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# ELECTROCARDIOGRAPHIC DYNAMICS OF THE ST SEGMENT AND T WAVE IN NON–ST-SEGMENT ELEVATION MYOCARDIAL INFARCTION

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To assess the characteristics and dynamics of ST-segment and T-wave changes in non–ST-segment elevation myocardial infarction, 200 patients were examined, including 164 men and 36 women; the mean age was 62.21±9.38 years. Based on coronary angiography findings, patients were divided into two groups: Group I included 94 patients with non–ST-segment elevation myocardial infarction and non-obstructive coronary artery lesions (stenosis <50 %); Group II included 106 patients with non–ST-segment elevation myocardial infarction and obstructive coronary artery lesions (stenosis≥50 %). In Group I, predominantly transient electrocardiographic changes were observed. During the acute phase, ST-segment depression in leads V4–V6 was most common (62.8 % of patients), and less frequent in leads II, III, and aVF (21.3 %). In Group II, ST-segment depression was deeper and more persistent; ST depression≥1 mm was recorded in 79.2 % of patients, predominantly in leads V4–V6 and II, III, aVF, which was significantly more frequent than in Group I (p=0.016). No significant intergroup differences were found for isolated T-wave inversion or for the combined ST↓+T pattern. ST-segment normalization on days 5–7 occurred significantly more often in Group I (p<0.001). Progression to transmural myocardial infarction (ST-segment elevation myocardial infarction) was observed only in Group II (p=0.019).

**Key words:** non-ST-segment elevation myocardial infarction; electrocardiogram; ischemic heart disease; obstructive and non-obstructive coronary artery lesions.

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# ЕЛЕКТРОКАРДІОГРАФІЧНА ДИНАМІКА СЕГМЕНТА ST І ЗУБЦЯ Т ПРИ ІНФАРКТІ МІОКАРДА БЕЗ ПІДЙОМУ СЕГМЕНТА ST

З метою оцінки особливостей динаміки змін сегмента ST і зубця Т у пацієнтів з інфарктом міокарда без підйому ST обстежено 200 пацієнтів, з них 164 чоловіки і 36 жінок, середній вік 62,21±9,38 років. Пацієнти були розділені на 2 групи: І група включала 94 пацієнтів з ІХС та інфарктом міокарда без підйому сегмента ST з необструктивним ураженням коронарних артерій; ІІ група – 106 пацієнтів з ІХС та інфарктом міокарда без підйому сегмента ST з обструктивним ураженням коронарних артерій. У пацієнтів І групи відмічені переважно транзиторні зміни ЕКГ. У гострому періоді на ЕКГ переважала горизонтальна або низхідна депресія сегмента ST у відведеннях V4–V6 (у 62,8 % пацієнтів), рідше — у відведеннях II, III і aVF (у 21,3 %). У ІІ групі депресія сегмента ST була вираженою і більш стійкою. У 79,2 % пацієнтів реєструвалася депресія ST≥1 мм, переважно у відведеннях V4–V6 і II, III, aVF, що в порівнянні з І групою мало значущий характер (p=0,016). Щодо інверсії зубця Т і поєднання ST↓+T між групами істотних відмінностей не відзначалося. Нормалізація ST на 5–7 добу значно частіше відзначалася у пацієнтів в І групі. Перехід в трансмуральний інфаркт міокарда спостерігався лише у пацієнтів ІІ групи. Найбільш виражена відмінність між групами виявлена за ознакою переходу в трансмуральний інфаркт міокарда (p<0,001).

**Ключові слова:** інфаркт міокарда без підйому сегмента ST, електрокардіограма, ішемічна хвороба серця, обструктивне та необструктивне ураження артерій.

Non–ST-segment elevation myocardial infarction is a type of acute coronary syndrome characterized by partial coronary artery occlusion, leading to reduced oxygenated blood flow to the myocardium and myocardial necrosis. This condition requires urgent medical care because it may result in fatal outcomes [3, 10, 12, 15].

According to published data, approximately 800,000 cases of acute coronary syndrome are registered annually, and about 60 % of these cases correspond to non–ST-segment elevation myocardial infarction. The electrocardiogram is most often the first diagnostic test performed in suspected acute coronary syndrome; ST-segment depression and/or T-wave inversion may be detected. Knowledge of electrocardiographic patterns that help localize the culprit coronary artery in non–ST-segment elevation myocardial infarction is clinically important; however, it remains insufficiently studied and contemporary evidence is limited [2, 6, 14].

In non–ST-segment elevation myocardial infarction with multivessel disease, ST-segment and T-wave changes may evolve dynamically over time, which can support diagnosis and help identify the affected coronary territory.

**The purpose** of the study to evaluate the characteristics and dynamics of ST-segment and T-wave changes in non–ST-segment elevation myocardial infarction depending on the presence of obstructive versus non-obstructive coronary artery lesions.

**Materials and methods.** A single-center observational study included 200 patients with non–ST-segment elevation myocardial infarction aged 33–86 years. The study was conducted at the Republican Treatment and Diagnostic Center (Baku, Azerbaijan) in 2019–2024.

The mean age of the patients was 62.21±9.38 years; 42.5 % were aged 61–70 years. Men predominated (n=164, 82.0 %). No significant differences in age-group distribution were observed between men and women ($p>0.05$).

According to the degree of coronary artery disease assessed by coronary angiography, patients were divided into two groups: Group I included 94 patients with non-obstructive coronary lesions (stenosis <50 %); Group II included 106 patients with obstructive coronary lesions (stenosis≥50 %).

Inclusion criteria were a diagnosis of non–ST-segment elevation myocardial infarction confirmed by clinical presentation (typical ischemic chest pain or equivalent), laboratory evidence of myocardial injury (elevated high-sensitivity troponin T), and electrocardiographic changes consistent with myocardial ischemia. Exclusion criteria were previous ST-segment elevation myocardial infarction, cardiomyopathies, and significant valvular heart disease. All participants provided written informed consent. The study was conducted in accordance with the principles of the Declaration of Helsinki.

A standard 12-lead electrocardiogram was recorded within the first 24 hours of hospitalization and repeated on days 5–7.

High-sensitivity troponin T testing was performed to confirm acute myocardial injury. Serum troponin T was measured by a chemiluminescent microparticle immunoassay 6 hours after the onset of typical ischemic chest pain. Troponin T concentration was determined using the TNT-HS assay (Roche Diagnostics, Germany) on a Cobas 6000 analyzer (e 601 module, Roche, Switzerland). The assay measurement range was 0.1–2.0 ng/mL.

At admission, the GRACE (Global Registry of Acute Coronary Events) risk score was calculated for all patients. The severity of heart failure was assessed according to the Killip classification.

Progression to transmural myocardial infarction (ST-segment elevation myocardial infarction) during hospitalization was defined as new persistent ST-segment elevation in at least two contiguous leads accompanied by recurrent ischemic symptoms and a further rise of cardiac biomarkers and/or angiographic evidence of acute coronary occlusion/intraluminal thrombus.

Prior to hospital admission, 76 patients (38.0 %) received acetylsalicylic acid (Borisov Plant, Belarus), 71 (35.5 %) beta-blockers (Grindex, Latvia; Borisov Plant, Belarus), 59 (29.5 %) statins (Borisov Plant, Belarus), 44 (22.0 %) angiotensin-converting enzyme inhibitors or angiotensin II receptor blockers (Hemofarm, Serbia), and 9 (4.5 %) (Atabay, Türkiye). During hospitalization, patients received standard guideline-directed therapy in registered dosage forms and therapeutic doses.

Statistical analysis was performed using Statistica 10 (StatSoft, USA). Normality of distribution was assessed using the Shapiro–Wilk test. For normally distributed variables, the Student's t-test for independent samples was applied; for non-normally distributed variables, the Mann–Whitney U test was used. Between-group comparisons for categorical variables used the $\chi^2$ test with Yates' correction. A two-sided p-value <0.05 was considered statistically significant.

**Results of the study and their discussion.** The study population demonstrated a typical clinical profile for non–ST-segment elevation myocardial infarction, characterized by a high prevalence of cardiovascular risk factors and comorbidities. Chest pain was the dominant presenting symptom, and elevated troponin confirmed acute myocardial injury in all enrolled patients. Most patients were hemodynamically stable at admission, although a subset presented with signs of heart failure and cardiogenic shock.

At admission, the clinical condition was assessed as satisfactory in 168 patients (84.0 %). Signs of left ventricular failure (Killip class II) were observed in 28 patients (14.0 %), and cardiogenic shock (Killip class IV) was diagnosed in 4 patients (2.0 %). Among comorbidities, chronic heart failure was present in 49 patients (24.5 %), chronic kidney disease in 17 (8.5 %), and atrial fibrillation in 22 (11.0 %). Dyslipidemia was diagnosed in 138 patients (69.0 %); 31.0 % of these patients were aware of the diagnosis prior to hospitalization and received treatment.

The mean GRACE score at admission was 132±25 points, corresponding to moderate risk. In 46 patients (23.0 %), the GRACE score exceeded 140, indicating high risk of complications and mortality, supporting the need for early invasive evaluation in this category of patients.

Table 1

**Baseline characteristics of the examined patients**

| Parameter | Patients with non–ST-segment elevation myocardial infarction (n=200) |
|---|---|
| Chest pain, n ( %) | 194 (97.0) |
| Mean troponin T, ng/mL | 0.812±0.304 |
| Systolic blood pressure, mmHg | 131.6±18.2 |
| Diastolic blood pressure, mmHg | 82.4±11.7 |
| Diabetes mellitus, n ( %) | 52 (26.0) |
| Arterial hypertension, n ( %) | 143 (71.5) |
| Mean body mass index, kg/m² | 28.7±4.3 |
| Current smoking, n ( %) | 89 (44.5) |
| Duration of coronary artery disease, years | 6.2±3.6 |
| Prior myocardial infarction, n ( %) | 39 (19.5) |
| Family history of coronary artery disease, n ( %) | 24 (12.0) |
| Previous coronary revascularization, n ( %) | 31 (15.0) |

On admission, ST-segment depression≥0.5 mm was observed in 139 of 200 patients, most frequently in leads V4–V6. A pathological Q wave was detected in 18 patients (9.0 %), and rhythm or conduction disturbances were recorded in 35 patients (17.5 %).

In Group I, electrocardiographic changes were predominantly transient. During the acute phase, horizontal or downsloping ST-segment depression was most often recorded in leads V4–V6 (62.8 %), and less frequently in leads II, III, and aVF (21.3 %). The mean depth of ST-segment depression was 0.8±0.3 mm. Within the first 24 hours, the T wave was more commonly flattened or inverted (45.7 %), predominantly in the precordial leads. By days 3–5, positive dynamics were observed: in 71.2 % of patients, ST-segment depression resolved with restoration of the isoelectric line; residual T-wave inversion persisted in 28.8 %.

In Group II, ST-segment depression was more pronounced and persistent. ST-segment depression≥1 mm was recorded in 79.2 % of patients, predominantly in leads V4–V6 and II, III, aVF. A combined pattern of ST-segment depression and T-wave inversion (depth up to 3 mm) was observed in 24.5 % of patients. On days 5–7, persistent abnormalities were common: ST-segment depression remained in 36.8 % and T-wave inversion in 49.1 %. Complete electrocardiographic normalization by the end of the first week was observed in 40.6 % of patients. Progression to transmural myocardial infarction (ST-segment elevation myocardial infarction) occurred in 8 patients (7.5 %), accompanied by clinical deterioration and angiographic signs of acute coronary occlusion and intraluminal thrombus.

Table 2

**Comparative analysis of electrocardiographic changes between groups**

| Parameter | Group I (n=94) | Group II (n=106) | $\chi^2$ | P |
|---|---|---|---|---|
| ST-segment depression≥1 mm, n ( %) | 59 (62.8) | 84 (79.2) | 5.855 | 0.016 |
| T-wave inversion, n ( %) | 43 (45.7) | 57 (53.8) | 0.984 | 0.322 |
| Combined ST↓+T pattern, n ( %) | 26 (26.7) | 43 (40.6) | 3.124 | 0.078 |
| ST-segment normalization on days 5–7, n ( %) | 67 (71.3) | 43 (40.6) | 17.764 | <0.001 |
| Progression to transmural myocardial infarction, n ( %) | 0 | 8 (7.5) | 5.555 | 0.019 |

Table 2 shows that ST-segment depression≥1 mm was detected significantly more often in Group II than in Group I (p=0.016). ST-segment normalization on days 5–7 was significantly more frequent in Group I (p<0.001). Progression to transmural myocardial infarction was observed only in Group II (p=0.019).

Normalization of the ST segment by days 5–7 represents a favorable sign indicating resolution of ischemia. Conversely, persistence of ST–T abnormalities should prompt reassessment of management and closer monitoring. Serial electrocardiography is therefore an especially valuable non-invasive tool for dynamic assessment.

Our results are consistent with published evidence indicating that ST–T changes are associated with in-hospital outcomes in non–ST-segment elevation myocardial infarction [1, 4, 5, 11, 13]. In particular, Hossain et al. reported that ST-segment depression and T-wave inversion at admission are linked to higher rates of adverse in-hospital outcomes and mortality [9].

Overall, these findings highlight the clinical significance of electrocardiographic monitoring in non–ST-segment elevation myocardial infarction and support the importance of continuous ECG monitoring in selected patients [7, 8].

**Conclusions**

In patients with non–ST-segment elevation myocardial infarction and non-obstructive coronary artery lesions, electrocardiographic abnormalities tend to be transient and relatively mild. ST-segment depression and T-wave changes usually regress rapidly during the first days of hospitalization, and ST-segment normalization by days 5–7 is common, reflecting a more limited ischemic burden. By contrast, in patients with obstructive coronary artery disease, ST-segment depression is deeper and persists longer, T-wave inversion is more frequent, and recovery of electrocardiographic parameters is slower. This phenotype is associated with a higher residual ischemic burden and a clinically meaningful risk of progression to transmural myocardial infarction during the in-hospital period. Therefore, early recognition of persistent or worsening ST–T changes should be considered an important signal for intensified monitoring, prompt reassessment of treatment strategy, and timely invasive evaluation. Overall, serial electrocardiography provides actionable prognostic information and can complement angiographic findings when stratifying risk and tailoring management in non–ST-segment elevation myocardial infarction.

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