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Original Article

The Clinical Impact of the Dynamic Morphology of T-Wave Inversion After Primary Percutaneous Coronary Intervention in Patients With ST-Segment Elevation Myocardial Infarction

Jongkwon Seo[1], MD; Byung Gyu Kim[1], MD; Moo-Nyun Jin[1], MD; Hye Young Lee[1], MD; Byung Ok Kim[1], MD; Young Sup Byun[1], MD; Gwang Sil Kim[1*], MD

ABSTRACT

Background: T-wave inversion, which develops shortly after primary percutaneous coronary intervention (PCI) in patients with ST-segment elevation myocardial infarction (STEMI), is related to reperfusion or myocardial viability. We aimed to evaluate the clinical outcome according to changes in T-wave inversion in patients with STEMI.

Methods: We categorized patients into 3 groups according to T-wave morphology after primary PCI: no newly developed T-wave inversion, newly developed T-wave inversion but resolved within 6 months (recovered T-wave), and newly developed T-wave inversion and persistent over 6 months (persistent T-wave). Newly developed T-wave inversion was defined as new-onset T-wave inversion within 48 hours after primary PCI. The primary endpoint was major adverse cardiac and cerebrovascular events (MACCE), comprising cardiac death, myocardial infarction, target vessel revascularization, stroke, and re-hospitalization for heart failure.

Results: A total of 299 patients were analyzed and followed up for a mean of 25 months. Among them, 70, 158, and 71 had no newly developed T-wave inversion, recovered inversion, and persistent inversion, respectively. The cumulative MACCE rate was significantly lower in patients with recovered inversion than in those with no or persistent inversion (10.1% vs 21.4% vs 18.3%, respectively; *P*=0.04). In multivariate Cox regression analysis, the no T-wave inversion group (hazard ratio [HR], 2.05; 95% confidence interval [CI], 1.0 to 4.39; *P*=0.05) and the persistent T-wave inversion group (HR, 1.98; 95% CI, 0.93 to 4.18; *P*=0.07) were associated with more frequent MACCE.

Conclusions: Newly developed T-wave inversion that disappears within 6 months was associated with a favorable long-term outcome compared with no newly developed or persistent T-wave inversion. ***(Iranian Heart Journal 2022; 23(2): 26-33)***

KEYWORDS: ST-elevation myocardial infarction, T-wave inversion, Clinical outcome

[1] Division of Cardiology, Department of Internal Medicine, Sanggye Paik Hospital, Seoul, Korea.

***Corresponding Author:** Gwang Sil Kim, MD; Division of Cardiology, Department of Internal Medicine, Sanggye Paik Hospital, Seoul, Korea.
Email: zidan007@paik.ac.kr **Tel:** +821093286887

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Serial electrocardiography (ECG) changes are often observed in patients with ST-segment elevation myocardial infarction (STEMI). There are specific ECG patterns that predict poor outcomes. Previous studies have shown that persistent T-wave inversion and q-wave following STEMI are associated with more extensive myocardial damage,[1] whereas newly developed T-wave inversion after reperfusion therapy is the marker of reperfusion and predicts more benign in-hospital courses.[2] Patients with newly developed T-wave inversion could have better outcomes than ones with no T-wave inversion. However, there are few reports regarding the prognosis associated with subsequent changes (maintenance or disappearance of T-wave inversion) during follow-up within patients with newly developed T-wave inversion.

Thus, we aimed to evaluate the clinical outcome among the following 3 groups following primary percutaneous coronary intervention (PCI) after STEMI: no T-wave inversion, recovered T-wave inversion, and persistent T-wave inversion.

METHODS

Patients and Study Design

Between January 2011 and December 2015, a total of 321 patients who underwent primary PCI at Sanggye-Paik Hospital in Seoul, South Korea were enrolled in the study. Twenty-two patients were excluded: embolic MI not requiring stent implantation (n=8), incomplete data including drug history (n=4), rescue PCI after thrombolysis (n=4), and loss to follow-up before 6 months (n=6). Finally, 299 patients with STEMI were included in the study. Data were collected from the patients' electronic medical records and angiographic findings. Multivessel disease was defined as having stenosis greater than 70% in at least 2 major coronary arteries. Heart failure was defined as an ejection fraction of less than 40%. Follow-up was done at 2 postoperative weeks and then every 1 to 3 months, during which a physical examination was performed. The study protocol was approved by the institutional review board at Sanggye Paik Hospital (2019-06-012).

Assessment of T-Wave Inversion

We categorized patients into 3 groups according to T-wave morphology after primary PCI: no newly developed T-wave inversion, newly developed T wave inversion but resolved within 6 months (recovered T-wave group), and newly developed T-wave inversion and persistent over 6 months (persistent T-wave group).

T-wave inversion was defined as 0.5 mm below the isoelectric line in more than 2 adjacent leads with maximal ST-segment elevation. New T-wave inversion was defined as the new onset of T-wave inversion in leads with maximal ST-segment elevation within 48 hours after primary PCI.

Follow-up

The adverse cardiac and cerebrovascular events (MACCE) rate was compared between the 3 groups. MACCE was defined as a composite of cardiac death, target vessel revascularization, stroke, and rehospitalization due to heart failure during the follow-up period. In general, the patients were followed up in the outpatient department every 1 to 3 months. Follow-up angiography was performed when the patients had symptoms or signs suggesting ischemic heart disease.

Statistical Analysis

The Statistical Package of Social Science for Windows, version 25.0 (SPSS Inc, Chicago, IL, USA), was used for all statistical analyses. The *t* test was employed to compare continuous variables, and the χ^2 test was applied to compare frequency variables.

A Kaplan–Meier survival analysis was drawn upon to compare event rates. Hazard ratios (HRs) were calculated using a Cox regression analysis. Univariate and multivariate analyses were utilized to determine the predictors of clinical outcomes. Variables with a *P* value of 0.1 or less in univariate analysis were included in the multivariate analysis. HRs were provided with 95% confidence intervals (CIs). For all the tests, a *P* value of less than 0.05 was considered significant.

RESULTS

A total of 299 patients were analyzed and followed up for a mean period of 25 months. The number of patients without newly developed T-wave inversion was 70 (23%), those with recovered T-wave inversion was 158 (53%), and those with persistent T-wave inversion group was 71 (24%).

There were no statistically significant differences in baseline characteristics such as age, sex, hypertension, diabetes, and dyslipidemia between the 3 groups. There was no variation in smoking history or previous cardiovascular disease history as well. In laboratory data, no significant differences were observed in cardiac markers, creatine kinase-MB (CK-MB), and troponin I levels, whereas a statistically significant difference existed in aspartate aminotransferase (AST) and alanine transaminase (ALT) levels between the groups. The recovered T-wave group had the lowest AST and ALT levels and was associated with the highest left ventricular ejection fraction (LVEF) in echocardiography. Inflammatory markers, white blood cell counts, and high-sensitivity C-reactive protein levels were lowest in the recovered T-wave group (Table 1).

The angiographic findings are summarized in Table 2. The persistent T-wave group had more right coronary artery STEMI, and the rest of the group had more left anterior descending STEMI. The door-to-balloon time was the shortest in the no T-wave group, but the symptom-to-balloon time was the shortest in the recovered T-wave group, although the difference was not statistically significant. As shown in Table 2, the ratio of patients with low-grade thrombolysis in myocardial infarction (TIMI) flow at initial coronary angiography was the highest in the persistent T-wave inversion group and the lowest in the recovered T-wave inversion group. However, the postprocedural TIMI flow grade and the rate of aspiration thrombectomy were similar in all 3 groups. In addition, the total stent number, the diameter, and the length were also not different between the 3 groups. The cumulative MACCE rate was significantly lower in the recovered T-wave group than in the no new T-wave and persistent T-wave groups (10.1% vs 21.4% vs 18.3%, respectively; *P*=0.04) (Table 3). A Kaplan–Meier survival curve (Supplemental Figure 1) showed a lower incidence rate of MACCE in the recovered T-inversion group. In multivariate Cox regression analysis, the no T-wave inversion group (HR, 2.05; 95% CI, 1.0 to 4.39; *P*=0.05) and the persistent T-wave inversion group (HR, 1.98; 95% CI, 0.93 to 4.18; *P*=0.07) were associated with more frequent MACCE compared with the recovered T-wave inversion group (Table 4).

Table 1: Baseline characteristics according to T-wave groups

	No T-Wave (n=70)	Recovered T-Wave (n=158)	Persistent T-Wave (n=71)	*P* value
Age, y	60±14	59±14	62±12	0.46
Male	61 (87.1)	131 (82.9)	56 (78.9)	0.43
Hypertension	30 (43.5)	67 (42.4)	34 (47.9)	0.74
Diabetes	18 (26.9)	31 (20.9)	14 (20.6)	0.58
Dyslipidemia	8 (11.6)	17 (10.8)	5 (7.0)	0.61
Previous MI	4 (5.7)	4 (2.5)	3 (4.2)	0.48
Previous stroke	1 (1.4)	9 (5.7)	4 (5.6)	0.34
Current smoker	38 (55.9)	87 (57.2)	31 (45.6)	0.24
Hemoglobin, mg/dL	14.8±1.6	14.7±1.7	14.5±1.6	0.42
WBC, /uL	12470±4630	11013±3504	11785±3774	0.03
Hs-CRP, mg/dL	1.16±3.17	0.45±0.93	0.91±2.03	0.07
CK-MB, IU/L	49.3±90.7	39.2±19.2	55.83±96.2	0.38
Troponin I, ng/mL	15.14±28.0	8.1±22.1	11.56±24.9	0.13
AST, U/L	90.4±140.6	50.9±67.9	72.4±85.3	0.01
ALT, U/L	48.1±64.7	30.6±38.6	33.0±22.6	0.02
Triglyceride, mg/dL	122±81	148±138	114±70	0.09
LDL cholesterol, mg/dL	111±36[a]	116±33[a]	101±28[b]	0.01
HDL cholesterol, mg/dL	40±8	41±10	41±8	0.62
LVEF (%)	48.2±12.2	53.1±11.0	49.4±10.2	0.01
WMSI	6.93±9.9	5.9±8.7	7.9±10.7	0.34
Discharge Medication				
Aspirin	69 (98.5)	155 (98.1)	70 (98.6)	0.98
Plavix	57 (81.4)	120 (75.9)	50 (70.4)	0.82
Statin	67 (95.7)	148 (93.7)	69 (97.2)	0.79
Beta-blocker	57 (81.4)	128 (81)	58 (81.7)	0.98
ACEI	42 (60)	78 (49.4)	34 (47.9)	0.51
Follow-up duration (days)	761±614	770±592	740±484	0.93

Values are presented as the mean ± the standard deviation.
ACEI, Angiotensin-converting enzyme inhibitor; ALT, Alanine transaminase; AST, Aspartate aminotransferase; CK, Creatine kinase; HDL, High-density lipoprotein; Hs-CRP, High-sensitivity C-reactive protein; LDL, Low-density lipoprotein; LVEF, Left ventricular ejection fraction; MI, Myocardial infarction; WMSI, Wall motion score index

Table 2: Angiographic findings according to T-wave groups

	No T-Wave (n=70)	Recovered T-Wave (n=158)	Persistent T-Wave (n=71)	***P* value**
Culprit Vessel				0.02
LAD	42 (60.9)	83 (52.5)	26 (37.7)	
RCA	21 (30.4)	59 (37.3)	39 (56.5)	
LCX	6 (8.7)	16 (10.1)	4 (5.8)	
Multivessel disease	39 (56.5)	73 (46.5)	36 (52.2)	0.36
Symptom to balloon time, min	486±790	282±513	387±781	0.10
Door-to-balloon time, min	84±30	95±46	102±51	0.06
Initial TIMI flow grade 0~1	45 (65.2)	101 (63.9)	57 (81.4)	0.03
Final TIMI flow grade 2~3	68 (97.1)	151 (95.6)	66 (93.0)	0.53
Aspiration thrombectomy	53 (75.7)	125 (79.1)	65 (91.5)	0.22
Glycoprotein IIb/IIIa use	21 (30.0)	48 (30.4)	23 (32.4)	0.74
Number of stents	1.1±0.3	1.0±0.3	1.0±0.3	0.24
Stent diameter (mm)	3.3±1.7	3.5±2.2	3.3±0.5	0.76
Stent length (mm)	21.2±7.3	21.9±5.9	22.0±6.8	0.72

LAD, Left anterior descending artery; LCX, Left circumflex artery; RCA, Right coronary artery; TIMI, Thrombolysis in myocardial infarction

Table 3: MACCE at 2 years according to T-inversion type

Endpoint	No T-Inversion (n=70)	Recovered T (158)	Persistent T (n=71)	*P* value
MACCE	15 (21.4)	16 (10.1)	13 (18.3)	0.04
Cardiac death	3 (4.3)	2 (1.3)	1 (1.4)	0.56
TVR	4 (5.7)	7 (4.4)	4 (5.6)	0.64
Stroke	1 (1.4)	1 (0.01)	2 (0.01)	0.72
Rehospitalization due to HF	7 (10.0)	6 (3.8)	6 (8.5)	0.03

HF, Heart failure; MACCE, Major adverse cardiac and cerebrovascular event; TVR, Target vessel revascularization

Table 4: Multivariate analysis of MACCE

	Univariate		Multivariate	
	Hazards Ratio (95% confidence interval)	*P* value	Hazards Ratio (95% confidence interval)	*P* value
Age	1.02 (1.02-1.05)	0.05	1.01 (0.98-1.04)	0.56
Male	1.21 (0.50-1.28)	0.35		
Door-to-balloon time over 90 minutes	0.70 (0.56-1.36)	0.29		
Initial TIMI flow grade 0~1	0.96 (0.50-1.85)	0.90		
Hypertension	1.70 (0.93-3.10)	0.08	1.63 (0.86-3.09)	0.14
Diabetes	2.17 (1.14-4.09)	0.02	1 81 (0.94-3.48)	0.07
Multivessel	1.81 (0.97-3.38)	0.06	1.67 (0.96-3.24)	0.12
Heart failure	1.65 (1.23-3.27)	0.03	1.55 (1.21-3.24)	0.04
Current smoker	1.81 (0.69-4.70)	0.23		
T-inversion Category				
Recovered	1		1	
No	2.08 (1.01-4.31)	0.04	2.05 (1.0-4.39)	0.05
Persistent	2.00 (0.97-4.15)	0.06	1.98 (0.93-4.18)	0.07

MACCE, Major adverse cardiac and cerebrovascular event; TIMI, Thrombolysis in myocardial infarction

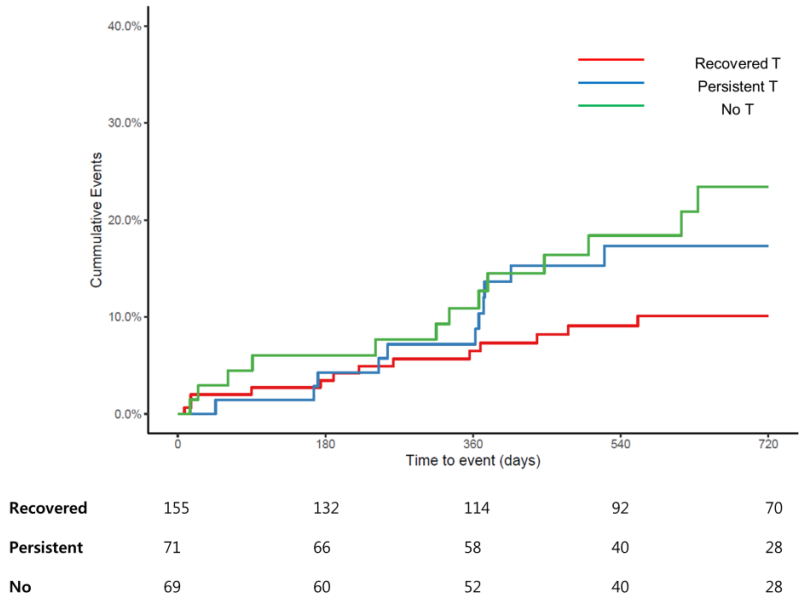

Figure 1: The image depicts major adverse cardiac and cerebrovascular events (MACCE) during the follow-up in the 3 different T-wave groups.

DISCUSSION

The main finding of this study was that the recovered T-wave inversion group after primary PCI due to STEMI showed better clinical outcomes than the no newly developed T-wave group and the persistent T-wave group. The results were robust, even after adjustments for confounding factors.

STEMI is one of the most dangerous acute presentations of coronary artery disease.[3] Despite advances in medicine and intervention technology, in-hospital mortality is reported to range between 5% and 8%,[4] and 1-year mortality is still high at 14%. Therefore, even after successful initial treatment, continuous optimal medical treatment and regular follow-up are important. In addition, studies to predict myocardial viability or prognosis after STEMI through modalities such as computed tomography,[5] magnetic resonance imaging,[6] or echocardiography[7] are being published continuously. Still, these tests have disadvantages in terms of cost and that they cannot be performed frequently due to hazards to patients because of the contrast material or radiation exposure. Meanwhile, ECG is a test that does not cause any harm to the patient due to the test itself, has a short test time, and has a great advantage in terms of cost. In addition, it can determine the mechanical state of the heart by reflecting the electrical activity after MI. Previous studies have published research on the association between these changes in ECG and prognosis after MI.

The results of the present study correspond with the results of several earlier studies, which reported that early developed T-wave inversion after reperfusion therapy is known to be one of the good prognostic predictors[8] and patients with newly developed T-wave inversion after primary PCI have favorable long-term outcomes.[9] In contrast, persistent T-wave inversion was correlated with poor outcomes in previous studies.[10,11]

Nevertheless, there is a dearth of data on the clinical impact of dynamic ECG changes in patients with STEMI after primary PCI. For this reason, we divided our patients into the 3 groups mentioned earlier. An important finding in our study was that there was a considerable difference in the clinical outcome between the recovered T-wave group and the persistent T-wave group. As shown in Figure 1, during approximately 1 year after primary PCI, no significant difference was observed in MACCE between the 2 groups. In the persistent T-wave group, however, events started to occur from approximately 1 year after primary PCI. The MACCE graph of the persistent T-wave group showed tendencies similar to those of the no newly developed T-wave inversion group as from 1 year after primary PCI.

In previous studies, patients with persistent T-wave inversion were shown to have more extensive myocardial damage and irreversible myocardial necrosis when visualized using cardiac magnetic resonance imaging.[1,12,13] Therefore, we think that the persistent T-wave group might have more extensive and irreversible myocardial damage than the recovered T-inversion group, although early T-inversion is associated with a reperfusion state.

According to our data, the symptom-to-balloon time was the shortest in the recovered T group, although the difference was not statistically significant, and the frequency of the initial TIMI flow grade of 0 to 1 was significantly lower in the recovered T group. Previous studies have shown that a short symptom-to-balloon time is associated with favorable clinical outcomes.[14-16] Myocardial cell death starts as early as 20 minutes after coronary artery occlusion and is usually complete within 6 hours.[17] Thus, a shorter pain-to-balloon time is directly associated with myocardial salvage. Denktas et al[18] reported that door-to-balloon time had reached its limit of effect in the preceding decade, thus efforts to shorten pain-to-balloon time are important. From this point of view, a faster pain-to-

balloon time would have caused less myocardial damage, and this part may be related to the occurrence of T-wave inversion.

The recovered T-inversion group also showed lower levels of inflammatory markers, AST, and ALT than the other groups. Elevated inflammatory marker levels can be an independent poor prognostic factor in patients with STEMI.[19] A high transaminase level is also correlated with systolic dysfunction and myocardial necrosis.[20] These results are also consistent with our data, suggesting that the highest LVEF and the lowest AST and ALT levels in the recovered T-wave group were associated with better outcomes.

We postulate that initially good TIMI flow grades, low levels of inflammation markers, low AST and ALT levels, and better LVEF are associated with myocardial viability. These factors could affect good prognosis with the dynamic morphology of T wave inversion in ECG. Recovery of inverted T-wave inversion could be interpreted as recovery from myocardial damage. Therefore, performing ECG 6 months after primary PCI can be a meaningful test to predict prognosis.

There were some limitations to this study, of course. First, because our study was a nonrandomized, observational study, selection bias and unmeasured confounding factors could not be eliminated. Second, the patients in our study may not reflect the general population of a wide region. Third, the small sample size could have weakened the statistical power. Fourth, we did not take into consideration the medications being taken by the patients.

CONCLUSIONS

The present study suggests that newly developed T-wave inversion that disappears within 6 months is a favorable prognostic factor in patients with STEMI compared with patients without newly developed T-wave inversion or with persistent T-wave inversion.

Authors' Contributions

JKS and GSK conceptualized the hypothesis, designed the study, and drafted the manuscript. HYL, YSB, and IHJ collected and interpreted the data. BOK and KJR conceptualized the hypothesis and revised the manuscript.

Conflict of Interest

All the authors have no conflicts of interest to declare.

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