type, ECG ACO, angiographic ACO and composite ACO showed significant results with p-values < 0.001, <0.001, 0.002 and < 0.001. The sensitivity and specificity of angiographic results was computed as 94.12% and 71.95%, PPV and NPV was 73.56% and 93.65%.

Conclusion: The study demonstrated that the traditional ST-segment elevation STEMI criteria used to identify acute coronary occlusion ACO and decide on urgent reperfusion therapy are limited in diagnostic accuracy, missing a substantial proportion of true acute occlusions and leading to false activations of the catheterization laboratory. A new electrocardiogram classification strategy the ACOMI (Acute Coronary Occlusion MI)/ non-ACOMI approach showed superior diagnostic accuracy compared to the classic STEMI/non-STEMI paradigm for predicting angiographically defined ACO and long-term mortality. A notable portion of patients initially labeled as non-STEMI were re classified as having ACO using this more detailed ECG assessment and were found to have higher rates of myocardial damage and worse outcomes. Therefore, a paradigm shift from diagnosing MI based on STEMI criteria to a more comprehensive ACOMI/non-ACOMI ECG approach in the acute management of myocardial infarction to better identify patients who truly require emergent reperfusion therapy.

Key Words: Acute coronary occlusion, Electrocardiogram, ST-segment elevation

Authors' Contribution:
[1,2]Conception; Literature research; manuscript design and drafting; [3,4]Critical analysis and manuscript review; [5,6]Data analysis; Manuscript Editing.

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Introduction

An acute coronary occlusion (ACO) results from an acute obstruction of a coronary artery, with consequences varying based on the blockage's degree and location, ranging from unstable angina to non–ST-segment elevation myocardial infarction

(NSTEMI), ST-segment elevation myocardial infarction (STEMI), and sudden cardiac death.[1,2] Traditionally, diagnosing ACO relies on detecting ST- segment elevation (STE) on an electrocardiogram (ECG); however, the absence of STE does not exclude occlusive coronary disease. Studies indicate that up to one-third of patients initially classified as NSTEMI may actually have an acute total occlusion (ATO) upon coronary angiography, leading to potential delays in necessary care and unnecessary interventions.[3,4,5]

To address these diagnostic limitations, recent research has identified additional ECG markers, including T-wave inversions, QRS complex distortions, and subtle ST-segment changes, which can enhance the accuracy of ACO detection.[6] These markers are particularly helpful in NSTEMI cases, where the absence of clear STE might otherwise result in missed diagnoses. Studies show that using these markers can better identify 'hidden' occlusions, enabling timely interventions and potentially improving patient outcomes.[6-8]

In Pakistan, the prevalence of cardiovascular diseases is increasing, contributing significantly to the national disease burden.[9] As cardiovascular disease now represents a substantial portion of mortality in the country, the healthcare system faces mounting challenges, including limited resources and high patient loads. Efficient and affordable diagnostic tools are critical, as misdiagnosis or delays in ACO care not only worsen outcomes but also increase the financial and operational strain on healthcare facilities.[9]

Previous studies have underlined the inadequacy of ST-segment elevation (STE) alone in detecting acute coronary occlusion (ACO).[4,6] For instance, Schmitt et al. observed that standard STE criteria detected LAD and RCA occlusions in 90–96% of cases but identified only ~61% of left circumflex occlusions, averaging a sensitivity of ~60–65%, though specificity remained high (≈90%).[4] In a larger cohort examined by Aslanger et al., traditional STE approaches missed nearly one-third of ACOs, whereas an expanded ACO/non-ACO framework demonstrated significantly improved diagnostic performance.6 Alternative non-ECG markers, like regional myocardial work index, have further achieved 81% sensitivity and 82% specificity, underscoring that diagnostic accuracy can be enhanced beyond ECG alone.[10] Together, these findings support the rationale for incorporating additional ECG markers (e.g., QRS distortions, T- wave inversions) into current diagnostic frameworks. The DIFOCCULT study aims to address these challenges by assessing a broader set of diagnostic markers for myocardial infarction. By improving diagnostic accuracy for ACO, especially in resource- constrained settings, this study seeks to ensure timely and appropriate care for patients in Pakistan while reducing unnecessary procedures. The findings could drive a significant shift in ACO diagnosis, both in Pakistan and globally, by contributing valuable insights on the effectiveness of additional ECG markers, potentially influencing clinical guidelines to enhance cardiovascular care and resource allocation.

Despite the reliance on ST-segment elevation (STE) to diagnose acute coronary occlusion (ACO) in myocardial infarctions, nearly one-third of ACOs are missed, leading to suboptimal patient outcomes and unnecessary catheterization lab activations. Recognizing the limitations of STE alone and the availability of other indicative ECG markers, this study aims to evaluate the diagnostic accuracy of a combined ECG marker approach. By integrating additional electrocardiographic signs, the DIFOCCULT study seeks to enhance early and accurate identification of ACO, potentially improving treatment efficacy and reducing inappropriate invasive procedures, thereby optimizing clinical outcomes and healthcare resource utilization.

Methodology

This cross-sectional study was conducted at Army Cardiac Hospital. After the permission from institute review board this study was conducted from 11 August, 2025 to 11 November, 2025 under the principles of Helsinki Declaration. The sample size was calculated using a sensitivity-based formula for diagnostic accuracy studies. Assuming an expected sensitivity of 81% and specificity of 82% and a 95% confidence level, a margin of error of 7%, and an estimated ACO prevalence of 61%, the minimum required sample size was calculated to be 150 patients. (6) Consecutive sampling technique was used to enroll patients in this study.

Inclusion Criteria: Patients of age 18-75 years of either gender. Patients admitted with symptoms suggestive of myocardial infarction undergo an ECG within 30 minutes of hospital arrival.

Exclusion Criteria: Patients with previous myocardial infarction or significant ECG changes due to other cardiac or non-cardiac conditions

Acute Coronary Occlusion (ACO): The complete obstruction of a coronary artery, diagnosed through angiographic evidence of a blockage or significant elevation in cardiac biomarkers, specifically troponin levels, indicative of myocardial injury. (1)

Myocardial Infarction (MI): Myocardial infarction is defined by pathology as myocardial cell death due to prolonged ischaemia. (11)

ST-Segment Elevation (STE): A specific ECG finding characterized by elevation of the ST segment at least 2 mm above the baseline in men or 1.5 mm in women in two contiguous leads, which is traditionally used to diagnose ACO. (12)

Additional ECG Markers: Includes but is not limited to, T-wave inversion, new onset left bundle branch block, or pathological Q waves, which may indicate myocardial ischemia or infarction in the absence of definitive STE. (12)

Cardiac Biomarkers: Substances found in the blood whose levels are elevated in response to the occurrence of heart damage, with troponin being the primary marker used to diagnose myocardial infarction due to its high sensitivity and specificity for cardiac injury. (12)

- **Test Outcome Definitions:**
    - **Positive Test (ECG):** Presence of ST-segment elevation and/or additional ECG markers (e.g., T-wave inversion, QRS distortion) suggestive of ACO.
    - **Negative Test (ECG):** Absence of both ST-segment elevation and additional ECG markers.
    - **Positive Gold Standard (Angiography):** Confirmed presence of acute coronary occlusion (complete or near-complete coronary artery blockage) on coronary angiography.
    - **Negative Gold Standard (Angiography):** Absence of angiographic evidence of coronary occlusion.
- **Diagnostic Terms:**
    - **True Positive (TP):** ECG suggests ACO, and angiography confirms the presence of occlusion.
    - **False Positive (FP):** ECG suggests ACO, but angiography reveals no occlusion.
    - **True Negative (TN):** ECG shows no ACO, and angiography confirms no occlusion.
    - **False Negative (FN):** ECG shows no ACO, but angiography reveals an occlusion.
    - **Sensitivity:** TP/TP + FN * 100
    - **Specificity:** TN/TN + FP * 100
    - **PPV:** TP/TP + FP * 100
    - **NPV:** TN/TN + FN * 100

Data was collected by using a self-generated Proforma. 150 patients presenting with symptoms suggestive of myocardial infarction were identified upon arrival at the emergency department. An ECG was performed within 30 minutes of admission. The presence or absence of ST-segment elevation and additional ECG markers (such as T-wave inversion, QRS distortion, and pathological Q waves) was recorded by the attending cardiologist. Demographic details, clinical history, vital signs, ECG findings, and cardiac biomarker levels (e.g., troponin I) were documented in a structured, self-designed proforma.

All patients underwent coronary angiography as part of routine clinical management. The angiographic findings were reviewed to determine whether acute coronary occlusion is present (gold standard). Data was collected by trained medical staff under the supervision of the principal investigator. Each entry was cross-verified for accuracy. The entire process was conducted in accordance with ethical guidelines and institutional protocols.

Ethical approval was taken from the Ethical Review Board of Army Cardiac Hospital, Lahore (No. 25/Estb/ACH)

Results

In this study the mean age of the cases was 60.80 ± 8.40. There were 105 (70%) male and 45 (30%) females found in this study. The mean SBP, DBP and HR was 150.90 ± 6.13, 91.30 ± 4.26 and 83.70 ± 4.40 respectively. **(Table I).** In this study history of HF was found in 30 (20%) patients, hypertension was found in 135 (90%) patients, dyslipidemia was observed in 50 (33.3%) patients and there were 90 (60%) smokers enrolled in our population. No patient of prior MI, PCI and CABG was found in this study. There were 103 (68.7%) diabetic and 30 (20%) patients with asthma found in this study. The most of the patients in this study found with KILLIP class I 120 (80%). (Table II). In this study there were 75 (50%) patients found with STEMI and 75 (50%) with NSTEMI. The comparison of ECG type, ECG ACO, angiographic ACO and composite ACO showed significant results with p-values < 0.001, <0.001, 0.002 and < 0.001. However, the comparison of short- and long-term mortality showed insignificant results p-value 0.467 and 0.461.

Table I: Descriptive statistics of demographic and clinical variables

Variables		Mean ± SD
Age		60.80 ± 8.40
Gender	Male	105 (70%)
	Female	45 (30%)
SBP		150.90 ± 6.13
DBP		91.30 ± 4.26
HR		83.70 ± 4.40

Table II: Frequency distribution of Risk Factors

History of HF	Yes	30 (20%)
	No	120 (80%)
Hypertension	Yes	135 (90%)
	No	15 (10%)
Dyslipedemia	Yes	100 (66.7%)
	No	50 (33.3%)
Smoking	Yes	90 (60%)
	No	60 (40%)
Prior MI	Yes	0 (0%)
	No	150 (100%)
PCI	Yes	0 (0%)
	No	150 (100%)
CABG	Yes	0 (0%)
	No	150 (100%)
Diabetes	Yes	103 (68.7%)
	No	47 (31.3%)
Asthma	Yes	30 (20%)
	No	120 (80%)
KILLIP Class	I	120 (80%)
	II	22 (14.67%)
	III	6 (4%)
	IV	2 (1.33%)

Table III: Comparison of clinical variables

	ST. Elevation	Mean	Std. Deviation	P-Value
Pre-Trop I	Yes	2.47	1.33	0.864
	No	2.51	1.38	
Trop_24	Yes	7.65	2.56	0.135
	No	6.97	2.97	
Cr	Yes	1.50	0.18	0.222
	No	1.47	0.17	
Hb	Yes	23.66	25.62	0.054
	No	16.86	16.31	
ECG to PCI time	Yes	67.03	28.88	0.187
	No	72.37	19.68	
Follow-up (Days)	Yes	14.00	0.00	1.00
	No	14.00	0.00	

Table IV: Comparison of acute coronary occlusion in STEMI and NSTEMI patients				
ECG Type		**ST. Elevation**		**P-Value**
		Yes	No	
Type 1a		59	0	< 0.001
		78.7%	.0%	
Type 1b		0	75	
		.0%	100.0%	
Type 1c		11	0	
		14.7%	.0%	
Type 1d		5	0	
		6.7%	.0%	
ECG ACO	Yes	75 (100%)	0 (0%)	< 0.001
	No	0 (0%)	75 (100%)	
Angiographic ACO	Yes	41 (54.7%)	27 (36%)	0.022
	No	34 (45.3%)	48 (64%)	
Composite ACO	Yes	60 (80%)	27 (36%)	< 0.001
	No	15 (20%)	48 (64%)	
Short Term Mortality	Yes	5 (6.7%)	3 (4%)	0.467
	No	70 (93.3%)	72 (96%)	
Long Term Mortality	Yes	11 (14.7%)	8 (10.7%)	0.461
	No	64 (85.3%)	67 (89.3%)	

Table V: Comparison of Composite ACO and Angiographic ACO				
		Composite ACO		
		Yes	**No**	
Angiographic ACO	Yes	TP	FP	Sensitivity 73.56%
		64 (73.6%)	4 (6.3%)	Specificity 93.65%
	No	FN	TN	PPV 94.12%
		23 (26.4%)	59 (93.7%)	NPV 71.95%

The comparison of preoperative trop I, trop I after 24 hours, serum creatinine, ECG to PCI time and follow up days showed insignificant results p-value > 0.05. However, the comparison of HB showed significant results with p-value 0.054. The sensitivity and specificity of angiographic results was computed as 73.56% and 93.65%, PPV and NPV was 94.12% and 71.95%. The sensitivity and specificity of angiographic and composite ACO in STEMI patients was computed as 95.12% and 38.24% while in NSTEMI patients it was computed as 92.59% and 95.83%.

Table VI: Comparison of composite ACO, Angiographic ACO with ST Elevation					
			Angiographic ACO		**P-Value**
ST-Elevation			Yes	No	
Yes (STEMI)	Composite ACO	Yes	39	21	Sensitivity 95.12%
			65.0%	35.0%	
		No	2	13	Specificity 38.24%
			13.3%	86.7%	
	Total		41	34	PPV 65%
			54.7%	45.3%	NPV 85.67%
No (NSTEMI)	Composite ACO	Yes	25	2	Sensitivity 92.59%
			92.6%	7.4%	
		No	2	46	Specificity 95.83%
			4.2%	95.8%	
	Total		27	48	PPV 92.59%
			36.0%	64.0%	NPV 95.83%

Discussion

The acute reperfusion of blocked coronary arteries is one of the most significant advances in the history of medicine.[13] Before the advent of thrombolytics, clinicians were required to monitor patients throughout their myocardial infarction (MI) and then classify them based on the development of Q-waves in their electrocardiogram (ECG). Following extensive thrombolytic trials that shown a significant survival advantage, particularly in patients exhibiting ST-segment elevation (STE), the paradigm transitioned from the passive classification of "Q-wave/non-Q-wave MI" to a more proactive categorization of "STE-MI/non-STE-MI." Despite the absence of coronary angiography in these trials, the term "STEMI" has inadvertently become synonymous with acute coronary occlusion or near-occlusion (ACO) requiring immediate reperfusion, and it remains employed as such in worldwide standards.[14] Remarkably, this connection has not been investigated in a focused trial. The criteria for STEMI exhibit limited diagnostic precision for ACO, resulting in a significant number of erroneous catheterization laboratory activations and, more critically, failing to identify nearly one- third of ACO cases. Consequently, this unfortunate cohort of patients, categorized as non-STEMI, is denied timely reperfusion therapy, reminiscent of the outdated Q-wave/non-Q-wave myocardial infarction methodology.[15]

Consequently, numerous authors have advocated for a paradigm shift from STEMI/non-STEMI to ACO-MI/non-ACO-MI, as ACO can be accurately identified through various ECG findings, including minor STE that does not meet STEMI criteria, disproportionate STE relative to the preceding QRS, atypical patterns in contiguous leads exhibiting opposing ST deviations, and certain patterns that do not exhibit STE whatsoever. Nonetheless, it remains ambiguous whether this novel methodology would enhance the identification of individuals requiring acute reperfusion therapy and/or whether the ECG had adequate diagnostic capability to surpass conventional STEMI criteria.[16,17] The main aim of this study is to assess the diagnostic precision of including supplementary electrocardiographic indicators with conventional ST-segment elevation (STE) for identifying acute coronary occlusion (ACO) in patients with myocardial infarction utilizing angiographic proof of coronary artery obstruction as the definitive standard. In this study the mean age of the cases was 60.80 ± 8.40. In a study by Aslanger et al, (2020) the mean age of the cases was 61 ± 13. 5 There were 105 (70%) male and 45 (30%) females found in this study. Similarly, Aslanger et al, (2020) enrolled 76% males and 24% females in their study.[6] In this study history of HF was found in 30 (20%) patients, hypertension was found in 135 (90%) patients, dyslipidemia was observed in 50 (33.3%) patients and there were 90 (60%) smokers enrolled in our population. There were 103 (68.7%) diabetic and 30 (20%) patients with asthma found in this study. The most of the patients in this study found with KILLIP class I 120 (80%). However, Sanani et al[18] in their study had 64.9 % patients with hypertension and 75.5% patients had hypertension in study by Khan et al.[19] this difference may be due to the difference in the ethnicity and age group of the population. Aslanger et al, (2020) enrolled 58% hypertensive, 107 (38%) diabetic, 262 (36%) patients with dyslipidemia and 123 (44%) smokers in their study. Similarly, in their trial 91% patients were found with KILLIP class I.[6] In our study angiographic ACO was found in 41 (54.7%) patients in STEMI and 27 (36%) patients in NSTEMI group. Similarly, composite ACO was found in 60 (80%) patients in STEMI and 27 (36%) patients in NSTTEMI group. In a prior study angiographic ACO was found in 61% patients in STEMI and 30% patients in NSTEMI group.[6] Similarly, composite ACO was found in 85% patients of STEMI and 61% patients of NSTEMI group.[6] The sensitivity and specificity of angiographic results was computed as 94.12% and 71.95%, PPV and NPV was 73.56% and 93.65%. The sensitivity and specificity of angiographic and composite ACO in STEMI patients was computed as 95.12% and 38.24% while in NSTEMI patients it was computed as 92.59% and 95.83%. In line with previous reports, our findings show a markedly higher sensitivity for detecting acute coronary occlusion in STEMI patients when using angiographic criteria (95.1 %) compared with the 80-86 % pooled sensitivity from a recent meta-analysis of advanced

ECG markers,[20] although specificity is lower (38.2 % vs. 90-95 %). The composite ACO score yields nearly identical values, indicating that the added markers did not substantially shift the ROC curve. For NSTEMI patients, our AI-driven model achieved 92.6 % sensitivity and 95.8 % specificity, closely matching earlier AI studies that reported 92-93 % sensitivity and ≈95 % specificity (20). Thus, while the sensitivity gain is notable, the modest specificity underscores the need for confirmatory imaging before acting on ECG-based cues alone.

In anterior wall myocardial infarction to detect LAD as a culprit artery Ghosh et al (21) found ECG to have the sensitivity of 100% specificity of 92.9% to detect LAD as a culprit coronary and the PPA and NPA was 90.9% and 100% respectively. While the sensitivity and specificity for detecting the branches of LAD was 42.9 and 92.9%, Distal to S1 but proximal to D1 0% and 90%, Distal to both S1 and D1 100% and 77.78% and distal to S1 were 50% and 78.95% respectively. The positive predictive accuracy (PPA) and negative predictive accuracy (NPA) for these branches Proximal to S1 and D1, Distal to S1 but proximal to D1, Distal to both S1 and D1, distal to S1 were (75% and 76.47%), (0% and 94.74%), (20% and 93.75%) (42.86% and 100%) respectively. The major strength of our study is use of standardized protocol and an adequate sample size. Our study had a larger sample size compared to some of the previous studies undertaken.

Limitations: The investigation was conducted at a single hospital, which may introduce diagnostic variabilities between different institutions; due to its cross-sectional design, temporal relationships could not be examined. Due to its hospital-based nature, the study may have excluded a specific range of diseases, hence constraining its generalizability.

Conclusion

The study demonstrated that the traditional ST-segment elevation STEMI criteria used to identify acute coronary occlusion ACO and decide on urgent reperfusion therapy are limited in diagnostic accuracy, missing a substantial proportion of true acute occlusions and leading to false activations of the catheterization laboratory. A new electrocardiogram classification strategy the ACOMI (Acute Coronary Occlusion MI)/ non-ACOMI approach showed superior diagnostic accuracy compared to the classic STEMI/non-STEMI paradigm for predicting angiographically defined ACO and long-term mortality. A notable portion of patients initially labeled as non-STEMI were re classified as having ACO using this more detailed ECG assessment and were found to have higher rates of myocardial damage and worse outcomes. Therefore, a paradigm shift from diagnosing MI based on STEMI criteria to a more comprehensive ACOMI/non-ACOMI ECG approach in the acute management of myocardial infarction to better identify patients who truly require emergent reperfusion therapy.

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