Usefulness of T Wave Inversion in Leads With ST Elevation on the Presenting Electrocardiogram to Predict Spontaneous Reperfusion in Patients With Anterior ST Elevation Acute Myocardial Infarction

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Inversion of the T waves (T−) in electrocardiographic leads with ST-segment elevation after the initiation of reperfusion therapy is considered a sign of reperfusion. However, the significance of T− on presentation before the initiation of reperfusion therapy is unclear. The aim of this study was to assess whether T− on presentation predicts patency of the infarct-related artery in patients with acute ST-segment elevation myocardial infarctions (STEMIs) who undergo primary percutaneous interventions. The medical records, electrocardiograms, and angiographic findings of 209 consecutive patients who underwent emergent coronary angiography as part of primary percutaneous coronary intervention protocol activation for STEMI were reviewed. A total of 179 patients (86%) had positive T waves (T+), 16 (8%) had biphasic T waves (T+/−), and 14 (7%) had T−. Patency of the infarct-related artery (Thrombolysis In Myocardial Infarction [TIMI] flow grades 2 and 3) was seen in 64.3% of the patients in the T− group compared with only 31.2% in the T+/− group and 19.0% in the T+ group (p <0.001). Among patients with anterior STEMI, patency of the infarct-related artery was seen in all 7 patients in the T− group, compared with 50% of the 4 patients in the T+/− group and 10.1% of the 79 patients in the T+ group (p <0.001). There were no significant differences in TIMI flow grade among the groups in patients with nonanterior STEMIs (p = 0.985). In conclusion, T− in the leads with maximal ST-segment elevation on the presenting electrocardiogram was associated with higher prevalence of patency of the infarct-related artery before intervention (64.3%), especially in patients with anterior STEMIs (100%). **(Am J Cardiol 2014;113:270−274)**

In the present study, we assessed patency of the infarct-related artery before intervention in patients with ST-segment elevation myocardial infarctions (STEMIs) who underwent primary percutaneous coronary intervention (pPCI) at the Texas Heart Institute, St. Luke's Episcopal Hospital (Houston, Texas), on the basis of T-wave morphology.

Methods

We reviewed the medical records of consecutive patients who presented to St. Luke's Episcopal Hospital with suspected acute STEMI and for whom the pPCI protocol was activated and emergency coronary angiography was performed from November 3, 2010, through December 31, 2012. St. Luke's Episcopal Hospital is a large, urban tertiary center located in Houston, Texas. Patients with left bundle branch block, ventricular rhythm, or electronic ventricular pacing were excluded. Patients who received thrombolytic therapy or underwent pPCI before arrival to St. Luke's Episcopal Hospital and those who had postoperative infarctions were not included. We also excluded patients in whom culprit coronary artery lesions could not be identified and those with final diagnoses other than STEMI (takotsubo cardiomyopathy, myocarditis, etc). Demographic and clinical data were retrieved from the medical charts. Time from the onset of symptoms to presentation was retrieved from the pPCI quality assurance database. The presenting electrocardiograms of the patients were analyzed by 2 investigators (A.A. and Y.B.). The presence of ST-segment elevation, fulfilling the current guidelines for STEMI, was confirmed.[1−3] The configuration of the T waves in the 2 leads with maximal ST-segment elevation was determined: (1) positive T waves (T+), (2) biphasic T waves (T+/−; initial positive deflection above the ST segment follows by negative deflection ≥0.5 mm below the isoelectric line), or (3) negative T waves (T−; negative T waves ≥0.5 mm below the isoelectric line without initial positive deflection) (Figure 1). The readers were blinded to the angiographic data. The angiographic images were reviewed by 1 investigator (M.A.), who was blinded to the electrocardiographic data. The site of coronary artery occlusion and the initial Thrombolysis In Myocardial Infarction (TIMI) flow grade before intervention were determined.

The 3 groups were compared using chi-square analysis for categorical data and analysis of variance for continuous variables. A p value <0.05 was considered statistically significant.

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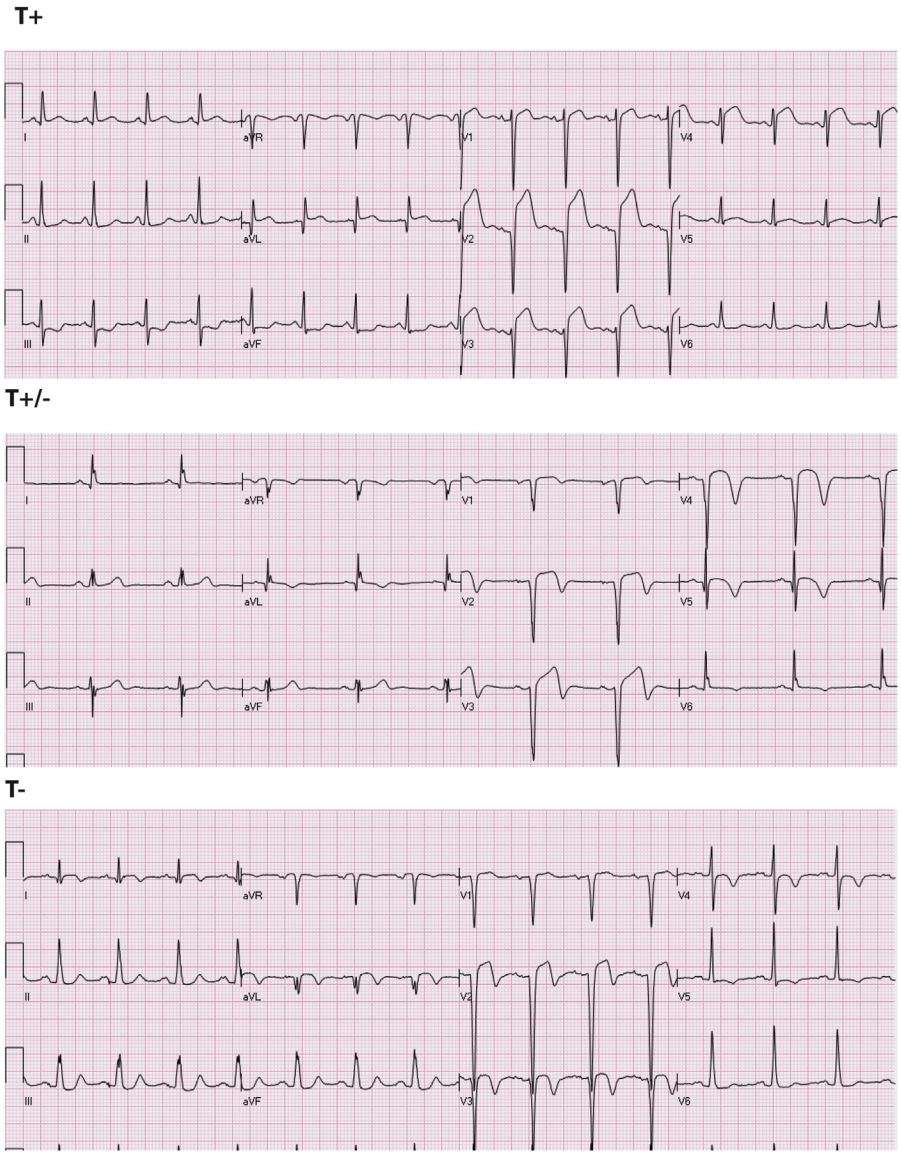

Figure 1. Sample electrocardiograms from 3 patients with anterior STEMIs. T+: a 51-year-old man presented within 2 hours of the onset of symptoms. Electrocardiography showed ST-segment elevation in leads aVL and V_1 to V_4 with peaked positive T waves. Coronary angiography showed complete occlusion of the proximal left anterior descending artery with TIMI flow grade 0. T+/−: a 33-year-old man presented with stuttering chest pain for several hours. Electrocardiography showed ST-segment elevation in leads aVL and V_1 to V_5. The T wave in lead aVL was biphasic, with an initial negative deflection and terminal positive deflection. In leads V_2 and V_3 (the leads with maximal ST-segment elevation), the initial part of the T wave was positive, and the terminal part was negative (<0.1 mV below the isoelectric line). The T waves in leads V_4 to V_6 were negative. Coronary angiography revealed a distal left anterior descending artery lesion with TIMI flow grade 0. T−: a 57-year-old man presented >6 hours after the onset of symptoms. Electrocardiography showed ST-segment elevation in leads I, aVL, V_2, and V_3. The terminal part of the T wave was negative in leads I, aVL, and V_2 to V_5. Coronary angiography showed a proximal lesion in the left anterior descending coronary artery with TIMI flow grade 2.

Results

A total of 209 patients were included, of whom 179 (86%) had T+, 16 (8%) had T+/−, and 14 (7%) had T−. Baseline demographic and clinical data of the 3 groups are listed in Table 1. There were no differences in gender among the groups. However, patients with T+ were younger. In contrast, there were fewer Caucasian patients and more African-American and Hispanic patients in the T− group. Fewer patients in the T+ group had histories of diabetes mellitus; however, there were no differences in the prevalence of hypertension, previous myocardial infarction, or previous coronary artery bypass graft surgery among the groups.

In the T+/− group, there were more patients with inferior STEMIs and fewer patients with anterior STEMIs. Time from the onset of symptoms to pPCI was comparable among the 3 groups. Peak creatine kinase-MB and cardiac troponin I were comparable among the groups. There were no differences in the percentage of patients who were treated with pPCI among groups; however, more patients in the T+/− group underwent coronary artery bypass grafting and fewer were treated conservatively (without revascularization procedures).

Table 1
Baseline demographic and clinical data of the patients

Variable	T+ (n = 179)	T+/− (n = 16)	T− (n = 14)	p Value
Men	126 (70%)	11 (69%)	8 (57%)	0.584
Age (yrs)	61 ± 13	69 ± 12	65 ± 11	0.028
Race/ethnicity				0.008
White	117 (65%)	10 (63%)	2 (14%)	
Black	34 (19%)	2 (13%)	7 (50%)	
Hispanic	21 (12%)	4 (25%)	4 (29%)	
Asian	7 (4%)	0	1 (7%)	
Diabetes mellitus	58 (33%)	9 (56%)	8 (57%)	0.04
Hypertension	146 (82%)	13 (81%)	13 (93%)	0.58
No previous myocardial infarction	168 (94%)	14 (88%)	13 (93%)	0.547
Previous coronary bypass	15 (8%)	4 (25%)	1 (7%)	0.093
Infarct location				0.009
Anterior	79 (44%)	4 (25%)	7 (50%)	
Inferior	91 (51%)	12 (75%)	5 (36%)	
Anterior + inferior	2 (1%)	0	2 (14%)	
Lateral	7 (4%)	0	0	
Time from symptom onset to pPCI (h)				0.305
<1	89 (50%)	7 (44%)	7 (50%)	
1−3	29 (16%)	5 (31%)	1 (7%)	
3−6	31 (17%)	0	2 (14%)	
>6	30 (17%)	4 (25%)	4 (29%)	
Peak creatine kinase-MB (ng/ml)	108 ± 138	69 ± 95	67 ± 104	0.266
Peak troponin I (ng/ml)	22.2 ± 22.4	23.8 ± 23.1	19.7 ± 20.4	0.877
Revascularization procedures				
Primary percutaneous coronary intervention	160 (90%)	14 (88%)	13 (93%)	0.888
Coronary artery bypass surgery	8 (5%)	4 (25%)	1 (7%)	0.004
No revascularization	16 (9%)	0	1 (7%)	0.093

Data are expressed as mean ± SD or number (percentage).

Table 2
Angiographic data

Variable	T+ (n = 179)	T+/− (n = 16)	T− (n = 14)	p Value
Infarct-related coronary artery				0.051
Left anterior descending	86 (48%)	3 (19%)	6 (43%)	
Left circumflex	19 (11%)	3 (19%)	1 (7%)	
Right	67 (37%)	6 (38%)	6 (43%)	
Left main	1 (1%)	1 (6%)	0	
Graft	5 (3%)	3 (19%)	1 (7%)	
Other	1 (1%)	0	0	
TIMI flow grade				<0.001
0	132 (74%)	6 (38%)	4 (29%)	
1	14 (8%)	5 (31%)	1 (7%)	
2	33 (18%)	5 (31%)	8 (57%)	
3	0	0	1 (7%)	

Table 3
Initial Thrombolysis In Myocardial Infarction flow grade by ST-segment elevation myocardial infarction type

TIMI Flow Grade	T+ (n = 79)	T+/− (n = 4)	T− (n = 7)	p Value
Anterior STEMI				<0.001
0	66	1	0	
1	6	1	0	
2	7	2	6	
3	0	0	1	
Nonanterior STEMI				0.114
0	66	5	4	
1	8	4	1	
2	26	3	2	
3	0	0	0	

Table 4
Initial Thrombolysis In Myocardial Infarction flow grade by time elapsed from onset of symptoms to primary percutaneous coronary intervention

TIMI Flow Grade	T+ (n = 89)	T+/− (n = 7)	T− (n = 7)	p Value
Time <1 hour				<0.001
0	64	1	2	
1	8	2	0	
2	17	4	4	
3	0	0	1	
Time >1 hour				0.007
0	68	5	2	
1	6	3	1	
2	16	1	4	
3	0	0	0	

Angiographic data are listed in Table 2. The infarct-related artery was less often the left anterior descending coronary artery and more often the left circumflex coronary artery, left main coronary artery, or a graft in the T+/− group.

TIMI flow grade 0 was seen more often in the T+ group (73.7%) than in the T+/− group (37.5%) or T− group (28.6%). Patency of the infarct-related artery (TIMI flow grade 2 or 3) was seen in 64.3% of the patients in the T− group and only 31.2% in the T+/− group and 18.0% in the T+ group ($p < 0.001$).

In patients with anterior STEMIs, patency of the infarct-related artery was seen in all 7 patients in the T− group, compared with 50% of the 4 patients in the T+/− group and 10.1% of the 79 patients in the T+ group ($p < 0.001$; Table 3). The sensitivity and specificity of T− for patency were 43.8% and 89.2%, respectively. In contrast, there were no significant differences in patency of the infarct related artery among the groups in patients with nonanterior STEMIs ($p = 0.985$; Table 3).

Among the 103 patients who underwent coronary angiography within 1 hour of the onset of symptoms, patency of the infarct-related artery was seen in 71.4% of the 7 patients in the T− group and only 57.1% of the 7 patients in the T+/− group and 20.2% in the 89 patients in the T+ group ($p = 0.002$;

Table 4). In the 106 patients who underwent coronary angiography >1 hour after the onset of symptoms, infarct-related artery patency was seen in 57.1% of the 7 patients in the T− group and only 11.1% of the 9 patients in the T+/− group and 17.8% of the 90 patients in the T+ group ($p = 0.033$).

Discussion

The major findings of our study are that T-wave inversion in the leads with maximal ST-segment elevation on the presenting electrocardiogram was associated with a higher prevalence of patency of the infarct-related artery before intervention (64.3%), especially in patients with anterior STEMIs (100%) and those who underwent angiography within 1 hour of the onset of symptoms (71.4%). In contrast, the infarct-related artery was occluded (TIMI flow grade 0 or 1) in most patients in the T+ group (81.0%), especially those with anterior STEMIs (89.9%).

The current guidelines for the treatment of STEMI emphasize the importance of shortening the time interval between the occlusion of the infarct-related artery and reperfusion to salvage myocardium and minimize infarct size.[1,2] This is based on the paradigm that in patients with STEMIs, necrosis progresses rapidly because of the presence of ongoing transmural ischemia. In contrast, emergent reperfusion therapy is currently not indicated for patients without ST-segment elevation, unless they have ongoing symptoms despite initial medical therapy or hemodynamic instability,[1,2,4] because it is assumed that those patients do not have ongoing progression of the wave front of necrosis. However, it is plausible that in some patients presenting with ST-segment elevation, spontaneous reperfusion, even partial, aborts the progression of the wave front of necrosis. In these patients, stenting may be indicated to prevent reischemia or reinfarction, but not for immediate myocardial salvage. Hence, in these patients, if stable, the door-to-balloon time can be extended beyond the current recommendation of 90 minutes, similar to the approach for non−ST-segment elevation acute coronary syndromes.[4] As mentioned, the current guidelines do not mention this option, and emergent reperfusion therapy, preferentially by pPCI, is indicated for all patients who present with ST-segment elevation and symptoms that started within the preceding 12 hours (even if symptoms subsided).[1,2]

Although a decrease in the severity of symptoms, especially chest pain, may indicate reperfusion, in many patients (especially the elderly, women, and patients with diabetes), the presenting symptoms are atypical. Moreover, most patients receive analgesics; thus, resolution of pain may be misleading. Resolution of ST-segment elevation compared with the initial electrocardiogram may indicate reperfusion. However, in many patients, there is no more than 1 electrocardiogram. Moreover, the current guidelines do not address the issue of "spontaneous" ST-segment resolution. As long as ST-segment elevation persists (even if there is a >70% decrease in the magnitude of ST-segment elevation compared with a previous electrocardiogram), emergent reperfusion therapy is indicated.

T− in the leads with ST-segment elevation early after initiation of reperfusion therapy has been described as a marker of reperfusion and a good prognostic sign.[5–9] However, T-wave inversion can also be seen as part of natural evolution within a few days, even in patients who do not undergo reperfusion therapy.[7,10,11] In these cases, T-wave inversion, along with the development of Q waves, is a sign of "evolved myocardial infarction." Indeed, Eskola et al[10] reported that among the 1,522 patients included in the Danish Trial in Acute Myocardial Infarction 2 (DANAMI-2), the presence of abnormal Q waves along with T-wave inversion (evolving myocardial infarction) was an independent predictor of long-term (2.7 years) outcomes. However, they did not separate the effects of Q waves and T-wave inversion.[10] It is well known that Q waves on the presenting electrocardiogram are associated with adverse outcomes in patients who undergo thrombolytic therapy.[12] More recently, Shimada et al[13] studied patients with STEMIs who underwent PCI. They reported that in-hospital major adverse cardiac events occurred more often among the 51 patients with terminal T-wave inversion than among the 137 patients without T-wave inversion (35% vs 17%, $p = 0.007$). There were no significant differences in TIMI flow grade before pPCI between the groups ($p = 0.56$).[13] However, the average time from the onset of symptoms to presentation at the hospital was 28 ± 43 hour for patients with terminal T-wave inversion and 15 ± 45 hours for patients without terminal T-wave inversion ($p = 0.07$). Thus, many of their patients presented very late. The investigators noted that subgroup analyses showed the same direction of the effect of terminal T-wave inversion in patients presenting ≤2 versus >2 hours after the onset of symptoms. However, data were not shown.[13] Our study may be representative of the current situation in large urban medical centers in which patients with suspected STEMIs are undergoing rapid reperfusion therapy. Indeed, in those treated early and especially in patients with anterior STEMIs, T-wave inversion was associated with patency of the infarct-related artery. These data explain the findings of Herz et al,[14] showing that in patients receiving thrombolytic therapy, T− in the leads with maximal ST-segment elevation tended to be associated with reduced mortality in those receiving fibrinolytic therapy within 2 hours of the onset of symptoms. In contrast, in those who were treated 2 to 6 hours after the onset of symptoms, T-wave inversion was associated with increased mortality.

Even in cases in which T− is a manifestation of a more advanced stage of infarction, myocardial salvage is probably limited at that stage, and emergent reperfusion therapy might not result in a limitation of infarct size. Further studies are needed to confirm whether the combination of resolution of symptoms and ST-segment resolution, or absolute cutoffs of ST-segment elevation, and the configuration of the T waves are accurate in identifying patients with STEMIs in whom acute reperfusion therapy within 90 minutes of first medical encounter may not be indicated (because of either spontaneous reperfusion or completion of infarction).

Interestingly, the incidence of diabetes mellitus was higher in the T+/− and T− groups than in the T+ group. Patients with diabetes mellitus tend to have hypercoagulability, and spontaneous reperfusion is less expected. However, Brener et al[15] used data from the Controlled Abciximab and Device Investigation to Lower Late Angioplasty Complications (CADILLAC) and Harmonizing Outcomes With Revascularization and Stents in Acute Myocardial Infarction (HORIZONS-AMI) randomized trials

and also reported that diabetic patients with STEMIs have a higher incidence of initial TIMI flow grade 3 than nondiabetic patients.

This was a retrospective study from a single medical center. The numbers of patients in the T+/− and T− groups are small. The severity of symptoms when the qualifying electrocardiogram was performed were not recorded, nor the trend (worsening or resolution). We used one 12-lead electrocardiogram. It might be that spontaneous reperfusion or reocclusion of the infarct-related artery occurred in some patients in the interval between electrocardiography and angiography.

Disclosures

The authors have no conflicts of interest to disclose.

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