ORIGINAL ARTICLE

Admission Tpe interval predicts reperfusion success in STEMI patients treated with fibrinolytic agents

Başvuru anındaki Tpe aralığı fibrinolitik ajan ile tedavi edilen STYME hastalarında reperfüzyon başarısını öngörür

Ali Çoner, M.D.,[1] Sinan Akıncı, M.D.,[1] Mehmet Hüsamettin Akküçük, M.D.,[2] Cihan Altın, M.D.,[3] Haldun Müderrisoğlu, M.D.[4]

[1]Department of Cardiology, Başkent University Faculty of Medicine Alanya Application and Research Center, Alanya, Turkey
[2]Department of Emergency Medicine, Başkent University Faculty of Medicine Alanya Application and Research Center, Alanya, Turkey
[3]Department of Cardiology, Başkent University Medical Faculty of Medicine İzmir Zübeyde Hanım Application and Research Center, İzmir, Turkey
[4]Department of Cardiology, Başkent University Faculty of Medicine, Ankara, Turkey

ABSTRACT

Objective: Myocardial infarction is a leading cause of morbidity and mortality. Fibrinolytic administration is still a life-saving choice in ST-segment elevated myocardial infarction (STEMI), but the rate of successful reperfusion can be inconsistent. Failed reperfusion adds additional clinical risks to rescue percutaneous coronary intervention for STEMI patients. The interval between the peak of the T wave and the end of the T wave (Tpe) and the ratio of Tpe and a corrected measurement of the time from the start of the Q wave to the end of the T wave (Tpe/QTc ratio) are relatively new electrocardiogram (ECG) indices and have not yet been tested in STEMI patients treated with fibrinolytic agents.

Methods: A total of 177 STEMI patients (mean age: 60.5±11.1 years; 138 men and 39 women) were enrolled in this retrospective study to evaluate ECG parameters. The Tpe interval and the Tpe/QTc ratio at baseline and at the 90th minute following the administration of fibrinolytic therapy were analyzed. The clinical and ECG findings of successful and failed reperfusion groups were compared.

Results: Successful reperfusion was achieved in 119 patients (67.2%). The average Tpe interval on the admission ECG was shorter (91.7 *vs.* 100.9 milliseconds [ms]) ($p<0.001$) and shortened more in the successful reperfusion group (9.3 *vs.* 4.5 ms) ($p<0.001$). A cut-off value of 89.0 ms for the Tpe interval on the admission ECG was found to be related to reperfusion success with a sensitivity of 90.9%.

Conclusion: The Tpe interval was a predictor for reperfusion success in STEMI patients treated with fibrinolytic agents.

ÖZET

Amaç: Miyokart enfarktüsü günümüzde morbidite ve mortalitenin en sık rastlanan sebebidir. Fibrinolitik uygulanması ST-segment yükselmeli miyokart enfarktüsünde (STYME) hayat kurtarıcı bir seçenek olmaya devam etmektedir, öte yandan başarılı reperfüzyon oranları net değildir. Başarısız reperfüzyon takiben uygulanacak kurtarıcı perkütan koroner girişim (PKG) esnasında STYME hastaları için ek klinik risk durumu oluşturmaktadır. Tpe aralığı ve Tpe/QTc oranı yeni tanımlanan elektrokardiyografi (EKG) parametreleridir ve fibrinolitik ajanlar ile tedavi edilen STYME hastalarında daha önce araştırılmamıştır.

Yöntemler: Çalışmaya 177 STYME hastası (ortalama yaş 60.5±11.1 yıl: 138 erkek ve 39 kadın) dahil edildi ve EKG parametreleri geriye dönük olarak incelendi. Tpe aralığı ve Tpe/QTc oranı başvuru anı ve fibrinolitik uygulanmasını takiben 90. dakikada ölçüldü. Klinik özellikler ve EKG bulguları başarılı ve başarısız reperfüzyon gruplarında karşılaştırıldı.

Bulgular: Başarılı reperfüzyon 119 hastada izlendi (%67.2). Başvuru anındaki ortalama Tpe aralığı başarılı reperfüzyon sağlananlarda daha kısa idi (91.7 ve 100.9 ms) ($p<0.001$) ve fibrinoliz sonrası başarısız reperfüzyon grubuna göre daha çok kısaldığı izlendi (9.3 ve 4.5 ms) ($p<0.001$). Başvuru EKG'sinde izlenen Tpe aralığı için belirlenen 89.0 ms değerinde başarılı reperfüzyon duyarlılığı %90.9 olarak bulundu.

Sonuç: Tpe aralığı fibrinolitik ajanlar ile tedavi edilen STYME hastalarında başarılı reperfüzyonun öngördürücüsüdür.

Received: March 10, 2019 *Accepted:* June 14, 2019

Correspondence: Dr. Ali Çoner. Başkent Üniversitesi Tıp Fakültesi Alanya Uygulama ve Araştırma Merkezi, Kardiyoloji Anabilim Dalı, Alanya, Antalya, Turkey.
Tel: +90 242 - 510 25 25 e-mail: conerali@hotmail.com

Acute myocardial infarction (MI) could be considered a community-based health problem as it is still a leading cause of death in the modern era.[1] "Time is muscle" in the setting of acute MI and reperfusion of myocardial tissue should be performed as soon as possible. Percutaneous coronary intervention (PCI) and the administration of fibrinolytic drugs are 2 choices for reperfusion management. Recent guidelines for revascularization in ST-segment elevated myocardial infarction (STEMI) recommend the PCI procedure within target time intervals.[2] If PCI cannot be performed within the target time interval, fibrinolytic therapy can be a life-saving treatment for STEMI patients. Unfortunately, the success of fibrinolytic treatment is inconsistent and failure of this treatment can increase complications during a subsequent PCI procedure, particularly bleeding complications.[3,4]

The time interval between the peak of the T wave to end of the T wave (Tpe) is an established electrocardiogram (ECG) index that has been found to be related to the development of ventricular arrhythmia.[5] In recently published clinical studies, the Tpe interval and the ratio of Tpe and a measurement of the time from the start of the Q wave to the end of the T wave corrected for heart rate (Tpe/QTc ratio) have been defined as markers of myocardial perfusion,[6] but these have not yet been evaluated in STEMI patients treated with fibrinolytic administration. The objective of this study was to analyze the admission Tpe interval and Tpe/QTc ratio in STEMI patients treated with fibrinolytic agents and to determine the role of these ECG indices in the prediction of reperfusion success with fibrinolytic therapy.

METHODS

This study was approved by Baskent University Institutional Review Board (Project no: KA18/315) and supported by Baskent University Research Fund.

Study population

Patients with a STEMI presentation who were admitted between September 2016 and June 2018 within 12 hours of the initial symptoms and were given fibrinolytic therapy due to an inability to access percutaneous revascularization within 120 minutes following the STEMI diagnosis during first medical contact were enrolled in the study. A 12-lead ECG recording of each patient was obtained at admission and at the 90th minute following the administration of fibrinolytic therapy. Demographic data and adjunctive medical treatment management were also recorded for each patient. Patients with a missing ECG recording (admission or post fibrinolysis) and patients with an uninterpretable ECG (bundle branch block pattern, atrial fibrillation, prominent U wave) were excluded. The patients were divided into 2 groups based on the percentage of resolution of the ST-segment elevation pattern: successful reperfusion and failed reperfusion. Patients with a resolution of ST-segment elevation of at least 50% at the 90th minute were classified as successful reperfusion and patients who did not meet this resolution criterion were considered a case of failed reperfusion. The Tpe interval, QTc interval, and Tpe/QTc ratios were calculated using the admission and post-fibrinolysis ECG recordings for both groups. These ECG indices were compared between the successful and failed reperfusion groups.

Abbreviations:

AUC	*Area under the curve*
DTB	*Door-to-balloon*
ECG	*Electrocardiogram*
LVEF	*Left ventricular ejection fraction*
MI	*Myocardial infarction*
Ms	*Milliseconds*
PCI	*Percutaneous coronary intervention*
QTc	*Corrected measurement of the time from the start of the Q wave to the end of the T wave*
ROC	*Receiver operating characteristic*
STEMI	*ST-segment elevated myocardial infarction*
Tpe	*Interval between the peak of the T wave and the end of the T wave*

In addition to the ECG evaluations, successful and failed reperfusion patients were compared based on cardiac troponin levels (admission and peak levels during the in-hospital course) and left ventricular ejection fraction (LVEF) measurements (admission and discharge).

ECG recordings and interpretation

All of the ECG recordings were performed in the supine position at a speed of 25 mm/second and a gain of 10 mm/mV. The Tpe interval and Tpe/QTc ratios were calculated using a magnifying glass and a ruler. The measurements were calculated by a single cardiologist. The heart rate recorded at admission and after fibrinolysis was noted. The QTc interval was defined as the correction of the QT interval measurement for heart rate using Bazett's formula of QTc interval=QT interval/(RR interval)1/2. The Tpe interval was defined as the time interval from the peak of the T wave

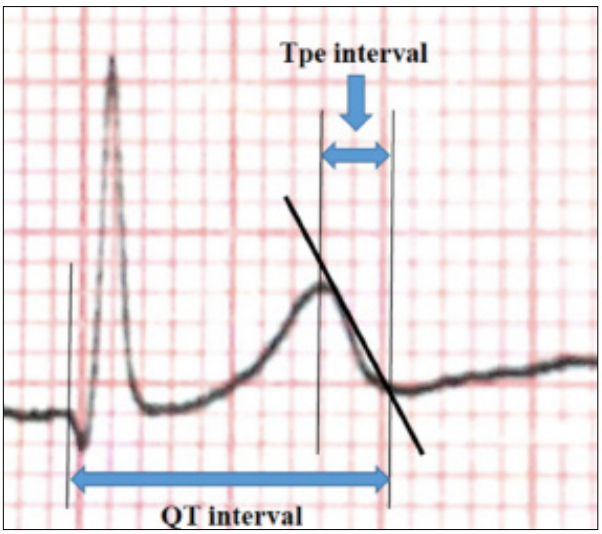

Figure 1. Sample electrocardiogram demonstrating Tpe interval measurement. QT interval: Time between the start of the Q wave and the end of the T wave; Tpe: Interval between the peak of the T wave and the end of the T wave.

to the end of the T wave. The end of the T wave was the intersecting point of a tangent line at the terminal part of the T wave and the T-P baseline (Fig. 1). The aim was to measure the Tpe interval from a lead with a minimal ST-segment deviation. Tpe interval measurements were performed in leads with an ST-segment deviation <0.055 mV from the isoelectric line and T waves were expected to be in a positive deflection. All of the measurements (Tpe and QTc intervals) analyzed were the average of 3 consecutive beats and the Tpe/QTc ratios were calculated according to the average values. The intraobserver coefficient of variation was evaluated at 2.9%.

Statistical analysis

Continuous variables were expressed as mean±SD and categorical variables as percentages. The assumption of normality was tested via the Shapiro-Wilk test. Continuous variables between 2 groups were evaluated using Student's t-test and categorical variables were evaluated with a chi-square test. Fisher's exact test was used for categorical variables with a frequency of fewer than 5 on 2x2 tables. Continuous variables before and after treatment for each group were evaluated with a paired t-test. Pearson correlation analysis was used to evaluate hospital admission time and ECG parameters. Multivariate logistic regression analysis was performed to examine the role of demographic characteristics of the population on the ECG indices. Intraobserver reliability for ECG measurements was tested with the intraclass correlation coefficient. An exploratory evaluation of additional cut-off points was performed using receiver operating characteristics (ROC) curve analysis. A p value <0.05 was accepted as significant in all of the statistical analyses.

RESULTS

Baseline clinical characteristics

A total of 209 STEMI patients were treated with fibrinolytic therapy during the study period. Thirty-two patients were excluded from the study due to uninterpretable ECG recordings, such as those demonstrating a bundle branch block, atrial fibrillation, globally biphasic T waves or prominent U waves. In all, the ECG data of 177 patients were used for analysis. Successful reperfusion criteria were achieved in 119 patients and 58 patients were classified as failed reperfusion. The overall reperfusion success rate was 67.2% for the study population.

Patients in the failed reperfusion group had a later admission to the hospital following the onset of initial cardinal symptoms (2.0 *vs.* 5.0 hours) (p<0.001) (Table 1). This delayed emergency admission means that patients who had failed reperfusion received reperfusion therapy too late. Pearson correlation analysis revealed that hospital admission time was found to be related to an increase in failed reperfusion (r=0.516; p<0.001). Failed reperfusion patients were older, but this difference was not significant statistically (59.7 *vs.* 62.0 years) (p=0.195). The percentage of males was similar in the successful and failed reperfusion groups (78.9 *vs.* 75.8%) (p=0.637). The failed reperfusion group had a higher incidence of hypertension (36.9 *vs.* 51.7%), prior usage of acetylsalicylic acid (21.8 *vs.* 34.4%), and lower usage of reteplase (61.3 *vs.* 43.1%), but these characteristics did not reach the level of statistical significance (p value: 0.062, 0.072, and 0.063, respectively). The successful reperfusion group had a higher incidence of acetylsalicylic acid use (100 *vs.* 93.1%) and statin use (35.2 *vs.* 20.6%) at the time of fibrinolytic administration (p value: 0.011 and 0.048, respectively).

The percentage of patients with an MI with anterior wall involvement was greater in the successful reperfusion group, but this was also not significant

Table 1. Baseline clinical characteristics of the study population

	Successful reperfusion (119 patients)	Failed reperfusion (58 patients)	*p*
Admission time, hours (time from onset of symptoms to hospital admission)	2.0 (1.0–2.0)	5.0 (3.0–7.0)	<0.001
Age, years, mean±SD	59.7±10.9	62.0±11.3	0.195
Gender, male, n (%)	94 (78.9)	44 (75.8)	0.637
Former CAD history, n (%)	18 (15.1)	10 (17.2)	0.717
Diabetes mellitus, n (%)	26 (21.8)	16 (27.5)	0.400
Hypertension, n (%)	44 (36.9)	30 (51.7)	0.062
Hyperlipidemia, n (%)	19 (15.9)	6 (10.3)	0.313
Smoking, n (%)	71 (59.6)	28 (48.2)	0.152
Family history of premature CAD, n (%)	35 (29.4)	12 (20.6)	0.217
Prior ASA usage, n (%)	26 (21.8)	20 (34.4)	0.072
Prior beta blocker usage, n (%)	15 (12.6)	10 (17.2)	0.406
Fibrinolytic agent used, n (%)			
Tissue plasminogen activator	29 (24.3)	19 (32.7)	0.063
Reteplase	73 (61.3)	25 (43.1)	
Tenecteplase	17 (14.2)	14 (24.1)	
Adjunctive medical therapy at admission, n (%)			
ASA	119 (100)	54 (93.1)	0.011
P2Y12 inhibitor loading	119 (88.2)	48 (82.7)	0.318
Beta blocker	6 (5.0)	1 (1.7)	0.429
Statin	42 (35.2)	12 (20.6)	0.048
Myocardial infarction localization, n (%)			
Anterior wall involvement	62 (52.1)	22 (37.9)	0.076

ARVC: ASA: Acetylsalicylic acid; CAD: Coronary artery disease; SD: Standard deviation.

statistically (52.1 *vs.* 37.9%) (p=0.076).

Echocardiographic findings and hs-troponin levels at admission and follow-up

The admission LVEF calculations were higher in the successful reperfusion group (48.7 *vs.* 43.0%) (p<0.001). At the time of discharge from the hospital, the LVEF level was higher than at admission in both groups, but LV systolic functions were better in the successful reperfusion group (50.7 *vs.* 46.9%) (p=0.013).

The Hs-troponin level was similar in both groups at admission, but the peak hs-troponin level during hospitalization was higher in the failed reperfusion group. However, this difference was not statistically significant (27200.3 *vs.* 36875.4 ng/L) (p=0.098) (Table 2).

Electrocardiographic findings

Electrocardiographic interpretation was performed in descending order from leads V4 (39.7%), D2 (24.1%), V5 (17.5%), D3 (13.2%), and V6 (5.5%). Various demographic variables (age, gender, smoking, hypertension, diabetes mellitus) were investigated via multivariate logistic regression analysis for increased prolongation of the Tpe interval, QTc interval, and the increment in the Tpe/QTc ratio on the admission ECG. Of these variables, only male gender was found to be related to a prolonged Tpe interval, QTc interval, and increased Tpe/QTc ratio (Table 3). The admission Tpe and QTc intervals were statistically different between the 2 groups: The admission Tpe interval was shorter in the successful reperfusion group (91.7 *vs.* 100.9 ms) (p<0.001), as was the QTc interval at admission (408.0 *vs.* 422.7 ms) (p<0.001).

Table 2. Follow-up of left ventricular ejection fraction and hs-troponin level of the study population

	Total study population (177 patients)	Successful reperfusion (119 patients)	Failed reperfusion (58 patients)	*p*
Admission LVEF (%, ±SD)	46.9 (±8.9)	48.7 (±8.3)	43.0 (±9.1)	<0.001
Discharge LVEF (%, ±SD)	49.5 (±9.0)	50.7 (±8.9)	46.9 (±8.8)	0.013
In-group interaction p value for ΔLVEF	<0.001	<0.001	<0.001	
Admission hs-troponin (pg/mL)	520.0 (220.0–1393.6)	480.7 (210.0–1328.9)	698.5 (254.2–1990.9)	0.669
Maximum hs-troponin (pg/mL)	28478.2 (8400.3–63019.3)	27200.3 (6884.9–56365.0)	36875.4 (9789.3–73348.3)	0.098
In-group interaction p value for Δhs-troponin	<0.001	<0.001	<0.001	

LVEF: Left ventricular ejection fraction; SD: Standard deviation.

Table 3. Effect of male gender on electrocardiogram repolarization indices

Parameter	Hazard ratio	95% confidence interval	*p*
Tpe interval (≥50th percentile)	3.003	1.283–7.042	0.011
QTc interval (≥50th percentile)	2.331	1.016–5.348	0.046
Tpe/QTc ratio (≥50t^{h} percentile)	3.937	1.623–9.523	0.002

QTc: Corrected measurement of the time from the start of the Q wave to the end of the T wave; Tpe: Interval between the peak of the T wave and the end of the T wave.

Table 4. Electrocardiography findings of the study population

	Total study population (177 patients)	Successful reperfusion (119 patients)	Failed reperfusion (58 patients)	*p*
Admission Tpe interval (ms)	94.6 (±7.8)	91.7 (±5.2)	100.9 (±8.8)	<0.001
Follow-up Tpe interval (ms)	86.6 (±9.8)	82.4 (±6.4)	96.4 (±9.3)	<0.001
In-group interaction p value for Tpe interval	<0.001	<0.001	<0.001	
Admission QTc interval (ms)	412.6 (±21.2)	408.0 (±15.8)	422.7 (±27.3)	<0.001
Follow-up QTc interval (ms)	433.1 (±21.4)	431.5 (±17.4)	436.6 (±28.0)	0.220
In-group interaction p value for QTc interval	<0.001	<0.001	<0.001	
Admission Tpe/QTc ratio	0.228 (0.214–0.239)	0.225 (0.213–0.234)	0.238 (0.218–0.259)	<0.001
Follow-up Tpe/QTc ratio	0.195 (0.181–0.212)	0.190 (0.177–0.201)	0.220 (0.204–0.241)	<0.001
In-group interaction p value for Tpe/QTc ratio	<0.001	<0.001	<0.001	

QTc: Corrected measurement of the time from the start of the Q wave to the end of the T wave; Tpe: Interval between the peak of the T wave and the end of the T wave.

Similarly, the Tpe/QTc ratio at admission was smaller in the successful reperfusion group (0.225 *vs.* 0.238) (p<0.001) (Table 4).

The hospital admission time was determined to be related to a possible, weak increase in the Tpe interval (r=0.390; p<0.001) and the QTc interval (r=0.288;

Table 5. Delta changes in electrocardiography findings of successful and failed reperfusion groups

	Successful reperfusion (119 patients)	Failed reperfusion (58 patients)	*p*
Δchange of Tpe interval (ms±SD)	9.3 (±4.0)	4.5 (±1.9)	<0.001
Δchange (prolongation) of QTc interval (ms±SD)	23.5 (±13.7)	14.9 (±12.6)	<0.001
Δchange of Tpe/Qtc ratio	0.034 (0.025–0.043)	0.017 (0.012–0.022)	<0.001

QTc: Corrected measurement of the time from the start of the Q wave to the end of the T wave; Tpe: Interval between the peak of the T wave and the end of the T wave.

p<0.001). The correlation coefficient for hospital admission time and the Tpe/QTc ratio was less than 0.25 (r=0.203; p<0.007).

Follow-up electrocardiographic recordings were performed at the 90th minute after fibrinolytic administration. In both groups, the Tpe intervals were significantly shorter. The Tpe interval decreased to 82.4 milliseconds (ms) in the successful reperfusion group and 96.4 ms in the failed reperfusion patients (both p values: <0.001). The QTc interval increased in both groups, but this increment was steeper among the successfully reperfused patients. The QTc interval increased to 431.5 ms in the successful reperfusion patients and 436.6 ms in the failed reperfusion patients (both in-group interaction p values: <0.001). The mean QTc interval lengthened from 412.6 ms to 433.1 ms in the entire study population (p<0.001). After fibrinolytic therapy, the Tpe/QTc ratio decreased in both groups, but the decrease in the successfully reperfused patients was greater than that of the other group (0.190 *vs.* 0.220) (p<0.001). Delta changes at admission and during follow-up of the Tpe interval, QTc interval, and Tpe/QTc ratio were wider among the successfully reperfused patients, and all of these delta changes reached the level of statistical significance (Table 5).

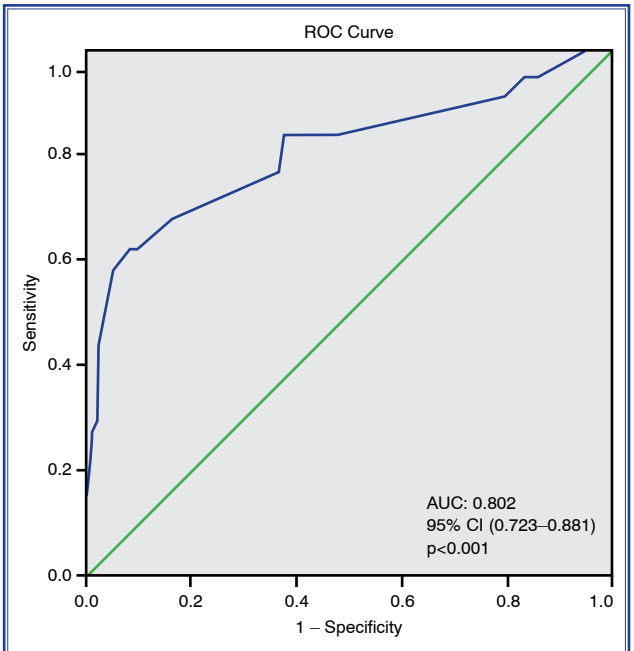

Figure 2. ROC curve analysis of the average Tpe interval on the admission ECG. AUC: Area under the curve; CI: Confidence interval; ECG: Electrocardiogram; ROC: Receiver operating characteristic; Tpe: Interval between the peak of the T wave and the end of the T wave.

In ROC curve analysis, a cut-off value of 89.0 ms for the admission Tpe interval predicted successful reperfusion with fibrinolytic therapy with a sensitivity of 90.9% and a specificity of 79.8% (Area under the curve [AUC]=0.802, 95% confidence interval [0.723–0.881]; p value<0.001) (Fig. 2). ROC curve analysis of the Tpe/QTc ratio also demonstrated a correlation with the success of fibrinolytic therapy, but the correlation level was lower (correlation value for AUC: 0.678; p value<0.001).

DISCUSSION

The objective of this clinical investigation was to research the Tpe interval and the Tpe/QTc ratio in STEMI patients treated with fibrinolytic therapy. Both of these ECG indices were evaluated and compared between patients with successful and failed reperfusion before and after fibrinolytic administration. The current guidelines for acute MI patients presenting with the ST-segment elevation recommend primary PCI or fibrinolytic therapy to restore myocardial reperfusion.[2] Successful myocardial reperfusion performed emergently following hospital admission is closely related to the short- and long-term survival of acute MI patients. Percutaneous revascularization

within the target time intervals is the first choice in clinical cardiology guidelines and recent large scale clinical trials.[7] This recommendation is most suited to high-volume catheter centers. The door-to-balloon (DTB) time is shorter in clinical trials than in daily practice,[8] and there is great variation in the DTB time among interventional cardiology centers. Restoration of tissue perfusion as soon as possible is essential in the setting of STEMI and fibrinolytic therapy is a vital choice for patients who do not have access to percutaneous revascularization within the target time intervals. However, the success of treatment with fibrinolytic agents varies widely and failed reperfusion after fibrinolytic administration carries an additional risk factor during a subsequent PCI procedure.

The Tpe interval is closely linked to ventricular repolarization and homogenous dispersion of ventricular repolarization. Recent studies revealed that the Tpe interval may have a role in the evaluation of myocardial ischemia in various types of coronary artery disease.[9–11] Many factors, such as advanced age, smoking, male gender, and hypertension, have been reported to affect Tpe and QTc intervals.[12–15] We assessed the role of these characteristics in the prolongation of the Tpe interval and found that a prolonged Tpe interval (p=0.011) and QTc interval (p=0.046), and an increased Tpe/QTc ratio (p=0.002) were closely related only to male gender among the parameters examined in our study population. Along with the Tpe interval, the QT interval and the heart rate-adjusted QTc interval (corrected QT interval) are also related to ventricular repolarization and dispersion of ventricular conduction.[16] The Tpe interval and the Tpe/QTc ratio have been investigated in STEMI patients who underwent a primary PCI,[17] but to our knowledge, the role of fibrinolytic agents has not yet been analyzed. In studies investigating a primary PCI procedure, the Tpe interval has been found to be shorten with successful reperfusion.[18,19] Çağdaş et al.[20] reported that the admission Tpe interval is closely linked to the development of a no-reflow pattern in STEMI patients treated with a primary PCI. Even in successfully revascularized patients evaluated in the presence of epicardial Thrombolysis In Myocardial Infarction coronary flow score of 3, myocardial tissue reperfusion may not completely recover and this lack of tissue reperfusion was found to be related to less shortening of Tpe intervals and Tpe/QTc ratios.[6] In our study population, failed reperfusion patients had a longer average Tpe interval at admission (91.7 *vs.* 100.9 ms) (p<0.001). Similarly, shortening of the Tpe interval at the 90th minute was more prominent in the successful reperfusion group (9.3 *vs.* 4.5 ms) (p<0.001). Despite the lack of resolution of ST-segment elevation in the failed reperfusion group, the average Tpe interval was shorter than that recorded at admission. Aside from the ST-segment resolution criterion applied, we were not able to explain the shortening of the average Tpe interval in failed reperfusion patients.

Various clinical parameters have been tested for the ability to predict the reperfusion success of fibrinolytic agents,[21] but a reliable parameter has not yet been found. In revascularization guidelines,[2] the rate of reperfusion success of fibrinolytic agents was described preliminarily as 75%. We found that the Tpe interval on the admission ECG was an important indicator of the success of fibrinolytic treatment. In our evaluation, a shorter admission Tpe interval indicated greater success for fibrinolysis and a cut-off value of 89.0 ms predicted successful reperfusion with a sensitivity of >90%. We concluded that additional evaluation of the admission Tpe interval can predict the reperfusion success of fibrinolysis. Furthermore, the length of time between the onset of chest pain and admission to emergency service should be evaluated carefully, because our results indicated that delayed hospital admission was found to be related to a possible increase in the Tpe interval (r=0.390; p<0.001) and an increase in failed reperfusion (r=0.516; p<0.001). Correlation analysis for the QTc interval (r=0.288; p<0.001) and Tpe/QTc ratios (r=0.203; p=0.007) demonstrated lower correlation coefficients and weak interaction. We observed a further decrease in the Tpe/QTc ratio in the successful reperfusion group; however the Tpe/QTc ratio was found to have only a weak correlation with the prediction of reperfusion success in ROC curve analysis (correlation coefficient for AUC: <0.7).

In our analysis, an anterior wall MI was more common in the successful reperfusion group, but this was not significant statistically. At the same time, a higher LVEF (at admission and discharge) and lower peak hs-troponin levels were detected in the successful reperfusion group. Previous studies have demonstrated that peak cardiac troponin levels were closely related to infarct size.[22] Despite the frequency of anterior wall

MI seen in the successful reperfusion group in this study, we think these conflicting data about LVEF and hs-troponin levels may be explained by the emergency service admission time. We concluded that the clinical presentation of anterior wall MI patients were more rumbling and these patients has admitted to the emergency service at an earlier time following the onset of chest pain. Therefore, these patients could be diagnosed and treated more quickly than patients with a non-anterior wall MI. However, in former studies, emergency service admission time has not been mentioned in the clinical evaluation.[23–25] The earlier administration of fibrinolytics could be a factor in lower hs-troponin levels and further restriction of infarct size, despite the large percentage of anterior wall MI patients in the successful reperfusion group.

Limitations

This study is a retrospective analysis of STEMI patients treated with fibrinolytic therapy during their emergency admission. ECG evaluation and measurements of the Tpe interval and Tpe/QTc ratio were performed manually, which may have affected the sensitivity.

Conclusion

Evaluation of the Tpe interval on an admission ECG was predictive of the reperfusion success of fibrinolytic agents. Technical developments to measure novel ECG parameters could increase the sensitivity of the evaluation of these parameters and should be explored in further clinical studies.

Ethics Committee Approval: The study protocol was approved by the Başkent University Institutional Review Board (Project no: KA18/315).

Peer-review: Externally peer-reviewed.

Conflict-of-interest: None.

Authorship contributions: Concept: A.Ç.; Design: A.Ç.; Supervision: A.Ç., S.A.; Materials: A.Ç., S.A., M.H.A., C.A.; Data: A.Ç., S.A.; Analysis: A.Ç., C.A.; Literature search: A.Ç., S.A., M.H.A.; Writing: A.Ç.; Critical revision: A.Ç., H.M.

REFERENCES

1. Yeh RW, Sidney S, Chandra M, Sorel M, Selby JV, Go AS. Population trends in the incidence and outcomes of acute myocardial infarction. N Engl J Med 2010;362:2155–65. [CrossRef]
2. Ibanez B, James S, Agewall S, Antunes MJ, Bucciarelli-Ducci C, Bueno H, et al; ESC Scientific Document Group. ESC Scientific Document Group. 2017 ESC Guidelines for the management of acute myocardial infarction in patients presenting with ST-segment elevation. Eur Heart J 2018;39:119–77. [CrossRef]
3. Sohal M, Foo F, Sirker A, Rajani R, Khawaja MZ, Pegge N, et al. Rescue angioplasty for failed fibrinolysis-long-term follow-up of a large cohort. Catheter Cardiovasc Interv 2011;77:599–604. [CrossRef]
4. Boghdady A, Elbadry MI. Comparison of successful myocardial reperfusion and adverse events in patients with ST-elevation myocardial infarction who underwent rescue percutaneous coronary intervention after failed fibrinolytic therapy with versus without manual coronary thrombus aspiration. Am J Cardiol 2015;116:1185–92. [CrossRef]
5. Maury P, Sacher F, Gourraud JB, Pasquié JL, Raczka F, Bongard V, et al. Increased Tpeak-Tend interval is highly and independently related to arrhytmic events in Brugada syndrome. Heart Rhythm 2015;12:2469–76. [CrossRef]
6. Duyuler PT, Duyuler S, Demir M. Impact of myocardial blush grade on Tpe interval and Tpe/QT ratio after successful primary percutaneous coronary intervention in patients with ST elevation myocardial infarction. Eur Rev Med Pharmacol Sci 2017;21:143–9.
7. West RM, Cattle BA, Bouyssie M, Squire I, de Belder M, Fox KA, et al. Impact of hospital proportion and volume on primary percutaneous coronary intervention performance in England and Wales. Eur Heart J 2011;32:706–11. [CrossRef]
8. Pinto DS, Frederick PD, Chakrabarti AK, Kirtane AJ, Ullman E, Dejam A, et al; National Registry of Myocardial Infarction Investigators. National Registry of Myocardial Infarction Investigators. Benefit of transferring ST-segment-elevation myocardial infarction patients for percutaneous coronary intervention compared with administration of onsite fibrinolytic declines as delays increase. Circulation 2011;124:2512–21. [CrossRef]
9. Zehir R, Karabay CY, Kalaycı A, Akgün T, Kılıçgedik A, Kırma C. Evaluation of Tpe interval and Tpe/QT ratio in patients with slow coronary flow. Anatol J Cardiol 2015;15:463–7. [CrossRef]
10. Haarmark C, Hansen PR, Larsen EV, Pedersen SH, Graff C, Andersen MP, et al. The prognostic value of the Tpeak-Tend interval in patients undergoing primary percutaneous coronary intervention for ST-segment elevation myocardial infarction. Journal of Electrocardiology 2009;42:555–60. [CrossRef]
11. Lin XM, Yang XL, Liu HL, Lai YQ. Relationship between Tpeak-Tend interval and coronary artery stenosis and effects of percutaneous transluminal coronary angioplasty on Tpeak-Tend. [Article in Chinese]. Nan Fang Yi Ke Da Xue Xue Bao 2010;30:1877–9.
12. Korantzopoulos P, Letsas KP, Christogiannis Z, Kalantzi K, Massis I, Milionis HJ, et al. Exercise-induced repolarization changes in patients with stable coronary artery disease. Am J Cardiol 2011;107:37–40. [CrossRef]

13. Kalantzi K, Gouva C, Letsas KP, Vlachopanou A, Foulidis V, Bechlioulis A, et al. The impact of hemodialysis on the dispersion of ventricular repolarization. Pacing Clin Electrophysiol 2013;36:322–7. [CrossRef]
14. Ciobanu A, Gheorghe GS, Ababei M, Deaconu M, Ilieşiu AM, Bolohan M, et al. Dispersion of ventricular repolarization in relation to cardiovascular risk factors in hypertension. J Med Life 2014;7:545–50.
15. Korantzopoulos P, Letsas KP, Christogiannis Z, Kalantzi K, Massis I, Goudevenos JA. Gender effects on novel indexes of heterogeneity of repolarization in patients with stable coronary artery disease. Hellenic J Cardiol 2011;52:311–5.
16 Stankovic I, Putnikovic B, Janicijevic A, Jankovic M, Cvjetan R, Pavlovic S, et al. Myocardial mechanical and QTc dispersion for the detection of significant coronary artery disease. Eur heart J Cardiovasc Imaging 2015;16:1015–22. [CrossRef]
17 Szydlo K, Wita K, Trusz-Gluza M, Zawada K, Piecuch A, Kulach A, et al. Repolarization parameters in patients with acute ST segment elevation myocardial infarction treated with primary percutaneous coronary intervention with respect to predischarge ST-T pattern: a preliminary study. Cardiology Journal 2009;16:52–6.
18. Eslami V, Safi M, Taherkhani M, Adibi A, Movahed MR. Evaluation of QT, QT dispersion, and T-wave peak to end time changes after primary percutaneous coronary intervention in patients presenting with acute ST-elevation myocardial infarction. J Invasive Cardiol 2013;25:232–4.
19. Elitok A, Ikitimur B, Onur I, Oz F, Emet S, Karaayvaz EB, et al. The relationship between T-wave peak-toend interval and ST segment recovery on intracoronary ECG during primary PCI. Eur Rev Med Pharmacol Sci 2015;19:1086–91.
20. Çağdaş M, Karakoyun S, Rencüzoğulları İ, Karabağ Y, Yesin M, Velibey Y, et al. Assessment of the relationship between reperfusion success and T-peak to T-end interval in patients with ST elevation myocardial infarction treated with percutaneous coronary intervention. Anatol J Cardiol 2018;19:50–7.
21. Kalaycı B. The relationship between hemogram parameters and thrombolytic treatment success in patients with ST elevation myocardial infarction. MN Kardiyoloji 2018; 25:115–20.
22. Hallén J. Troponin for the estimation of infarct size: what have we learned? Cardiology 2012;121:204–12. [CrossRef]
23. Boden H, Ahmad TA, Velders MA, van der Hoeven BL, Hoogslag GE, Bootsma M, et al. Peak and fixed-time high-sensitive troponin for prediction of infarct size, impaired left ventricular function, and adverse outcomes in patients with first ST-segment elevation myocardial infarction receiving percutaneous coronary intervention. Am J Cardiol 2013;111:1387–93. [CrossRef]
24 Reinstadler SJ, Feistritzer HJ, Klug G, Mair J, Tu AM, Kofler M, et al. High-sensitivity troponin T for prediction of left ventricular function and infarct size one year following ST-elevation myocardial infarction. Int J Cardiol 2016;202:188–93. [CrossRef]
25. Mohammad MA, Koul S, Smith JG, Noc M, Lang I, Holzer M, et al. Predictive value of high-sensitivity troponin T for systolic dysfunction and infarct size (six months) after ST-elevation myocardial infarction. Am J Cardiol 2018;122:735–43.

Keywords: Fibrinolytic administration; reperfusion success; ST-segment elevation myocardial infarction; Tpe interval.

Anahtar sözcükler: Fibrinolitik uygulanması; reperfüzyon başarısı; ST-segment yükselmeli miyokart enfarktüsü; Tpe aralığı.