

Original Article

Incidence of Total Occlusion of Major Coronary Arteries Without ST-T Wave Changes in Patients With Acute Coronary Syndrome

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ABSTRACT

Background: Acute coronary occlusion may occur without diagnostic ST-segment elevation. This study examined the incidence and angiographic patterns of total coronary occlusion and the impact of reperfusion timing on outcomes.

Methods: In this retrospective observational study, 300 participants with acute coronary syndrome (ACS) who presented between July 2023 and July 2024 were included. Based on admission electrocardiography (ECG), participants were categorized into 3 groups: STEMI (n = 103), ST-segment depression and/or T-wave abnormalities (n = 125), and normal ECG (n = 72). Clinical characteristics, serial cardiac biomarkers, echocardiographic findings, coronary angiographic data, door-to-balloon (DTB) time, and clinical outcomes were analyzed.

Results: Baseline characteristics were similar across groups, except for older age in participants with ST-segment depression/T-wave abnormalities ($P < .001$). High-sensitivity troponin elevation was common in participants with ischemic ECG changes but less frequent in those with normal ECGs ($P = .001$). Participants with ST-segment elevation myocardial infarction (STEMI) had more regional wall motion abnormalities and lower left ventricular ejection fraction ($P = .001$). Proximal left anterior descending and right coronary artery occlusions predominated in participants with ischemic ECG changes, whereas left circumflex (LC_x) and obtuse marginal occlusions were more frequent in those with normal ECGs ($P = .03$). DTB times less than 90 minutes were achieved in 89.3%, 83.2%, and 62.5% of STEMI, ST-segment depression, and normal ECG groups, respectively ($P = .001$). In participants with total LC_x occlusion, a DTB time less than 90 minutes was associated with lower mortality and shorter hospital stay.

Conclusions: Participants with ACS may have complete coronary occlusion despite absence of diagnostic ST-segment elevation, particularly with LC_x involvement. Reliance on ECG findings alone may delay recognition and reperfusion. Serial cardiac biomarkers, echocardiography, and early invasive assessment can improve diagnostic accuracy and facilitate timely management. (*Iranian Heart Journal 2026; 27(4): 60-72*)

KEYWORDS: acute coronary syndrome; acute coronary occlusion; left circumflex artery; electrocardiography; door-to-balloon time

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Acute coronary syndrome (ACS) refers to a group of clinical presentations resulting from sudden myocardial ischemia, including ST-segment elevation myocardial infarction (STEMI), non-ST-segment elevation myocardial infarction (NSTEMI), and unstable angina. Although substantial progress has been made in diagnostic techniques and therapeutic interventions, ACS continues to be a leading contributor to global morbidity and mortality, underscoring the need for prompt recognition and early reperfusion treatment.^{1,2}

ACS is most commonly triggered by atherosclerotic plaque disruption followed by thrombus formation, resulting in partial or complete impairment of coronary blood flow. Electrocardiography (ECG) remains a cornerstone of the initial evaluation of patients with suspected ACS because it provides rapid information regarding myocardial ischemia and helps guide treatment decisions. Nevertheless, although some ECG findings strongly suggest acute coronary occlusion, ischemic changes may be subtle, transient, or absent, particularly during the early phase of myocardial injury.³ In contemporary ACS management, urgent reperfusion decisions are primarily guided by the detection of ST-segment elevation on the presenting ECG. However, increasing evidence indicates that a substantial proportion of patients with complete coronary artery obstruction do not demonstrate diagnostic ST-segment elevation and may instead present with ST-segment depression, T-wave abnormalities, or even a normal ECG. Recent studies and meta-analyses have highlighted limitations of the traditional STEMI/NSTEMI paradigm and have shown that acute total coronary occlusion (TCO) may occur despite the absence of ST-segment elevation, potentially leading to delayed angiography and revascularization.⁴

Patients lacking diagnostic ST-segment elevation represent a heterogeneous

population in whom substantial myocardial ischemia may be present despite minimal or non-diagnostic ECG abnormalities. Consequently, reliance on ECG findings alone may underestimate disease severity and contribute to delays in definitive treatment.^{5,6} Diagnosis may be particularly challenging in patients with left circumflex coronary artery (LC_x)-related infarction because ischemic changes involving the lateral and posterior myocardial territories are often incompletely represented on the standard 12-lead ECG. Consequently, complete LC_x occlusion may occur without the characteristic ECG features typically associated with acute myocardial infarction, potentially delaying recognition and reperfusion therapy.⁷

Given these challenges, increasing attention has focused on identifying angiographic predictors of acute coronary occlusion beyond conventional STEMI criteria and on understanding the clinical significance of atypical or ECG-negative presentations. Clarifying the relationships among ECG findings, coronary anatomy, reperfusion timing, and clinical outcomes may improve risk stratification and support more effective management strategies for patients with ACS.^{7,8}

Accordingly, the present study was designed to examine the frequency and angiographic distribution of TCO across different ECG presentations, including in patients without diagnostic ST-segment elevation. In addition, we evaluated the association of ECG presentation and reperfusion timing with clinical outcomes, echocardiographic findings, and prognosis.

METHODS

Study Design and Patient Population

The present retrospective observational study was conducted in the Cardiology Department of Tanta University Hospital. A total of 386 patients presented to the emergency department with suspected ACS

between July 2023 and July 2024. Patients were identified retrospectively from hospital records and screened for eligibility. Of these, 300 consecutive patients met the predefined inclusion criteria and were included in the final analysis. Eighty-six patients were excluded because of incomplete clinical records, the absence of coronary angiography before discharge, or fulfillment of predefined exclusion criteria. All included patients underwent coronary angiography prior to hospital discharge.

Exclusion Criteria: Patients were excluded if they had incomplete clinical, laboratory, or angiographic data during hospitalization; could not be contacted for follow-up or declined participation in the telephone follow-up component of the study; or had a known history of malignancy or coagulation disorders. Individuals without evidence of obstructive coronary artery disease on angiography or with a confirmed alternative diagnosis were also excluded.

Patient Classification: Based on ECG findings at presentation, patients were categorized into 3 groups:

- **Group 1:** STEMI.
- **Group 2:** ST-segment depression or T-wave abnormalities consistent with myocardial ischemia.
- **Group 3:** No significant ST-segment or T-wave changes.

A predefined subgroup analysis was performed in patients with angiographically confirmed total LC_x occlusion to evaluate the association between ECG presentation, reperfusion timing, serial troponin measurements, and clinical outcomes.

Data Collection: Clinical, laboratory, and angiographic data were obtained from hospital medical records and catheterization reports. Follow-up information was obtained through structured telephone interviews after

verbal and/or written consent had been obtained for participation in the follow-up component of the study.

Baseline Demographic, Clinical, and Laboratory Data: Baseline demographic characteristics included age, sex, body mass index, and conventional cardiovascular risk factors, such as previous cerebrovascular stroke or transient ischemic attack, hypertension, peripheral arterial disease, hypercholesterolemia, diabetes mellitus, smoking status, and a positive family history of cardiovascular disease. All patients underwent a standard 12-lead ECG to assess for ST-segment deviations. The Killip classification was documented at admission. Serum cardiac biomarkers, including high-sensitivity troponin and CK-MB, were obtained at presentation. High-sensitivity troponin levels were recorded at presentation (T0), 6 hours (T6), and 12 hours (T12) whenever available according to institutional ACS protocols.

Definition of Myocardial Injury and Infarction: Myocardial injury was defined in accordance with the Fourth Universal Definition of Myocardial Infarction,⁹ based on elevated serum concentrations of cardiac troponin I, troponin T, or the MB isoenzyme of creatine phosphokinase. Myocardial infarction (MI) was classified as STEMI or NSTEMI according to ECG criteria. ST-segment elevation was defined as 0.2 mV or greater in at least 2 contiguous precordial leads or 0.1 mV or greater in 2 contiguous limb leads.

Cardiac Imaging and Interventional Procedures: Transthoracic echocardiography was performed for all patients prior to discharge using a Vivid E9 ultrasound system (GE Vingmed Ultrasound, Horten, Norway) equipped with an M5S phased-array transducer (2.5–5.0 MHz). Echocardiographic

measurements were obtained using standardized methods consistent with the recommendations of the American Society of Echocardiography. Left ventricular end-diastolic and end-systolic volumes and dimensions, ejection fraction, and valvular abnormalities were assessed.¹⁰ Repeat transthoracic echocardiography was scheduled approximately 3 months after discharge whenever feasible. Regional wall motion abnormalities (RWMA), left ventricular ejection fraction, and left ventricular dimensions were reassessed using the same standardized methodology. Coronary angiography was performed in accordance with contemporary European Society of Cardiology recommendations to define coronary anatomy and identify the culprit vessel. Percutaneous coronary intervention (PCI) was undertaken for the culprit vessel during the index procedure, while additional significant lesions were scheduled for staged PCI during subsequent admissions when indicated. Door-to-balloon (DTB) time was defined as the interval between hospital arrival and first balloon inflation or device deployment during primary PCI. Patients were categorized according to DTB times below 90 minutes or above 90 minutes.

Follow-Up

In-hospital clinical outcomes were recorded for all patients during the index admission. Clinical follow-up was performed at 3 months after discharge for echocardiographic reassessment and at 1 year for mortality assessment. Follow-up information was obtained through outpatient records and structured telephone interviews with patients or their next of kin. The follow-up completion rate was comparable across study groups. Mortality events reported during telephone interviews were verified, whenever possible, through review of hospital medical records and available death documentation. Outcome assessment was performed by investigators

who were not blinded to the patients' clinical characteristics or ECG group assignment.

Statistical Analysis

Data were entered and analyzed using IBM SPSS Statistics for Windows, version 23.0 (IBM Corp). Qualitative data were presented as frequencies and percentages, whereas quantitative data were expressed as mean (SD) or median (IQR), as appropriate. A 2-sided *P* value of .05 or less was considered statistically significant. The χ^2 test and Fisher exact test were employed to assess associations between categorical variables. Comparisons between 2 independent groups were performed using the independent-samples *t* test or Mann-Whitney *U* test, as appropriate. Comparisons among more than 2 groups were conducted using 1-way analysis of variance (ANOVA) or the Kruskal-Wallis test according to data distribution. For the assessment of correlations between quantitative variables, Pearson correlation coefficient was used for normally distributed data, whereas Spearman rank correlation coefficient was applied for non-normally distributed or ordinal data. For repeated binary measurements of high-sensitivity troponin obtained at presentation (T0), 6 hours (T6), and 12 hours (T12) in patients with total LC_x occlusion, temporal changes were assessed using Cochran Q test. Given the exploratory nature of the study, no formal adjustment for multiple comparisons was performed. Accordingly, all statistical comparisons should be interpreted as exploratory and hypothesis-generating. No multivariable regression analyses were performed because the study was designed as an exploratory observational investigation.

Ethical Considerations

The study was conducted in accordance with the Declaration of Helsinki. Ethical approval was obtained from the Research Ethics Committee of the Faculty of Medicine, Tanta University (Committee reference

number: 36264PR33/8/24). Because of the retrospective study design, waiver of informed consent was granted where applicable. Verbal and/or written informed consent was obtained from patients or their next of kin for participation in the telephone follow-up component of the study. All patient data were anonymized and handled confidentially throughout the study.

RESULTS

A total of 300 patients presenting with ACS were included in this retrospective analysis. Based on admission ECG findings, patients were categorized into 3 groups: Group 1 (STEMI), 103 patients with ST-segment elevation; Group 2 (STD), 125 patients with ST-segment depression and/or T-wave abnormalities indicative of myocardial ischemia; and Group 3 (normal ECG), 72 patients without ST-segment or T-wave changes.

Baseline Demographics and Clinical Presentation:

Most baseline demographic variables, including sex, body mass index, and traditional cardiovascular risk factors, were comparable among the 3 groups. Nonetheless, patients in the STD group were significantly older than those in the STEMI and normal ECG groups (mean [SD], 64.35 [6.38] vs 61.40 [6.81] and 61.50 [6.63] years, respectively; $P < .001$) (Table 1). Chest pain was the predominant presenting symptom across all groups, reported in 72.8% of the STEMI group, 60.8% of the STD group, and 70.8% of patients with normal ECG findings ($P = .60$). Dyspnea was more frequently observed in the STD group (33.6%), while syncope and other symptoms were rare across the cohort.

Clinical Status and Heart Failure at Presentation:

Killip class III–IV was observed in 20.4% of patients with STEMI, 32.8% of patients with STD, and 11.1% of those with normal ECG findings ($P = .002$) (Table 1).

Table 1. Baseline Characteristics of Patients in Each of the 3 Groups

Characteristic	STE (n = 103)	STD (n = 125)	Normal (n = 72)	F or χ^2	P
Age					
Mean (SD)	61.40 (6.81)	64.35 (6.38)	61.50 (6.63)	F, 7.121	< .001*
Sex					
Male, No. (%)	54 (52.4)	71 (56.8)	48 (66.7)	χ^2 , 3.586	.17
Female, No. (%)	49 (47.6)	54 (43.2)	24 (33.3)		
BMI					
18–24.9, No. (%)	73 (70.9)	94 (75.2)	50 (69.4)	χ^2 , 3.851	.70
25–29.9, No. (%)	17 (16.5)	15 (12.0)	14 (19.4)		
30–34.9, No. (%)	8 (7.8)	12 (9.6)	7 (9.7)		
35–39.9, No. (%)	5 (4.9)	4 (3.2)	1 (1.4)		
Hypertension, No. (%)	67 (65.0)	70 (56.0)	45 (62.5)	χ^2 , 2.071	.35
Diabetes mellitus, No. (%)	47 (45.6)	43 (34.4)	29 (40.3)	χ^2 , 2.991	.22
Dyslipidemia, No. (%)	55 (53.4)	79 (63.2)	41 (56.9)	χ^2 , 2.307	.32
Family history of CAD, No. (%)	5 (4.9)	9 (7.2)	10 (13.9)	χ^2 , 4.886	.08
Peripheral vascular disease, No. (%)	15 (14.6)	17 (13.6)	9 (12.5)	χ^2 , 0.154	.93
Cerebrovascular accident, No. (%)	15 (14.6)	11 (8.8)	7 (9.7)	χ^2 , 2.074	.36
Transient ischemic attack, No. (%)	6 (5.8)	12 (9.6)	4 (5.6)	χ^2 , 1.625	.44
Clinical Presentation					
Chest pain, No. (%)	75 (72.8)	76 (60.8)	51 (70.8)	χ^2 , 4.605	.60
Dyspnea, No. (%)	24 (23.3)	42 (33.6)	19 (26.4)		
Syncope, No. (%)	2 (1.9)	4 (3.2)	1 (1.4)		
Other, No. (%)	2 (1.9)	3 (2.4)	1 (1.4)		

Killip Class, No. (%)					
I-II	82 (79.6)	84 (67.2)	64 (88.9)	χ^2 , 12.774	.002*
III-IV	21 (20.4)	41 (32.8)	8 (11.1)		
Laboratory Findings					
High-sensitivity troponin, No. (%)					
T0	81 (78.6)	102 (81.6)	0 (0.0)	χ^2 , 267.949	.001*
T6	103 (100.0)	125 (100.0)	6 (8.3)		
T12	103 (100.0)	125 (100.0)	5 (6.9)		
CK-MB (high), No. (%)					
	103 (100.0)	125 (100.0)	0 (0.0)	χ^2 , 300.0	< .001*

Data are presented as mean (SD) or No. (%), as appropriate. *Statistically significant at $P < .05$.

BMI: body mass index; CAD: coronary artery disease; CK-MB: creatine kinase-MB; STD: ST-segment depression; STE: ST-segment elevation

Cardiac Biomarkers: At presentation (T0), elevated high-sensitivity troponin levels were observed in 78.6% of patients with STEMI and 81.6% of patients with STD, whereas all patients in the normal ECG group had normal values. At 6 hours (T6), elevated high-sensitivity troponin levels were present in all patients with STEMI and STD, compared with 8.3% of patients in the normal ECG group. Similar findings were observed at 12 hours (T12), with elevated high-sensitivity troponin levels present in all patients with STEMI and STD and in only 6.9% of patients with normal ECG findings. CK-MB was elevated in patients with ST-segment abnormalities but remained normal in those with normal ECGs.

Echocardiographic Findings: At baseline, RWMA were present in all patients with STEMI, 65.6% of patients with STD, and 66.7% of those with normal ECGs ($P = .001$). At discharge, RWMA persisted in 93.2% of patients with STEMI, 61.6% of patients with STD, and 61.1% of patients with normal ECG findings ($P = .001$). After 3 months, RWMA was present in 4.9%, 4.0%, and 6.9% of patients in the STEMI, STD, and normal ECG groups, respectively, with no significant difference between groups ($P = .93$). Left ventricular ejection fraction also differed significantly between groups. At baseline, preserved left ventricular ejection fraction ($> 50\%$) was observed in 12.6%, 40.8%, and 51.4% of patients in the STEMI,

STD, and normal ECG groups, respectively. Severely reduced left ventricular ejection fraction ($< 30\%$) was observed in 31.1%, 24.8%, and 5.6% of patients, respectively. At discharge, left ventricular ejection fraction less than 30% was present in 24.3%, 17.6%, and 2.8% of patients in the STEMI, STD, and normal ECG groups, respectively ($P = .001$). Nevertheless, after 3 months, left ventricular ejection fraction differences were no longer statistically significant ($P = .90$). Left ventricular dilation occurred at similar rates across the 3 groups at baseline (9%–11%; $P = .89$) and at discharge (2.4%–2.9%; $P = .99$). At 3-month follow-up, left ventricular dilation was present in 4.0% of patients with STD, compared with 1.9% of patients with STEMI and 2.8% of patients with normal ECG findings ($P = .90$).

Coronary Angiographic Findings: The distribution of coronary occlusion sites and coronary dominance patterns across the 3 study groups is presented in Table 3. No statistically significant differences were observed in the frequency of total occlusion involving the proximal or distal left main coronary artery, mid or distal left anterior descending artery (LAD), diagonal branch, proximal LCx, or distal right coronary artery (RCA). In contrast, occlusions of the proximal LAD, proximal RCA, and mid-RCA were significantly more frequent among participants presenting with ST-segment elevation or ST-segment depression/T-wave abnormalities

than among those with normal ECG findings. Conversely, occlusions involving the mid and distal LCx, obtuse marginal (OM) branch, and posterior descending artery (PDA) were observed more frequently in participants with normal ECG findings than in those with ischemic ECG changes.

Procedural and Outcome Data: Rates of multivessel disease (MVD), catheterization laboratory mortality, in-hospital mortality, and 1-year mortality were similar across the 3 groups. However, DTB times less than 90 minutes were achieved significantly more often in participants with STEMI (89.3%)

than in those with ST-segment depression (83.2%) and normal ECG findings (62.5%) (Table 3).

Among participants with total LCx occlusion, MVD was detected in 33.3% of participants with STEMI, 18.4% of participants with ST-segment depression, and 28.3% of participants with normal ECG findings ($P = .41$). A DTB time less than 90 minutes was achieved in 88.9% of participants with STEMI compared with 60.4% of participants with normal ECG findings ($P = .02$), whereas no statistically significant differences were observed for the remaining variables (Table 3 and Figure 1).

Table 2. Echocardiographic Findings in Patients in Each of the Three Groups

Characteristic	STE (n = 103)	STD (n = 125)	Normal (n = 72)	χ^2	P
RWMA, baseline, No. (%)	103 (100.0)	82 (65.6)	48 (66.7)	45.134	.001*
RWMA, discharge, No. (%)	96 (93.2)	77 (61.6)	44 (61.1)	41.889	.001*
RWMA, 3 mon, No. (%)	5 (4.9)	5 (4.0)	5 (6.9)	0.852	.931
LVEF, baseline, No. (%)					
> 50	13 (12.6)	51 (40.8)	37 (51.4)	42.019	.001*
40–50	31 (30.1)	22 (17.6)	19 (26.4)		
30–40	27 (26.2)	21 (16.8)	12 (16.7)		
< 30	32 (31.1)	31 (24.8)	4 (5.6)		
LVEF, discharge, No. (%)					
> 50	13 (12.6)	50 (40.0)	35 (48.6)	39.592	.001*
40–50	31 (30.1)	22 (17.6)	19 (26.4)		
30–40	27 (26.2)	22 (17.6)	11 (15.3)		
< 30	25 (24.3)	22 (17.6)	2 (2.8)		
Not done	7 (6.8)	9 (7.2)	5 (6.9)		
LVEF at 3 mon, No. (%)					
> 50	79 (76.7)	101 (80.8)	60 (83.3)	3.461	.90
40–50	8 (7.8)	6 (4.8)	2 (2.8)		
30–40	5 (4.9)	6 (4.8)	4 (5.6)		
< 30	4 (3.9)	3 (2.4)	1 (1.4)		
Not done	7 (6.8)	9 (7.2)	5 (6.9)		
LV dimension, baseline, No. (%)	Dilated: 11 (10.7)	Dilated: 11 (8.8)	Dilated: 7 (9.7)	0.229	.89
LV dimension at discharge, No. (%)	Dilated: 3 (2.9)	Dilated: 3 (2.4)	Dilated: 2 (2.8)	0.074	.99
Not done	7 (6.8)	9 (7.2)	5 (6.9)		
LV dimension at 3 mon, No. (%)	Dilated: 2 (1.9)	Dilated: 5 (4.0)	Dilated: 2 (2.8)	1.097	.90
Not done	7 (6.8)	8 (6.4)	6 (8.3)		

Data are presented as No. (%). *Statistically significant at $P < .05$.

RWMA: regional wall motion abnormality; LVEF: left ventricular ejection fraction

Table 3. Segmental Location of Total Occlusion, Coronary Dominance, and Outcomes in Patients in Each of the 3 Groups

Total Occlusion / Outcome	STE	STD	Normal	χ^2	P
LM-P, No. (%)	1 (1.0)	2 (1.6)	0 (0.0)	1.182	.55
LM-M, No. (%)	1 (1.0)	1 (0.8)	0 (0.0)	0.663	.72
LM-D, No. (%)	5 (4.9)	2 (1.6)	0 (0.0)	4.891	.087
LAD-P, No. (%)	26 (25.2)	17 (13.6)	1 (1.4)	19.462	.001*
LAD-M, No. (%)	10 (9.7)	10 (8.0)	2 (2.8)	3.142	.21
LAD-D, No. (%)	7 (6.8)	5 (4.0)	1 (1.4)	3.052	.22
Diagonal, No. (%)	5 (4.9)	5 (4.0)	2 (2.8)	0.482	.79
LCx-P, No. (%)	7 (6.8)	14 (11.2)	7 (9.7)	1.308	.52
LCx-M, No. (%)	3 (2.9)	8 (6.4)	11 (15.3)	9.811	.007*
LCx-D, No. (%)	3 (2.9)	11 (8.8)	20 (27.8)	27.441	.001*
OM, No. (%)	5 (4.9)	5 (4.0)	15 (20.8)	19.428	.001*
RCA-P, No. (%)	9 (8.7)	19 (15.2)	0 (0.0)	12.539	.002*
RCA-M, No. (%)	15 (14.6)	16 (12.8)	0 (0.0)	11.108	.004*
RCA-D, No. (%)	1 (1.0)	5 (4.0)	4 (5.6)	3.341	.19
PDA, No. (%)	5 (4.9)	5 (4.0)	9 (12.5)	6.138	.046*
Coronary dominance pattern					
RCA dominant, No. (%)	69 (67.0)	75 (60.0)	39 (54.2)	5.051	.28
LCx, No. (%)	28 (27.2)	40 (32.0)	30 (41.7)		
Codominant, No. (%)	6 (5.8)	10 (8.0)	3 (4.2)		
MVD, No. (%)	28 (27.2)	30 (24.0)	16 (22.2)	0.613	.74
DTB < 90, No. (%)	92 (89.3)	104 (83.2)	45 (62.5)	20.409	.001*
Length of hospitalization, No. (%)					
1–3 d	92 (89.3)	110 (88.0)	66 (91.7)	0.645	.72
3–7 d	11 (10.7)	15 (12.0)	6 (8.3)		
Cath lab death, No. (%)	5 (4.9)	6 (4.8)	3 (4.2)	0.054	.97
In-hospital mortality, No. (%)	2 (1.9)	2 (1.9)	2 (2.8)	0.134	.94
1-year mortality, No. (%)	2 (1.9)	3 (2.4)	2 (2.8)	0.134	.94

*Statistically significant at $P < .05$.

T occlusion: total occlusion; LM-P/M/D: proximal/mid/distal left main coronary artery; LAD-P/M/D: proximal/mid/distal left anterior descending artery; Diagonal, diagonal branches of LAD; LCx-P/M/D: proximal/mid/distal left circumflex artery; OM: obtuse marginal branch; RCA-P/M/D: proximal/mid/distal right coronary artery; PDA: posterior descending artery; RCA dominant: right coronary artery supplies PDA; LCx: left circumflex supplies PDA; Codominant, both RCA and LCx supply PDA

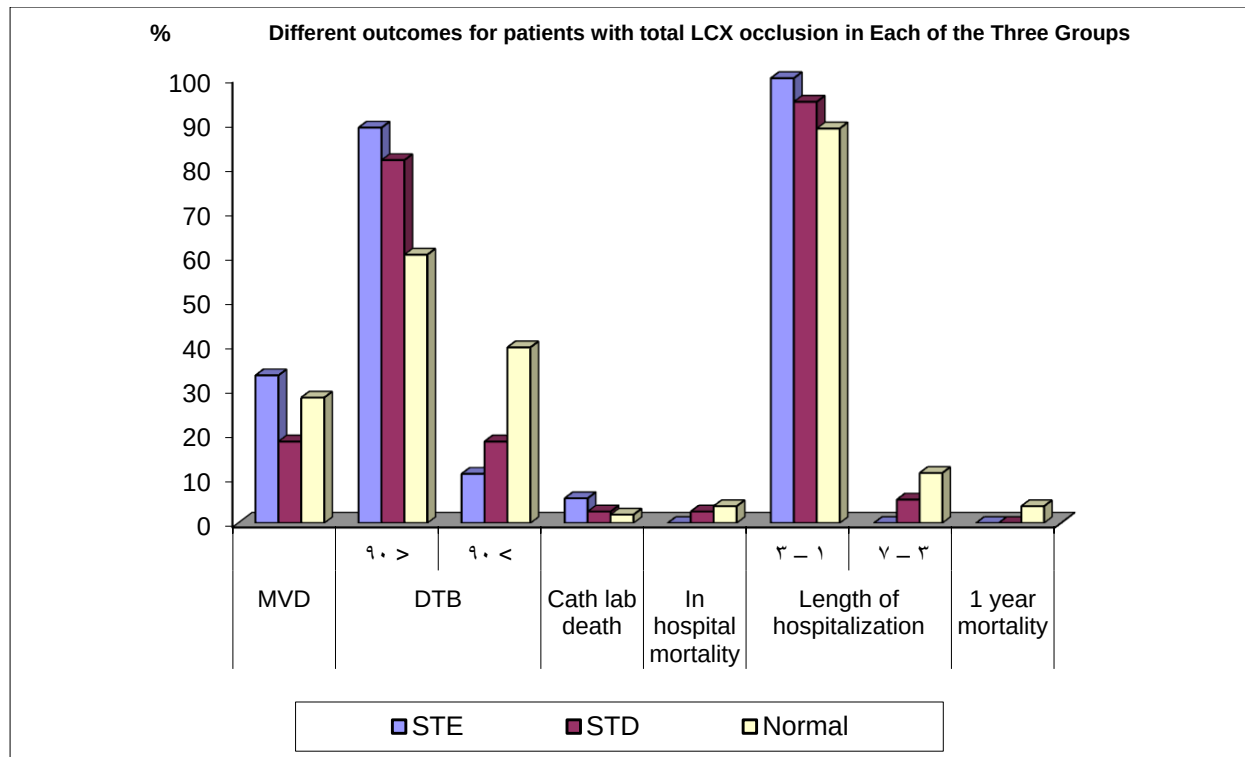


Figure 1. Different outcomes for patients with total left circumflex coronary artery (LCx) occlusion

Effect of DTB Time on LCx Occlusion: A separate analysis was performed among patients with total LCx occlusion according to reperfusion time (DTB less than 90 vs greater than 90 minutes). Patients achieving a DTB time of less than 90 minutes had lower in-hospital mortality (0% vs 10.0%; $P = .004$), lower 1-year mortality (0% vs 6.7%; $P = .02$), and higher early discharge rates (98.7% vs 76.7%; $P = .001$) compared with those with DTB greater than 90 minutes. Although the difference in catheterization laboratory mortality did not reach statistical significance (1.3% vs 6.7%; $P = .12$), the rate was numerically lower in the DTB less than 90-minute group (Figure 2). Serial assessment of high-sensitivity troponin demonstrated a significant change in biomarker positivity over time among patients with DTB times less than 90 minutes (Cochran $Q = 26.00$; $P < .001$), whereas no

significant temporal change was observed in patients with DTB times greater than 90 minutes ($Q = 2.57$; $P = .28$) (Table 4).

Table 4. Temporal Changes in High-Sensitivity Troponin Levels According to Door-to-Balloon Time in Participants With Total LCx Occlusion

Variable	DTB Time < 90 min (n = 79)	DTB Time > 90 min (n = 30)
hs-cTn at T0, elevated, No. (%)	37 (46.8)	7 (23.3)
hs-cTn at T6, elevated, No. (%)	50 (63.3)	10 (33.3)
hs-cTn at T12, elevated, No. (%)	50 (63.3)	10 (33.3)
Cochran Q	26.00	2.57
P	<.001*	.28

Cochran Q test was used to compare repeated binary measurements across the 3 time points.

DTB: door-to-balloon; hs-cTn: high-sensitivity cardiac troponin; LCx: left circumflex coronary artery; T0: baseline (presentation); T6: at 6 hours; T12: at 12 hours

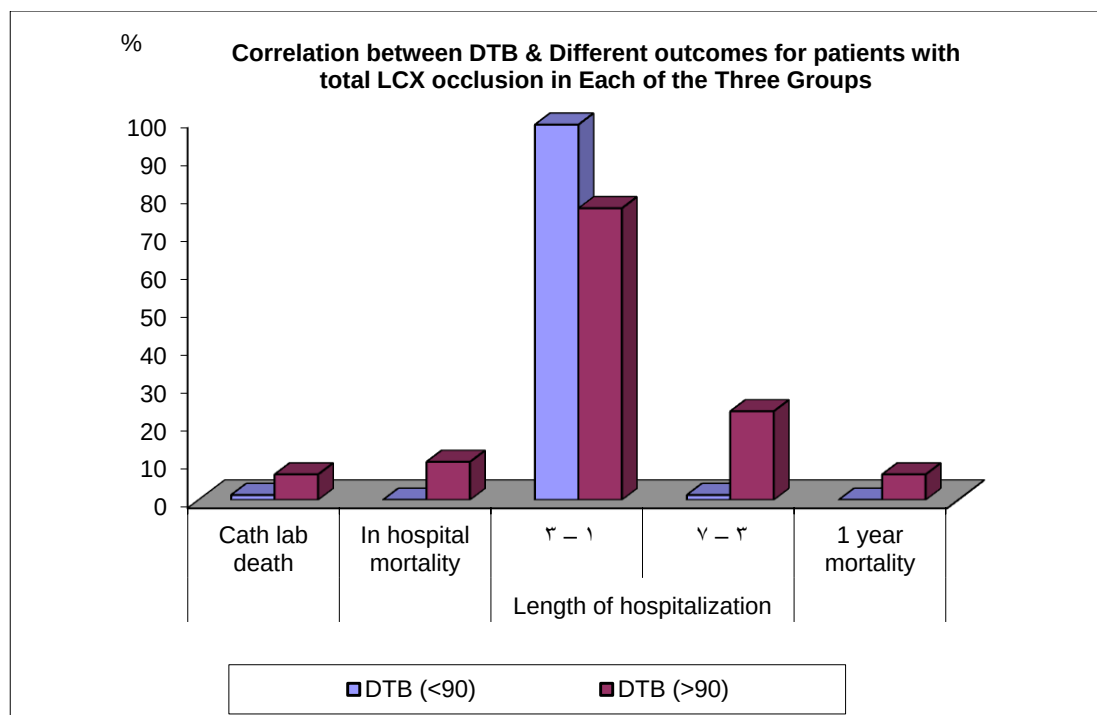


Figure 2. Correlation between door-to-balloon (DTB) time and different outcomes for patients with total left circumflex coronary artery (LCX) occlusion in each of the 3 groups

DISCUSSION

Traditionally, ACS has been classified according to the presence or absence of ST-segment elevation on the presenting ECG.¹¹ Be that as it may, accumulating evidence indicates that complete coronary artery occlusion may occur despite the absence of diagnostic ST-segment elevation or even in the setting of a normal ECG.^{7, 8, 12} The findings of the present study support this concept, as patients with angiographically confirmed TCO presented with a broad spectrum of ECG findings, including ST-segment depression and normal ECG patterns.

Patients presenting with ST-segment depression were significantly older and more frequently exhibited advanced Killip class at admission compared with the other study groups. Similar observations have been reported previously, suggesting that patients with non-ST-segment elevation ischemic ECG changes often present with a more complex clinical profile and greater

hemodynamic compromise despite the absence of classic ST-segment elevation. Although the present study was not designed to determine the mechanisms underlying these differences, the findings are consistent with previous reports describing higher clinical risk among patients presenting with ischemic ECG changes without ST-segment elevation.¹³

Echocardiographic assessment demonstrated more pronounced left ventricular dysfunction and a higher prevalence of RWMA during the acute phase among patients presenting with ST-segment elevation. Nonetheless, these differences diminished during follow-up, with no significant between-group differences observed in RWMA, left ventricular ejection fraction, or ventricular dimensions at 3 months. These findings suggest that ventricular functional recovery may occur across different ECG presentations following contemporary management and reperfusion strategies.¹⁴

In the current study, patients across the 3 ECG-defined groups demonstrated broadly

comparable baseline characteristics. Differences in outcomes were therefore likely related to variations in ECG presentation and reperfusion timing rather than underlying comorbidities. This finding aligns with prior studies emphasizing that early recognition of ischemic patterns and rapid intervention are key determinants of patient outcomes.¹⁵

Among patients with total LCx occlusion, those presenting without diagnostic ST-segment elevation were less likely to achieve reperfusion within 90 minutes. This observation is consistent with previous reports demonstrating that atypical ECG presentations may contribute to delays in coronary angiography and revascularization.¹⁶⁻¹⁸ Still, the relatively small number of patients with total LCx occlusion limits the interpretation of these subgroup findings. Although shorter door-to-balloon time was associated with lower mortality and more favorable clinical outcomes, these observations should be considered exploratory and hypothesis-generating and require confirmation in larger prospective multicenter studies.

Furthermore, because no multivariable adjustment was performed, the observed associations between ECG presentation, coronary anatomy, reperfusion timing, and clinical outcomes should not be interpreted as independent effects. Residual confounding related to differences in age, clinical severity, comorbidities, or other unmeasured factors may have influenced the reported findings. Future studies with larger sample sizes and predefined multivariable analyses are needed to validate these observations.

Coronary angiographic analysis revealed that proximal LAD and proximal or mid-RCA occlusions were more frequently associated with ischemic ECG changes, whereas occlusions involving the mid or distal LCx, OM branch, and PDA were more commonly observed among patients with normal ECG findings. This pattern may partly explain the absence of characteristic

ST-segment abnormalities in some patients with LCx-related infarction, as the lateral and posterior myocardial territories are not optimally represented on the standard 12-lead ECG.¹⁸⁻²¹ These findings suggest that ECG findings alone may not fully reflect the underlying coronary anatomy and support the integration of clinical assessment, cardiac biomarkers, and imaging data when evaluating patients with suspected ACS.

Strengths and Limitations

This study's principal strength lies in the inclusion of 3 well-defined participant groups based on presenting ECG patterns, enabling direct comparisons across a spectrum of ACS presentations. The integration of ECG findings, serial cardiac biomarker measurements, coronary angiographic data, and sequential echocardiographic assessment provided a comprehensive evaluation of myocardial injury, ventricular function, and clinical outcomes. Moreover, the dedicated analysis of participants with total LCx occlusion offers insights into a clinically important subgroup that may present without diagnostic ST-segment elevation.

Several limitations should be considered. First, the retrospective single-center design limits generalizability and may introduce selection bias; particularly because only participants who underwent coronary angiography and had complete clinical data were included, the results should be considered exploratory and require confirmation in larger prospective studies. Second, the relatively small sample size, especially within the LCx subgroup, may have reduced statistical power and resulted in unstable subgroup estimates. Third, no multivariable adjustment or correction for multiple comparisons was performed. Hence, all findings should be considered exploratory and hypothesis-generating. Fourth, follow-up was primarily based on structured telephone interviews, outcome assessors were not blinded to ECG group assignment, and some

mortality events were verified using available medical records and documentation, introducing the possibility of ascertainment bias. Finally, the duration of follow-up may not have been sufficient to capture late cardiovascular outcomes or long-term ventricular remodeling.

CONCLUSIONS

Individuals with ACS and angiographically confirmed TCO may present with a wide range of ECG findings, including ST-segment elevation, ST-segment depression, or even normal ECG findings. Participants with normal ECG findings were more likely to have LCx-related occlusions and experienced longer DTB times. These findings suggest that clinically significant coronary occlusion may occur despite the absence of diagnostic ST-segment elevation. Given the observational design and unadjusted analyses, the results should be considered exploratory and require confirmation in larger prospective studies.

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Authors' Contributions

MA: Conceptualization of the study, data analysis and interpretation, drafting the manuscript, critical revision of the manuscript, and performing coronary angiography and PCI. HS: Echocardiographic assessment, data collection, manuscript preparation, and assistance in coronary angiography and PCI. AE: Data collection and echocardiographic assessment. AF: Echocardiographic assessment, data analysis and interpretation, critical revision of the manuscript, and assistance in coronary angiography and PCI. AA: Echocardiographic assessment, data collection, and manuscript preparation.

All authors contributed to the study, reviewed the manuscript, and approved the final version.

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Availability of Data and Materials

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Ethical Approval and Consent to Participate

The study was conducted in accordance with the Declaration of Helsinki. Ethical approval was obtained from the Research Ethics Committee of the Faculty of Medicine, Tanta University (Committee reference number: 36264PR833/8/24). Because of the retrospective study design, waiver of informed consent was granted where applicable. Verbal and/or written informed consent was obtained from patients or their next of kin for participation in the telephone follow-up component of the study. All patient data were anonymized and handled confidentially throughout the study.

Consent for Publication

Not applicable.

Conflict of Interest

The authors declare that they have no competing interests.

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