European Review for Medical and Pharmacological Sciences 2015; 19: 1086-1091

The relationship between T-wave peak-to end interval and ST segment recovery on intracoronary ECG during primary PCI

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Abstract. – OBJECTIVE: T-wave peak to end interval (TPE) is a measure of repolarization dispersion, which has been reported as a major arrhythmogenic factor post acute myocardial infarction. The aim of our study was to investigate the changes in TPE in this patient population with regard to periprocedural intracoronary ECG findings.

PATIENTS AND METHODS: Forty-four patients (34 male and mean age of 54.9 ± 10.9 years) with acute STEMI were included. Intracoronary ECG was performed during primary PCI. TPE indices were calculated before and after the procedure. Measurement of the intracoronary ST-segment was carried out before and just after coronary blood flow was established in the infarct related artery. Intracoronary ST-segment resolution (IC-STR) was defined as ≥ 1 mm compared to baseline.

RESULTS: There was no difference with respect to baseline characteristics when patients with IC-STR were compared with patients without IC-STR. TPE values decreased significantly after primary PCI in patients with IC-STR (80.9 ± 22.8 ms vs. 65.8 ± 14.4 ms; $p < 0.001$) whereas they did not change significantly after PCI in patients without IC-STR (79.2 ± 20.9 ms vs. 68.5 ± 16.3 ms; $p = 0.18$).

CONCLUSIONS: TPE measured from surface ECG recordings is significantly reduced in STEMI patients with successful reperfusion after primary PCI, as determined by IC-ECG recordings.

Key Words:
STEMI, T peak-T end interval, Intracoronary ECG, Reperfusion.

Introduction

T-wave peak to end (TPE) interval has been used to evaluate repolarization in homogeneity in several studies, where the peak of the T-wave marks the end of epicardial repolarization while the end of the T-wave indicates the end of repolarization of the whole ventricular myocardium[1-3].

QT dispersion was proposed as a marker of electrical repolarization of the ventricular myocardium in 1994[4]. QT interval and dispersion is known to be affected with ischemia, various cardiac procedures and drugs[5,6]. Animal models have demonstrated that the TPE interval is more representative of transmural dispersion of repolarization than corrected QT (QTc)[6]. TPE may possibly measure electrical dispersion more precisely than QT, because it focuses on repolarization rather than depolarization. Effective management of acute MI may reduce QT interval and QT dispersion after successful reperfusion with thrombolysis as well as after revascularization with PCI or coronary bypass surgery[8,9]. Interpretation of the extent of ST-segment resolution in acute ST segment elevation myocardial infarction (STEMI) patients provides a valuable method in the evaluation of the clinical course. The magnitude of early resolution of ST-segment elevation on the surface ECG is a simple, non-invasive marker of the clinical outcomes in STEMI[10].

On the other hand, unipolar recordings of the intracoronary electrocardiogram (IC-ECG) obtained from the angioplasty guide wire have been demonstrated to be more sensitive and dependable in revealing myocardial ischemia during balloon inflation compared to surface ECG[11]. IC-ECG has been demonstrated to be more sensitive and specific for the identification of the injury suffered by the myocardium after the procedure compared to surface ECG in patients with stable coronary

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artery disease (CAD) treated with percutaneous coronary intervention (PCI)[12]. It has previously been demonstrated that IC-ECG may be used assess myocardial viability in acute MI[13]. IC-ECG has been compared with surface ECG in terms of ST segment changes in the setting of elective stent implantation in order to assess its ability to detect peri-procedural myocardial injury[12]. IC-ECG is an "in-lab" procedure which can be added to standard evaluation of myocardial injury in STEMI patients undergoing primary PCI and has been able to predict myocardial damage in this setting[14].

We speculated that change in a parameter which can be easily obtained from routine pre- and post-procedural surface ECG recordings, namely TPE interval, may have greater relation with IC-ECG findings compared to surface ECG changes following primary PCI in STEMI patients. The aim of our study was to investigate the changes in TPE interval in this patient population with regard to peri-procedural surface and intracoronary ECG findings.

Patients and Methods

A total of 44 consecutive acute STEMI patients were prospectively enrolled in which primary PCI was indicated according to American College of Cardiology Foundation/American Heart Association (ACCF/AHA) 2013 Guideline for the Management of ST-Elevation Myocardial Infarction[15]. The diagnosis of STEMI was made in patients with a chest pain duration of at least 30 minutes and a 12-lead surface ECG demonstrating ST-segment elevation of > 0.1 mV in ≥2 contiguous leads. Patients who underwent successful PCI with stent impantation and TIMI grade 3 flow post PCI with a door-to-balloon time of < 90 minutes were included. Patients with previous myocardial infarction in the same territory, atrial fibrillation, left bundle branch block, QRS duration > 120 ms and aged ≤ 18 years were excluded.

All patients gave informed consent before inclusion in the study, which complies with the Declaration of Helsinki. The study protocol was approved by the local Ethics Committee of Istanbul University, Turkey.

ECG Analysis

Standard surface ECG

All standard 12-lead ECGs were recorded with a speed of 25 mm/s and a 10 mm/mV gain. A 12-lead ECG was obtained before and 60 min after primary PCI in each patient. TPE interval was measured using the "Tangent Method"[16]. The time in milliseconds from the peak of the T wave (or nadir in the presence of a negative or biphasic T-wave) to the intersection between the tangent at the steepest point of the T-wave downslope and the isoelectric line was measured on digitized 12 lead ECG recordings using the on screen digital caliper software Cardio Calipers Version 3.3 (Iconico, Inc, New York, NY, USA). Because previous studies have postulated that precordial leads best reflect transmural dispersion of repolarization, whereas limb leads best reflect apical-basal or global spatial dispersion, TPE was measured from the peak of the T-wave to the end of the T-wave, using the best available T-wave in lead V5, a method that has been already described[16,17]. In cases in which V5 was not suitable for analysis leads, V4 and V6 were measured[17].

Intracoronary ECG

A standard 0.014 inch floppy guidewire used for routine PCI procedures was passed through the obstruction into a distal position of the infarct-related artery. Intracoronary ECG was recorded before balloon inflation and repeated immediately after achieving TIMI 3 flow[18]. The IC-ECG was performed by connecting the proximal end of the guidewire to a sterile ECG adaptor which was attached afterwards to an ECG recorder (PageWriter TC50, Phillips Medical Systems, Andover, MA, USA) with a paper speed of 25 mm/s and a 10 mm/mV of gain. IC-ECG recordings were obtained after contrast injections or balloon inflations and care was taken to refrain from displacement of the guidewire tip so that the occurrence of artifacts in ST segment recordings could be prevented. The magnitude of ST-segment elevation was measured 20 ms after the end of the QRS complex and recorded to the nearest 0.5 mm. In order to calculate the mean ST-segment elevation value, three successive QRS complexes were analyzed. The resolution of intracoronary ST segment elevation (IC-STR) immediately upon achieving TIMI 3 flow was considered significant if ≥ 1 mm compared to the baseline ST segment[14].

Coronary Angiography and Stenting

All angiographic data were evaluated by two cardiologists who were blinded to intracoronary and surface ECG findings. All patients were treated with aspirin 300 mg, clopidogrel 600 mg,

tirofiban (25 μg/kg bolus for 3 minutes followed by infusion at a rate of 0.15 μg/kg/minute) and intravenous heparin 70 IU/kg before primary-PCI as suggested by (ACCF/AHA) 2013 Guideline for the Management of ST-Elevation Myocardial Infarction[15]. The pain to balloon time and the door to balloon time (time elapsed until the restoration of TIMI 3 flow) were recorded for each patient. Coronary diameter stenoses ≥50% was labeled significant. Transthoracic echocardiography was performed in all patients within 24 hours of admission and left ventricular ejection fraction (LVEF) was estimated using biplane method on two dimensional images. Levels of high sensitive troponin T, high sensitive C-reactive protein (CRP), hemoglobin, creatin kinase MB (CK-MB), glucose, creatinine, potassium, total cholesterol, low density lipoprotein (LDL) cholesterol and triglycerides were measured using blood samples obtained at admission.

Statistical Analysis

Variables were analyzed for the presence of normal distribution using Shapiro-Wilk test. Continuous variables were expressed as mean ± standard deviation or median with interquartile range. Statistical analyses were performed using IBM SPSS 21 software (IBM Corporation, USA). Variables were compared using Mann-Whitney U test or the chi square test, as appropriate and p values < 0.05 were considered to be statistically significant.

Results

The study population consisted of 44 patients with STEMI (34 male, 77%) with a mean age of 54.9 ± 10.9 years who underwent successful primary PCI. Baseline demographic, clinical and laboratory characteristics of patients were summarized in Table I. Patients were analyzed with regard to the presence of IC-STR on intracoronary ECG recordings and change in TPE values after PCI procedure. There was no difference with respect to baseline characteristics when patients with IC-STR were compared with patients without IC-STR.

A total of 31 patients (70.5%) had reperfusion when IC-STR criteria for reperfusion were utilized. TPE values were significantly reduced after PCI, in patients with IC-STR (80.9 ms ± 22.8 ms vs. 65.8 ± 14.4 ms; $p < 0.001$). On the other hand, TPE values after PCI did not differ significantly from baseline when patients without IC-STR were considered (79.2 ms ± 20.9 ms vs. 68.5 ms ± 16.3 ms; $p = 0.18$) (Figure 1).

Table I. Baseline demographic and clinical characteristics of patient groups.

	ICR STR (+) n: 31	ICR STR (–) n: 13	p value
Age, y	54.7 ± 11.9	55.5 ± 8.3	0.82
Male, n (%)	28 (85%)	8 (62%)	0.11
Diabetes mellitus, n (%)	4 (12%)	4 (31%)	0.19
Hypertension n (%)	17 (52%)	5 (38%)	0.42
Smoking, n (%)	24 (73%)	10 (77%)	1.00
Family history, n (%)	16 (48%)	5 (38%)	0.53
LVEF, (%)	54.3 ± 9.6	55.3 ± 6.9	0.76
Creatinine, mg/dL	1.2 ± 0.41	1.1 ± 0.32	0.83
Hemoglobin, g/dL	13.7 ± 5.3	13.3 ± 1.8	0.64
Low density lypoprotein, mg/dL	120.4 ± 35.9	151.7 ± 39.6	0.03
High density lypoprotein, mg/dL	37.0 ± 8.9	36.4 ± 10.8	0.88
Triglycerides, mg/dL	146.9 ± 90.2	131.8 ± 51.5	0.65
Medical therapy			
Acetil salicilic acid, n (%)	31 (100%)	13 (100%)	1.00
Clopidogrel, n (%)	31 (100%)	13 (100%)	1.00
Beta blocker, n (%)	32 (97%)	11 (85%)	0.18
ACEI, n (%)	29 (88%)	10 (77%)	0.38
Statin, n (%)	31 (100%)	13 (100%)	1.00

LVEF, Left ventricular ejection fraction; ACE, Angiotensin converting enzyme ınhibitor; ICR STR, Intra Coronary ST resolution.

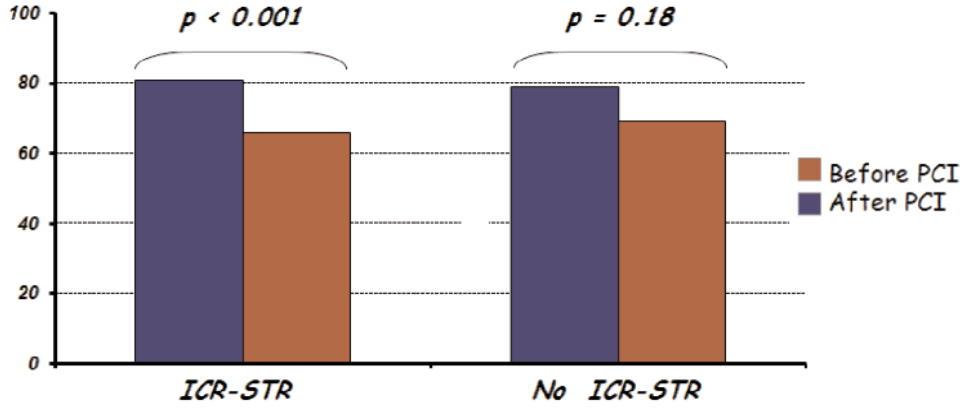

Figure 1.

Discussion

In this study, we investigated the relationship between IC-ECG guided reperfusion and an ECG parameter of ventricular repolarization, namely TPE interval in STEMI patients undergoing primary PCI. We have demonstrated that TPE interval is decreased in patients with clinical reperfusion, as demonstrated by resolution of ST segments in IC-ECG recordings.

The utility of IC-ECG in the determination of reperfusion has been investigated previously. Since the magnitude of the current of injury is affected by the distance of the recording electrode from the ischemic region, and an electrode placed on the actual heart surface should be more accurate than surface ECG leads in demonstrating ischemic ST-segment changes[18]. Uetani et al[12] have shown that IC-ECG is more sensitive than surface ECG in discriminating patients with periprocedural myocardial injury. They have demonstrated that IC-ECG shows significantly higher sensitivity for positive troponin T compared to surface ECG, in patients undergoing elective PCI for stable CAD. Long QT interval measured from surface ECG has been previously demonstrated to be related with risk of sudden death in acute myocardial infarction patients[19].

The TPE interval is a measure of the difference between the end of the shortest and the longest periods of ventricular repolarization[7,20]. The duration of action potential has been found to be longer in the midmyocardial M cells compared to other myocardial cells. Repolarization is known to be completed first in the epicardial cells. The peak of T wave is a representation of the end of the epicardial action potential, whereas the end of T wave signifies the end of the midmyocardial action potential. TPE is a reflection of transmural dispersion of repolarization[21]. TPE is known to be lengthened in acute coronary syndromes including ST- and non–ST-elevation myocardial infarction[22]. In a study by Haarmark et al[23], long TPE predicted mortality in 101 STEMI patients undergoing PCI. In that study, TPE pre-PCI, but not post-PCI, predicted patient survival. It was demonstrated that decrease in TPE was more pronounced in patients who died after the index MI. Authors have explained this discrepancy by stating that increased TPE has represented a temporary arrhythmogenic substrate in non-survivors that was resolved, in part, by reperfusion and that the interval subsequently has shortened and became comparable with TPE in survivors. In a recent study by Eslami et al[24], TPE interval was found to be reduced by primary PCI and has been suggested to be used as a potential marker for successful reperfusion. In concordance with their findings, we have demonstrated that TPE decreases significantly in patients with successful reperfusion. Moreover, we have shown that this was not the case in patients without significant ST segment resolution in intracoronary ECG recordings.

Effective management of acute myocardial infarction may reduce repolarization parameters after successful reperfusion. To the best of our knowledge, the current study is the first to demonstrate the relation between TPE and ST segment recovery on intracoronary ECG during primary percutaneous coronary intervention for STEMI. Larger trials are needed to correlate our findings with long-term outcomes.

Table II. Angiographic results of patient groups.

	ICR STR (+) n: 31	ICR STR (–) n: 13	*p* value
Infarction localization			
Inferior	12 (80%)	3 (20%)	
NA			
Infero-postero-lateral	6 (60%)	4 (40%)	
Anterior	13 (68.4%)	6 (31.6%)	
Infarct related artery			
Left anterior descending artery, n	13 (68.4%)	6 (31.6%)	NA
Right coronary artery, n	12 (80%)	3 (20%)	
Circumflex artery, n	6 (60%)	4 (40%)	
Number of coronary arteries narrowed			
1	12 (60%)	8 (40%)	0.165
>1	19 (79.2%)	5 (20.8%)	
TIMI frame count	16 ± 12	20 ± 14.5	0.18
Primary percutaneous coronary intervention			
Stent implantation, n	31 (100%)	13 (100%)	1.00
Bare metal stent, n	22 (71%)	10 (77%)	
Drug eluting stent, n	9 (29%)	3 (23%)	
Stent diameter (mm)	3 ± 0.75	3 ± 0.50	0.12
Stent length (mm)	18 ± 5	22 ± 6.50	0.16

TIMI, Trombolysis in myocardial infarction; NA, Not applicated.

Conclusions

TPE measured from surface ECG recordings is significantly reduced in STEMI patients with successful reperfusion after primary PCI, as determined by IC-ECG recordings. The relevance of this finding to clinical outcomes and the clinical usefulness of this simple bedside parameter remain to be determined with further studies.

Conflict of Interest

The Authors declare that they have no conflict of interests.

References

1) Yan GX, Lankipalli RS, Burke JF, Musco S, Kowey PR. Ventricular repolarization components on the electrocardiogram, cellular basis and clinical significance. J Am Coll Cardiol 2003; 42: 401-409.
2) Antzelevitch C. Heterogenity and cardiac arrhythmia: an overview. Heart Rhythm 2007; 4: 964-972.
3) Dogan U, Yavas G, Tekinalp M, Yavas C, Ata OY, Ozdemir K. Evaluation of the acute effect of palonosetron on transmural dispersion of myocardial repolarization. Eur Rev Med Pharmacol Sci 2012; 16: 462-468.
4) Barr CS, Naas A, Freeman M, Lang CC, Struthers AD. QT dispersion and sudden unexpected death in chronic heart failure. Lancet 1994; 343: 327-329.
5) Senel S, Cobankara V, Taskoylu O, Guclu A, Evrengul H, Kaya MG. Effect of infliximab treatment on QT intervals in patients with ankylosing spondylitis. J Investig Med 2011; 59: 1273-1275.
6) Kaya MG, Baykan A, Dogan A, Inanc T, Gunebakmaz O, Dogdu O, Uzum K, Eryol NK, Narin N. Intermediate-term effects of transcatheter secundum atrial septal defect closure on cardiac remodeling in children and adults. Pediatr Cardiol 2010; 31: 474-482.
7) Antzelevitch C. T peak-Tend interval as an index of transmural dispersion of repolarization. Eur J Clin Invest 2001; 31: 555-557.
8) Kosar F, Nisanoglu V, Aksoy Y, Colak C, Erdil N, Battaloglu B. Effects of coronary revascularization and concomitant aneurysmectomy on QT interval duration and dispersion. J Electrocardiol 2006; 39: 194-198.
9) Gulcan O, Sezgin AT, Demircan S, Atalay H, Turkoz R. Effect of coronary artery bypass grafting and aneurysmectomy on QT dispersion in moderate or severe left ventricular dysfunction. Am Heart J 2005; 149: 917-920.

10) De Lemos JA, Braunwald E. ST segment resolution as a tool for assessing the efficacy of reperfusion therapy. J Am Coll Cardiol 2001; 38: 1283-1294.

11) Friedman PL, Shook TL, Kirshenbaum JM, Selwyn AP, Ganz P. Value of the intracoronary electrocardiogram to monitor myocardial ischemia during percutaneous transluminal coronary angioplasty. Circulation 1986; 74: 330-339.

12) Uetani T, Amano T, Kumagai S, Ando H, Yokoi K, Yoshida T, Kato B, Kato M, Marui N, Nanki M, Matsubara T, Ishii H, Izawa H, Murohara T. Intracoronary electrocardiogram recording with a bare-wire system: perioperative ST-segment elevation in the intracoronary electrocardiogram is associated with myocardial injury after elective coronary stent implantation. JACC Cardiovasc Interv 2009; 2: 127-135.

13) Yajima J, Saito S, Honye J, Takayama T, Ozawa Y, Kanmatsuse K. Intracoronary electrocardiogram for early detection of myocardial viability during coronary angioplasty in acute myocardial infarction. Int J Cardiol 200; 79: 293-299.

14) Wong DT, Leung MC, Das R, Puri R, Liew GY, Teo KS, Chew DP, Meredith IT, Worthley MI, Worthley SG. Intracoronary ECG ST-segment recovery during primary percutaneous intervention for ST-segment myocardial infarction: insights from a cardiac MRI study. Catheter Cardiovasc Interv 2012; 80: 746-753.

15) O'Gara PT, Kushner FG, Ascheim DD, Casey DE Jr, Chung MK, de Lemos JA, Ettinger SM, Fang JC, Fesmire FM, Franklin BA, Granger CB, Krumholz HM, Linderbaum JA, Morrow DA, Newby LK, Ornato JP, Ou N, Radford MJ, Tamis-Holland JE, Tommaso CL, Tracy CM, Woo YJ, Zhao DX. 2013 ACCF/AHA guideline for the management of ST-elevation myocardial infarction: executive summary: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines: developed in collaboration with the American College of Emergency Physicians and Society for Cardiovascular Angiography and Interventions. Catheter Cardiovasc Interv 2013; 82: E1-27.

16) Antzelevitch C, Sicouri S, Di Diego JM, Burashnikov A, Viskin S, Shimizu W, Yan GX, Kowey P, Zhang L. Does Tpeak-Tend provide an index of transmural dispersion of repolarization? Heart Rhythm 2007; 4: 1114-1116.

17) Panikkath R, Reinier K, Uy-Evanado A, Teodorescu C, Hattenhauer J, Mariani R, Gunson K, Jui J, Chugh SS. Prolonged T peak-to-T end interval on the resting ECG is associated with increased risk of sudden cardiac death. Circ Arrhythm Electrophysiol 2011; 4: 441-447.

18) Balian V, Galli M, Marcassa C, Cecchin G, Child M, Barlocco F, Petrucci E, Filippini G, Michi R, Onofri M. Intracoronary ST-segment shift soon after elective percutaneous coronary intervention accurately predicts periprocedural myocardial injury. Circulation 2006; 114: 1948-54

19) Spragg DD, Akar FG, Helm RH, Tunin RS, Tomaselli GF, Kass DA. Abnormal conduction and repolarization in late-activated myocardium of dyssynchronously contracting hearts. Cardiovasc Res 2005; 67: 77-86.

20) Antzelevitch C. M cells in the human heart. Circ Res 2010; 106: 815-817.

21) Yan GX, Antzelevitch C. Cellular basis for the normal T wave and the electrocardiographic manifestations of the long-QT syndrome. Circulation 1998; 98: 1928-1936.

22) Rautaharju PM, Zhou SH, Gregg RE, Startt-Selvester RH. Electrocardiographic estimates of action potential durations and transmural repolarization time gradients in healthy subjects and in acute coronary syndrome patients--profound differences by sex and by presence vs absence of diagnostic ST elevation. J Electrocardiol 2011; 44: 309-310.

23) Haarmark C, Hansen PR, Vedel-Larsen E, Pedersen SH, Graff C, Andersen MP, Toft E, Wang F, Struijk JJ, Kanters JK. The prognostic value of the T-peak to T-end interval in patients undergoing primary percutaneous coronary intervention for ST-segment elevation myocardial infarction. J Electrocardiol 2009; 42: 555-560.

24) 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: 232-234.