

Positive T-Wave in Lead aVR as a Predictor of Major Adverse Cardiovascular Events in Patients with ST-Elevation Myocardial Infarction (STEMI): A Cohort Study

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Conflict of interest: Nil

Abstract

Background: Early identification is crucial, as evidenced by the high mortality rate linked to ACS. The present study was conducted to assess positive T-wave in lead aVR and major adverse cardiac events in patients with ST elevation myocardial infarction.

Materials & Methods: 92 patients with STEMI of both genders were divided into two groups based on the presence of a positive T wave (Group I) and a negative T wave (Group II) in lead aVR. Assessments of cardiac biomarkers such as troponin levels, creatinine kinase (CK), and CKMB, as well as lipid profiles, renal function, and other factors associated with myocardial infarction, were part of the laboratory studies. During their in-hospital stay, patients were monitored for MACE.

Results: In group I and group II, haemoglobin (gm%) was 13.4 and 13.8, white blood cells (109/L) was 13567.3 and 11235.8, pulse rate (beats per minute) was 86.2 and 87.4, systolic blood pressure (mmHg) was 110.2 and 109.4, Troponin I was 11.7 and 21.6, CK-MB was 81.4 and 68.3, creatinine was 1.4 and 0.81 and left ventricular ejection fraction (<40%) was seen in 31 and 25 respectively. The difference was significant ($P < 0.05$). V3, V4 (Anterior wall STEMI) was observed in 31% and 28%, V3, V4, I, AVL, V5, V6 (Antero-lateral wall STEMI) in 0 and 9%, V1, V2, V3, V4 (Antero-septal wall STEMI) in 25% and 17% and II, III, AVF (Inferior wall STEMI) in 44% and 46% in group I and II respectively. The difference was non-significant ($P > 0.05$). MACE was Arrhythmia in 18% and 5%, cardiogenic shock in 52% and 42%, pulmonary oedema in 65% and 37%, heart failure in 54% and 32%, deaths in 13% and 8% in group I and group II respectively. The difference was significant ($P < 0.05$).

Conclusion: In cardiology, a positive T wave in lead aVR is more significant than is now understood. Among study participants with a positive T wave in lead aVR on the ECG, there is an increased risk of significant adverse cardiac events during hospitalization, including heart failure, pulmonary oedema, cardiogenic shock, and death. Consequently, in-hospital MACE in patients with a STEMI diagnosis can be predicted using the positive T wave in lead aVR.

Keywords: Coronary artery disease, ST elevation, T-wave; MACE; Myocardial ischemia.

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Introduction

Early identification is crucial, as evidenced by the high mortality rate linked to ACS. Coronary artery disease is identified in just 22% of patients who arrive at emergency cardiology clinics complaining of chest pain.[1] ACS is a major cause of mortality and disability and places a heavy economic burden on the world. Numerous risk factors contribute to the disease's occurrence, which is becoming more common in India.[2]

India is a very diversified country in terms of geography, race, culture, education, institutions,

and economy. India is home to the second-largest population on the planet. These elements make controlling ACS much more challenging. According to World Health Organization (WHO) reports, India's ACS incidence is rising, indicating a significant change in the nation's epidemiology. [3,4]

Unstable Angina (UA), STMI, and non STEMI (NSTEMI) are all conditions that cause acute chest pain due to myocardial ischaemia; although their pathophysiologies may vary, they all share an

underlying imbalance between oxygen supply and demand.[5] ACS is influenced by a variety of risk factors, including modifiable factors like diabetes, hypertension, obesity, smoking/tobacco use, and diet as well as non-modifiable factors like family history, ethnicity, sex, age, and genetic predisposition. It is imperative to predict and treat major adverse cardiac events, such as heart failure, cardiogenic shock, pulmonary oedema, arrhythmias, and re-infarction, in high-risk patient hospitals. [6] Electrocardiography is now considered an important and common aspect of the initial assessment of patients with cardiac symptoms. It is a non-invasive, low-cost, and easily accessible technique for assessing ACS. [7]

Aim & Objectives

Aim: To evaluate the prognostic significance of a positive T-wave in lead aVR as a predictor of major adverse cardiac events (MACE) among patients with ST-elevation myocardial infarction (STEMI).

Objectives

- To compare baseline clinical, hemodynamic, laboratory, and echocardiographic parameters between STEMI patients with positive and negative T-waves in lead aVR.
- To compare the presenting symptoms and electrocardiographic infarct locations between the two groups.
- To determine the association between a positive T-wave in lead aVR and the occurrence of individual components of MACE, including arrhythmia, cardiogenic shock, pulmonary edema, acute heart failure, and in-hospital mortality.
- To assess whether a positive T-wave in lead aVR is associated with an increased risk of adverse in-hospital outcomes in STEMI.

Materials & Methods

Study Design: This prospective cohort study was conducted to evaluate the prognostic significance of a positive T-wave in lead aVR for major adverse cardiac events (MACE) among patients with ST-elevation myocardial infarction (STEMI).

Study Population: A total of 92 consecutive patients aged 40–65 years with a confirmed diagnosis of STEMI were enrolled. The study population comprised 59.8% males and 40.2% females. All eligible participants underwent baseline clinical, electrocardiographic, laboratory, and echocardiographic evaluation. Written informed consent was obtained before enrollment.

Study Place: The study was conducted in the Department of Cardiology in collaboration with the Department of General Medicine, Narayan Medical College & Hospital, Jamuhar, Rohtas, Bihar, India,

which has facilities for Intensive Coronary Care Unit (ICCU).

Study Period: The study was carried out over a period of one and five months from June 2022 to October 2023, with patient enrollment, follow-up, and outcome assessment.

Ethical Considerations: The study was conducted after approval from the Institutional Ethics Committee and in accordance with the principles of the Declaration of Helsinki.

Written informed consent was obtained from all participants or their legally authorized representatives after explaining the study procedures, potential risks, and benefits.

Inclusion Criteria: Patients were eligible if they:

- were aged 40–65 years;
- had STEMI diagnosed on the basis of compatible clinical presentation and characteristic electrocardiographic findings;
- underwent primary percutaneous coronary intervention (PCI) or thrombolytic therapy;
- had an interpretable admission 12-lead ECG with adequate assessment of lead aVR; and
- Patients experiencing prolonged chest discomfort and angina-equivalent symptoms indicative of myocardial ischemia.
- provided informed consent.

Exclusion Criteria

- Patients diagnosed with Non-ST-Elevation Myocardial Infarction (NSTEMI) or history of a previous myocardial infarction.
- Patients with prior myocardial infarction or known structural heart disease, bundle branch blocks or paced rhythm that could affect ECG interpretation and electrolyte imbalances or conditions affecting T-wave morphology.
- Patients with incomplete medical records or lost to follow-up.

Sample size calculation: To determine the required sample size using the formula:

$$n = Z^2 \times p \times (1-p) / d^2$$

Where:

- $Z=1.96$ (for 5% significance level),
- $p=0.50$ (anticipated prevalence rate),
- $d=0.102$ (margin of error from previous calculation).

Therefore, the minimum required sample size is 92.31 patients.

Study Methodology: A detailed clinical history was obtained regarding demographic characteristics, presenting symptoms, cardiovascular risk factors, and relevant comorbidities. Physical examination included

assessment of blood pressure, heart rate, oxygen saturation, cardiac examination, and signs of heart failure or hemodynamic instability.

A standard 12-lead ECG was obtained at admission before definitive reperfusion therapy. The T-wave in lead aVR was assessed and patients were categorized into two groups according to its polarity:

- **Group I (n=46):** Positive T-wave in lead aVR
- **Group II (n=46):** Negative T-wave in lead aVR

A positive T-wave was defined as a T-wave with a net positive deflection above the isoelectric line in lead aVR.

Reperfusion Procedure: Patients received standard STEMI management according to institutional protocol. Eligible patients underwent primary PCI where available and appropriate, while patients without timely PCI access or with appropriate indications received thrombolytic therapy. Coronary angiography and PCI were performed according to standard interventional cardiology practice. Procedural details and subsequent clinical outcomes were documented. As this was an observational cohort study, no additional surgical intervention was mandated by the study protocol.

Laboratory and Other Investigations: Baseline investigations included cardiac biomarkers (troponin, creatine kinase [CK], and CK-MB), complete blood count, renal function tests, serum electrolytes, and lipid profile. Two-dimensional transthoracic echocardiography was performed to assess left ventricular systolic function and regional wall-motion abnormalities.

Chest radiography was performed when clinically indicated to evaluate pulmonary congestion or edema. Patients were monitored throughout hospitalization for cardiovascular complications and MACE.

Outcome Measures: The primary outcome was the occurrence of MACE during hospitalization. MACE comprised:

- in-hospital mortality;
- cardiogenic shock;
- significant ventricular arrhythmias, including ventricular tachycardia or ventricular fibrillation;
- acute heart failure or pulmonary edema; and
- urgent repeat revascularization.

The incidence of individual components of MACE was compared between patients with positive and negative T-waves in lead aVR.

Statistical Analysis: Data were entered into Microsoft Excel and analyzed using IBM SPSS Statistics version 25.0 (IBM Corp., Armonk, NY, USA). Continuous variables were summarized as mean $\pm$ standard deviation (SD) and categorical variables as frequency and percentage. Normality of continuous variables was assessed before selecting parametric tests. The independent-samples Student's *t*-test was used to compare normally distributed continuous variables between the two groups. Categorical variables were compared using the Pearson chi-square test or Fisher's exact test, as appropriate.

The association between a positive T-wave in lead aVR and the occurrence of MACE was expressed using odds ratios (ORs) with 95% confidence intervals (CIs). Where appropriate, binary logistic regression was used to assess the independent association of a positive T-wave in lead aVR with MACE after adjustment for clinically relevant baseline variables.

A two-sided *p* value <0.05 was considered statistically significant.

Results

Table 1: Comparison of Hemodynamic, Laboratory, and Echocardiographic Parameters Between Study Groups

Parameter	Group I (n=46): Positive T-wave in aVR	Group II (n=46): Negative T-wave in aVR	<i>p</i> -value
Hemoglobin (g/dL)	13.4 $\pm$ 1.5	13.8 $\pm$ 1.6	0.48
White blood cell count (cells/mm ³)	13,567.3 $\pm$ 2,100	11,235.8 $\pm$ 1,900	0.15
Pulse rate (beats/min)	86.2 $\pm$ 12.5	87.4 $\pm$ 11.8	0.42
Systolic blood pressure (mmHg)	110.2 $\pm$ 13.4	109.4 $\pm$ 12.9	0.74
Troponin I (ng/mL)	11.7 $\pm$ 2.4	21.6 $\pm$ 3.1	0.01
CK-MB (U/L)	81.4 $\pm$ 14.7	68.3 $\pm$ 13.2	0.93
Serum creatinine (mg/dL)	1.4 $\pm$ 0.3	0.81 $\pm$ 0.2	0.01
Left ventricular ejection fraction (<40%)	31.0 $\pm$ 4.40	25.0 $\pm$ 1.33	<0.001

The table 1 presents that haemoglobin levels are similar between the groups (13.4 ± 1.5 vs. 13.8 ± 1.6 , $p = 0.487$). No significant difference, indicating that anaemia did not influence outcomes. However, white blood cell (WBC) count is higher in Group I (13567.3 ± 2100 vs. 11235.8 ± 1900 , $p = 0.15$), suggesting a stronger inflammatory response, but not statistically significant. The pulse rate shows a minor yet significant difference (86.2 ± 12.5 vs. 87.4 ± 0.59 , $p = 0.42$). No significant difference, indicating comparable autonomic responses. Whereas systolic blood pressure (SBP) remains comparable between the groups (110.2 ± 13.4 vs. 109.4 ± 12.9 , $p = 0.74$). No significant difference in baseline blood pressure. Notably, Troponin I, a key marker of myocardial injury, is significantly elevated in Group II (11.7 ± 2.4 vs. 21.6 ± 3.1 , $p = 0.01$), indicating more extensive cardiac damage. Similarly, CK-MB levels, another indicator of myocardial infarction severity, are

significantly higher in Group I (81.4 ± 14.7 vs. 68.3 ± 13.2 , $p = 0.93$). No significant difference, suggesting similar infarct size. Renal function, assessed via serum creatinine, is significantly higher in Group I (1.4 ± 0.3 vs. 0.81 ± 0.2 , $p = 0.010$). Group I had significantly higher creatinine levels ($p = 0.01$), indicating a higher risk of renal dysfunction, which is known to be associated with poor prognosis in STEMI. Lastly, left ventricular ejection fraction (LVEF $<40\%$) is significantly lower in Group II (31.0 ± 4.40 vs. 25.0 ± 1.33 , $p = 0.001$), suggesting a greater degree of left ventricular dysfunction in this group. Haemoglobin WBC count, Pulse Rate and Systolic Blood Pressure did not show significant differences, meaning these parameters are relatively stable across both groups. These findings may help in understanding the relationship between positive T-wave in lead aVR and the severity of myocardial infarction in STEMI patients.

Table 2: Comparison of Presenting Symptoms Between Patients with Positive and Negative T-Waves in Lead aVR

Presenting symptom	Group I: Positive T-wave in aVR (%)	Group II: Negative T-wave in aVR (%)	p-value
Chest pain	60	53	0.10
Dyspnea	41	33	0.38
Sweating (diaphoresis)	61	57	0.21
Nausea/vomiting	36	18	0.11

Table 2 show that chest pain was reported in 60% of patients in Group I compared with 53% in Group II ($p=0.10$). Dyspnea was present in 41% and 33% of patients, respectively ($p=0.38$). Sweating

(diaphoresis) occurred in 61% of Group I and 57% of Group II ($p=0.21$), while nausea/vomiting was reported in 36% and 18%, respectively ($p=0.11$).

Table 3: Comparison of Electrocardiographic Findings and Infarct Location Between Study Groups

ECG finding / Infarct location	Group I: Positive T-wave in aVR (%)	Group II: Negative T-wave in aVR (%)	p-value
Anterior wall STEMI (V3–V4)	31	28	0.81
Anterolateral wall STEMI (V3–V4, I, aVL, V5–V6)	0	9	
Anteroseptal wall STEMI (V1–V4)	25	17	
Inferior wall STEMI (II, III, aVF)	44	46	

Table 3 show the distribution of infarct location on ECG was compared between patients with positive and negative T-waves in lead aVR. Inferior-wall STEMI was the most frequent infarct location in both Group I (44%) and Group II (46%), followed

by anterior-wall STEMI (31% vs. 28%) and anteroseptal STEMI (25% vs. 17%). Anterolateral STEMI was observed in 0% of Group I compared with 9% of Group II. The difference was non-significant ($P > 0.05$).

Table 4: Comparison of Major Adverse Cardiac Events (MACE) Between Patients with Positive and Negative T-Waves in Lead aVR

Major adverse cardiac event	Group I: Positive T-wave in aVR (%)	Group II: Negative T-wave in aVR (%)	p-value
Arrhythmia	18	5	0.01
Cardiogenic shock	52	42	0.05
Pulmonary edema	65	37	0.01
Acute heart failure	54	32	0.02
In-hospital mortality	13	8	0.04

Table 4, figure I shows that MACE was Arrhythmia in 18% and 5%, cardiogenic shock in 52% and 42%, pulmonary oedema in 65% and

37%, heart failure in 54% and 32%, deaths in 13% and 8% in group I and group II respectively. The difference was significant ($P < 0.05$).

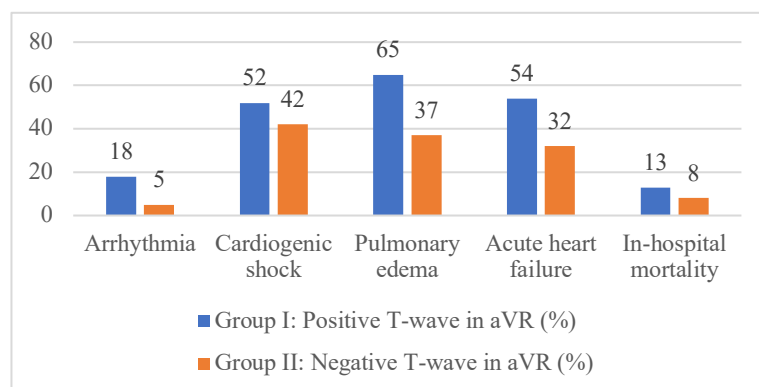


Figure 1: Major Adverse Cardiac Events (MACE)

Discussion

In 1902, Dutch physician William Einthoven created electrocardiography, which is now known as ECG. He gave details regarding the heart's electrophysiology.[8]

Nowaday, electrocardiography is regarded as a crucial and typical component of the early evaluation of patients exhibiting cardiac symptoms. It is a simple, affordable, and non-invasive method of ACS assessment. [9,10] Although Lead aVR, one of the ECG's twelve leads, has long been disregarded, recent studies have demonstrated that it can aid in the diagnosis and prognosis of a number of cardiac conditions.[11,12]

The present study was conducted to assess positive T-wave in lead aVR and major adverse cardiac events in patients with ST elevation myocardial infarction. We found that Haemoglobin levels are similar between the groups (13.4 ± 1.5 vs. 13.8 ± 1.6 , $p = 0.487$), and white blood cell (WBC) count is higher in Group I (13567.3 ± 2100 vs. 11235.8 ± 1900 , $p = 0.15$). Similarly, pulse rate (86.2 ± 12.5 vs. 87.4 ± 11.8 beats/min; $p = 0.42$) and systolic blood pressure (110.2 ± 13.4 vs. 109.4 ± 12.9 mmHg; $p = 0.74$) were comparable. An increased WBC count has been associated with systemic inflammatory response and worse cardiac outcomes in STEMI patients (Sharma et al., 2019). [13]

A significant difference was observed in troponin I, which was higher in Group II than Group I (21.6 ± 3.1 vs. 11.7 ± 2.4 ng/mL; $p = 0.01$). Thus, although the positive-T-wave group demonstrated worse clinical outcomes, the negative-T-wave group had a higher measured troponin concentration. Separham et al. (2018), in a prospective cohort of 400 patients with NSTEMI, similarly demonstrated that positive T-wave aVR was associated with important adverse clinical characteristics but was not an independent

predictor of MACE after multivariable adjustment. [14]

We found that Serum creatinine is significantly higher in Group I (1.4 ± 0.3 vs. 0.81 ± 0.2 , $p = 0.010$); Group I had significantly higher creatinine levels ($p = 0.01$), indicating a higher risk of renal dysfunction, which is known to be associated with poor prognosis in STEMI. Studies have indicated that impaired renal function is a predictor of increased mortality in STEMI patients (Parikh et al., 2018).[15]

Lastly, left ventricular ejection fraction (LVEF $< 40\%$) is significantly lower in Group II (31.0 ± 4.40 vs. 25.0 ± 1.33 , $p = 0.001$), suggesting a greater degree of left ventricular dysfunction in this group. A lower LVEF is associated with higher rates of heart failure and mortality post-STEMI (Goldberg et al., 2021).[16]

Chest pain was the most common presenting symptom in both groups, with 60% of patients in Group I (positive T-wave in aVR) and 53% in Group II (negative T-wave in aVR) reporting this symptom ($p = 0.10$). This aligns with previous studies indicating that chest pain remains the cardinal symptom of STEMI, occurring in approximately 80–90% of cases (Thygesen et al., 2018).[17]

Dyspnea was more prevalent in Group I (41% vs. 33%), though not statistically significant ($p = 0.38$). Dyspnea in STEMI patients is often attributed to heart failure or increased left ventricular filling pressures due to impaired myocardial function (Killip & Kimball, 1967).[18]

Sweating (diaphoresis) was reported in 61% of Group I and 57% of Group II patients ($p = 0.21$). This symptom is closely linked to sympathetic activation during acute coronary syndromes and is

a well-documented indicator of autonomic nervous system involvement (Amsterdam et al., 2014).[19]

Nausea and vomiting were more frequently reported in Group I (36% vs. 18%, $p = 0.11$). While not statistically significant, this finding is clinically relevant as nausea and vomiting are commonly associated with inferior wall myocardial infarction, likely due to vagal stimulation (Kerkhof et al., 2019). [20]

Inferior-wall STEMI represented the most frequent infarct location in both groups, occurring in 44% of patients with a positive T-wave and 46% with a negative T-wave. Anterior-wall STEMI occurred in 31% and 28%, respectively, while anteroseptal STEMI was observed in 25% and 17%. Anterolateral STEMI occurred in 0% of Group I and 9% of Group II. The reported comparison for anterior-wall STEMI was not statistically significant ($p=0.81$), and the available findings did not demonstrate a significant difference in infarct distribution between the groups. This finding is important because previous research has particularly linked positive T-wave aVR with extensive anterior ischemia and proximal LAD disease. Kobayashi et al. (2017) found that positive T-wave aVR was associated with a higher prevalence of left-main coronary disease and independently predicted 1-year MACE in first anterior-wall STEMI.[21]

In contrast, the present study included different STEMI territories and found no statistically significant difference in infarct location. The broader inclusion of inferior, anterior, anteroseptal, and anterolateral STEMI may partly explain this difference. Separham et al. (2018) also demonstrated that positive T-wave aVR was associated with severe coronary anatomical disease in NSTEMI, particularly three-vessel and/or left-main coronary artery disease, although it did not independently predict MACE after adjustment.[14] Thus, T-wave positivity in aVR may reflect the overall burden and distribution of ischemia rather than being restricted to a single infarct territory.

The most important finding of the present study was the significantly greater frequency of adverse cardiac events among patients with a positive T-wave in aVR. Arrhythmias occurred in 18% of Group I compared with 5% of Group II ($p=0.01$). Pulmonary edema was observed in 65% versus 37% ($p=0.01$), acute heart failure in 54% versus 32% ($p=0.02$), and in-hospital mortality in 13% versus 8% ($p=0.04$). Cardiogenic shock was also more frequent in Group I (52% vs. 42%), with a borderline statistically significant difference ($p=0.05$). Al-Zaiti et al. (2015) reported that a discordant positive T-wave pattern in aVR independently predicted sudden cardiac arrest (HR 2.0, 95% CI 1.0–4.9) and cardiac death (HR 1.9,

95% CI 1.0–3.7) in patients with ischemic cardiomyopathy.[22] The present finding of increased arrhythmia therefore supports the broader association between abnormal aVR repolarization and electrical instability.

The association with heart failure and pulmonary edema is also consistent with previous evidence. Kobayashi et al. (2017) demonstrated substantially higher long-term MACE and mortality among patients with positive T-wave aVR following anterior STEMI.[12] Similarly, Kazemi et al. (2021), in a prospective study of 340 STEMI patients, found that increasing T-wave amplitude in aVR was associated with progressively higher in-hospital and six-month mortality. Patients with T-wave amplitude ≥ 0 mV had the highest risk, and the investigators reported a relative risk of 2.30 for in-hospital mortality in the highest T-wave category.[23]

The mortality finding in the present study is also compatible with the long-term observations of Siren et al. (2020). In their TACOS study involving 527 patients with ACS and ischemic ECG changes, a positive or isoelectric T-wave in aVR was associated with increased 10-year all-cause mortality. After adjustment for age and sex, the hazard ratio for all-cause mortality was 1.43 (95% CI 1.12–1.83; $p=0.004$), while the corresponding hazard ratio for cardiovascular mortality was 1.54 (95% CI 1.14–2.07; $p=0.005$).[24]

Limitations of the study

- The relatively small sample size may limit the generalizability of the findings.
- The study was confined to a single tertiary care centre, which may introduce selection bias.
- The follow-up period was limited to in-hospital stay, and long-term outcomes were not assessed.
- Other confounding factors influencing MACE, such as thrombolytic therapy and coronary interventions, were not separately analyzed.

Conclusion

The presence of a positive T-wave in lead aVR on the ECG in STEMI patients correlates with a higher risk of major adverse cardiac events, including arrhythmias, cardiogenic shock, pulmonary oedema, heart failure, and mortality. These findings suggest that T-wave polarity in lead aVR should be considered a valuable prognostic marker in STEMI patients.

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