The Immediate and Short-Term Effect of Successful Percutaneous Coronary Intervention on Repolarization in Acute Myocardial Infarction Patients

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Objectives: The primary objective was to assess the immediate and short-term impact of successful percutaneous coronary intervention (PCI) on QT dispersion (QT disp) and corrected QT dispersion (QTc disp). Secondly, the impact of PCI on QT and QTc disp within different infarct-related arteries and the impact of successful PCI in these different arteries were evaluated.

Methods: Patients ($n = 140$, age 61.6 ± 12.9 , 69% male) undergoing direct primary PCI for acute MI were evaluated. Twelve-lead ECGs were obtained before (baseline), immediately after (0 h), 24 hours after, and 3 days after PCI. The QT and QTc interval in each of the 12-leads were measured and the shortest interval was subtracted from the longest to derive the QT disp and QTc disp, respectively.

Results: Angiography showed blockages in the left anterior descending, right coronary artery, and circumflex in 37.1, 48.9, and 15.0% of patients, respectively. Overall, 97 patients achieved successful reflow. QT and QTc disp were significantly improved in the group with successful reflow at each follow-up time after PCI versus baseline and corresponding values in the unsuccessful reflow group. QT disp was improved among patients with successful reflow irrespective of which infarct artery was responsible for the acute myocardial infarction.

Conclusions: Successful reflow with PCI is associated with a rapid reduction in QT disp and QTc disp that is maintained for at least 3 days after the event. Conversely, unsuccessful reflow was not associated with significant reductions in QT or QTc disp.

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The interlead variation of the QT interval provides an index of heterogeneity of repolarization within the ventricles of the heart.¹ The difference between the longest and the shortest QT interval on a 12-lead ECG (e.g., QT dispersion) is primarily due to changes in the duration of the T waves. From the initiation of the T wave to the peak of the T wave, the epicardium experiences rapid repolarization.

While the T wave is descending back towards the isoelectric point, the endocardium repolarizes and the final descending portion of the T wave marks repolarization of the M-region. Hence, the changes in QT dispersion reflect a prolongation of repolarization within one region of the heart but not within another region.¹ Enhanced heterogeneity, measured as an increase in QT dispersion, may

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increase the risk for re-entry and thus ventricular tachyarrhythmias.²

Several studies have evaluated QT and QTc disp in postmyocardial infarction patients but only a few have evaluated these electrocardiographic markers during the acute phase (< 3 days).³⁻⁸ We are unaware of studies evaluating the immediate impact (within a few minutes) of successful reperfusion on QT and QTc disp in patients experiencing acute myocardial infarctions or evaluations of primary PCI as the reperfusion strategy. In addition, the impact of infarct-related artery on QT and QTc disp have not been well investigated in the acute period and the effect of successful reperfusion in these individual arteries has not been performed previously.

Hence, our primary objective was to evaluate the immediate and short-term effects of successful primary PCI on QT and QTc disp among patients with acute myocardial infarctions. Secondly, we evaluated the impact of primary PCI on QT and QTc disp within different infarct related arteries and the impact of successful PCI within each infarct related artery.

MATERIALS AND METHODS

Patients (n = 140, 68.6% male, average age 61.6 ± 12.9 years) undergoing primary direct percutaneous intervention (PCI) for the treatment of acute myocardial infarction were eligible for inclusion. Subjects requiring PCI of more than one coronary artery were excluded. Patients were also excluded if their scheduled ECGs (as described below) showed a QRS interval duration greater than 0.12 seconds, they were not in sinus rhythm, or if the QT interval could not be reliably measured in at least 8 leads.

The affected coronary arteries via angiography were the left anterior descending (LAD) (n = 52, 37.1%), right coronary artery (RCA) (n = 67, 47.9%), and circumflex (CX) (n = 21, 15.0%). Anterograde perfusion of the infarct-related artery was graded according to the classification system of the Thrombolysis in Myocardial Infarction (TIMI) trial.⁹ Successful reflow was determined by the establishment of TIMI III blood flow with determination of less than 20% residual stenosis. Overall, 97 patients (69.3%) had successful reflow.

ECG Determination

Twelve lead ECGs were obtained before PCI (Baseline) and immediately after (0 h), 24 hours after, and 3 days after the procedure. The ECG for the 0 hour time point was taken in the PCI suite immediately after the procedure. ECGs were taken at the same time of day to minimize circadian changes and were recorded at a paper speed of 25 mm/sec. A single blinded investigator measured all ECG intervals. Measurements of QT, QRS, and RR intervals were performed using a precision (Schaedler's) ruler with 0.5 mm scale. Previous study has shown this to be more precise than computer or caliper methods.¹⁰ In a previous validation study, the intraobserver variability of the measurer was 5%.¹⁰

The QT interval was measured from the onset of the QRS complex to the end of T wave, defined as its return to the T-P isoelectric baseline. When U waves were present, the end of the T wave was measured to the nadir of the curve between the T and U waves. The QRS interval was measured from the onset of the Q wave (or R wave, if the Q was absent) to the end of S wave, defined as its return to the T-P isoelectric baseline. Whenever possible, the average measurement of the three complexes for each lead was taken. If the end of the T wave could not be reliably determined or when the T waves were isoelectric or of very low amplitude, QT measurements were not made and these leads were excluded from analysis. The corrected QT (QTc) interval was determined according to Bazett's formula: $QTc = QT/(RR^{1/2})$ in seconds.

QT disp and QTc disp was defined as the difference between the maximal and minimal measurements, respectively, occurring among the 12 leads on the standard ECG.

Statistical Analysis

Values are expressed as mean $\pm$ SD and a two-tailed value of $P < 0.05$ was considered statistically significant. Categorical comparisons were performed using Chi-squared analysis. Two group continuous variable comparisons were performed using Student's *t*-test. Multigroup comparisons were performed with one-way ANOVA and if significance is found, post-hoc Bonferroni corrected *t*-tests were used.

Table 1. Baseline Characteristics of Patients

Characteristics	Reflow vs No Reflow	
	Reflow (n = 97)	No Reflow (n = 43)
Age (years)	60.4 ± 12.0	64.7 ± 12.6
Men/women	70/27	26/17
LVEF (%)	43.7 ± 8.9	39.4 ± 13.8
Beta-blocker use (%)	19.6	30.2
MI history (%)	10.3	23.3
Hypertension (%)	47.4	58.1
Diabetes mellitus (%)	22.7	37.2
Obesity	36.1	30.2
Smoking status	52.6	27.9*
Angioplasty alone	44.3	44.2
Angioplasty + stent	45.4	41.9
Angioplasty w/ abciximab	10.3	13.9
RR interval (ms)	799.0 ± 189.2	749.30 ± 161.5
QRS interval (ms)	92.0 ± 16.3	94.3 ± 20.5
Mean QT interval (ms)	402.2 ± 48.6	393.8 ± 51.6
Mean QTc interval (ms)	454.4 ± 38.8	458.8 ± 49.6
QT disp (ms)	67.1 ± 38.6	67.0 ± 36.0
QTc disp (ms)	75.6 ± 41.8	79.0 ± 43.8

Characteristics	Infarct Related Artery		
	LAD (n = 52)	RCA (n = 67)	CX (n = 21)
Age (years)	59.6 ± 14.8	63.5 ± 11.5	60.6 ± 12.2
Men/women	34/18	45/22	17/4
RR interval (ms)	731.0 ± 158.6	801.5 ± 153.1	771.4 ± 170.5
QRS duration (ms)	91.3 ± 17.6	94.3 ± 18.6	91.1 ± 14.9
Mean QT interval (ms)	389.0 ± 51.9	409.9 ± 46.3	392.7 ± 49.1
Mean QTc interval (ms)	460.1 ± 36.3	454.0 ± 45.2	451.1 ± 47.0
QT disp (ms)	65.8 ± 44.6	71.2 ± 34.8	57.1 ± 34.8
QTc disp (ms)	76.5 ± 41.8	80.0 ± 40.7	65.9 ± 41.8

* P < 0.05, Angioplasty = percutaneous transluminal coronary angioplasty; LVEF = left ventricular ejection fraction.

RESULTS

Successful Reflow Versus No Reflow

No significant differences in baseline characteristics were found between the successful reflow and no reflow groups for any variable except for smoking status ($P = 0.012$) (Table 1). However, there were significant reductions in QT and QTc disp from baseline in the group with successful reflow at all evaluated time periods. Qualitatively, the QT and QTc disp went down continually from baseline until 3 days after successful PCI. No significant changes in QT and QTc disp from baseline were found in the no-reflow group. At each time period, the QT and QTc disp were significantly higher in the no reflow group than the successful reflow group (Table 2/Fig. 1).

Infarct Related Artery

No significant differences in baseline characteristics were found between subjects with LAD, RCA, or CX infarct related arteries (Table 1). Compared to baseline, the QT and QTc disp was significantly lower in the LAD and RCA groups by 3 days. Although qualitative reductions from baseline in QT and QTc disp were noted in the CX group, they were smaller than that seen in the other groups and did not achieve significance (Table 3).

When the subjects with successful reflow were evaluated separately in each of the individual infarct related artery groups, there was a significant reduction in QT disp versus baseline at the 3-day time period in each of the intragroup comparisons

Table 2. QT Disp and QTc Disp Before and at Different Time Periods after PCI in the Groups of Patients With Successful Reflow and No Reflow

	QT Disp		QTc Disp	
	Reflow	No Reflow	Reflow	No Reflow
Baseline	67.1 ± 38.6	67.0 ± 36.0	75.6 ± 41.8	79.0 ± 43.8
0 h	53.1 ± 27.7* ^γ	60.5 ± 31.3	59.8 ± 31.7* ^γ	70.6 ± 31.7
24 h	47.6 ± 31.9* ^γ	62.8 ± 35.9	54.0 ± 35.9* ^γ	74.3 ± 40.5
3 days	40.2 ± 30.7* ^γ	58.1 ± 29.9	44.4 ± 34.2* ^γ	69.1 ± 36.4
Intragroup ANOVA P value	0.0001	0.22	0.0001	0.26

* denotes $P < 0.05$ vs baseline for intragroup comparison across time points; ^γ denotes $P < 0.05$ for intergroup comparison at specified time point.

(LAD, RCA, CX). When QTc disp was evaluated, those with an RCA lesion had significant reductions versus baseline at the 3-hour time point, although a strong trend was noted for the LAD lesion group. In contrast, the subjects without successful reflow did not have significant reductions in QT or QTc disp versus baseline in the LAD, RCA, or CX groups at any time point. In direct comparison of successful reflow versus no reflow for each individual infarct related artery, subjects with an RCA infarction had significantly lower QT disp and QTc disp at the 24-h and 3-day time period if they had successful reflow (Table 4).

Intragroup ANOVA in reflow group for QT disp < 0.0001 and QTc disp < 0.0001.
Intragroup ANOVA in no reflow group for QT disp = 0.22 and QTc disp = 0.26.
* Denotes $p < 0.05$ with intragroup comparison vs baseline
^γ Denotes $p < 0.05$ with intergroup comparison at each time point

Figure 1. QT and QTc dispersion effects with and without successful reflow.

DISCUSSION

This study evaluated the immediate and short-term effects of primary PCI on QT and QTc disp among patients experiencing an acute myocardial infarction. Among the patients experiencing TIMI III blood flow (successful reflow), the QT and QTc disp were significantly decreased immediately after the PCI procedure and at each subsequent time period evaluated (24 hours and 3 days after the procedure) in a qualitative time dependent manner. In the absence of successful reflow, no significant change in QT or QTc disp occurred at any follow-up time. At each postPCI time, the QT and QTc disp in the successful reflow group was significantly lower than the corresponding time period in the unsuccessful reflow group.

Only a few trials evaluated QT and QTc disp in the acute phase (< 3 days) of myocardial infarctions.³⁻⁸ Four of these trials had follow-up ECGs taken approximately 2-3 days after event initiation, another study had a follow-up ECG greater than 24 hours from event initiation, and the final trial evaluated follow-up ECGs starting 12 hours after the event initiation.³⁻⁸

Only one of the aforementioned trials directly evaluated the effect of successful reperfusion on QT or QTc disp.⁸ In that trial, 72 subjects received intracoronary (84% of total) or intravenous thrombolytics and had follow-up ECGs taken at 2 ± 1 days and 14 ± 6 days after the onset of myocardial infarction.⁸ Patients were broken into three groups depending on whether they had achieved at least TIMI II blood flow within 12 hours before symptom onset (acute phase, $n = 28$), before the end of the recovery phase ($n = 23$), or not at all ($n = 21$). No differences were noted between the three groups for QT or QTc disp in the acute phase, but

Table 3. QT and QTc Disp Based on Infarct Related Artery

Infarct Artery	QT Disp			QTc Disp		
	LAD (n = 52)	RCA (n = 67)	CX (n = 21)	LAD (n = 52)	RCA (n = 67)	CX (n = 21)
Baseline	65.8 ± 42.0	69.9 ± 33.3	57.1 ± 34.8	76.5 ± 44.6	78.0 ± 37.7	65.9 ± 41.8
0 h	61.2 ± 33.8	51.9 ± 25.8	52.4 ± 25.7	71.2 ± 40.4	57.2 ± 30.3	62.7 ± 33.3
24 h	51.2 ± 34.2 ^γ	51.3 ± 28.8 ^γ	59.1 ± 46.7	59.0 ± 38.3 ^γ	58.5 ± 33.1 ^γ	70.1.4 ± 56.6
3 d	43.1 ± 31.0 ^{*γ}	48.1 ± 31.9 ^{*γ}	46.7 ± 31.2	48.4 ± 34.8 ^{*γ}	55.2 ± 38.2 ^{*γ}	53.0 ± 35.6
Intragroup ANOVA P Value	0.006	0.0001	0.67	0.002	0.0001	0.59

* denotes $P < 0.05$ with intragroup comparison vs baseline across time periods.

after the recovery phase there were significant differences between the three groups for QT (35 ± 10 , 49 ± 15 , 61 ± 31 ms, $P = 0.0001$) and QTc disp (38 ± 12 , 50 ± 15 , and 63 ± 32 ms, $P = 0.0003$), respectively. The lack of significant acute phase reductions in early successful reflow group for QT and QTc disp may have been due to the small sample sizes in the groups.

Another trial evaluated the effects of thrombolytics on QT disp in the acute myocardial infarction period but they did not take follow-up ECGs until

9 days after event initiation.¹¹ In that trial of 244 patients, thrombolytics were given within 2.6 hours of symptom onset and angiograms were performed 2.4 hours after that to evaluate TIMI blood flow.¹¹ These authors found that there were significant differences in QT disp in the subjects with TIMI 0, 1, 2, and 3 blood flow (96 ± 31 , 88 ± 31 , 60 ± 22 , and 52 ± 19 ms, $P < 0.0001$), respectively.

Hence, we are aware of no trial evaluating the immediate impact of successful reflow on QT and QTc disp. Unlike the first described thrombolytic

Table 4. QT Disp and QTc Disp Based on Infarct Related Artery in Patients With and Without Successful Reflow

Infarct Artery	Successful Reflow Group					
	QT Disp			QTc Disp		
	LAD (n = 40)	RCA (n = 41)	CX (n = 16)	LAD (n = 40)	RCA (n = 41)	CX (n = 16)
Baseline	62.0 ± 43.2	71.2 ± 32.2	63.8 ± 35.9	74.3 ± 48.2	77.7 ± 34.4	73.2 ± 44.0
0 h	58.5 ± 33.1	50.2 ± 23.7	47.5 ± 21.8	66.5 ± 36.8	54.5 ± 25.6	60.6 ± 43.8
24 h	50.0 ± 35.1	43.9 ± 26.2 ^γ	46.3 ± 34.0	56.1 ± 38.4	49.2 ± 29.8 ^γ	56.4 ± 30.1
3 d	41.5 ± 30.9 [*]	37.6 ± 29.1 ^{*γ}	40.0 ± 27.3 [*]	44.5 ± 34.6	42.0 ± 32.7 ^{*γ}	50.4 ± 38.1
Intragroup ANOVA P Value	0.017	0.0001	0.045	0.06	0.0001	0.40
Infarct Artery	No Reflow Group					
	QT Disp			QTc Disp		
	LAD (n = 12)	RCA (n = 26)	CX (n = 5)	LAD (n = 12)	RCA (n = 26)	CX (n = 5)
Baseline	78.3 ± 36.6	67.7 ± 35.4	56.0 ± 21.9	95.2 ± 44.7	78.5 ± 43.1	42.6 ± 24.6
0 h	70.1 ± 34.6	54.6 ± 29.2	68.0 ± 33.5	85.1 ± 49.0	61.6 ± 36.6	82.6 ± 38.0
24 h	55.0 ± 32.1	63.1 ± 23.2	64.0 ± 35.8	66.0 ± 38.2	73.0 ± 33.3	100.6 ± 71.7
3 d	53.3 ± 28.7	64.6 ± 30.0	48.0 ± 17.9	57.5 ± 36.2	76.0 ± 37.4	61.2 ± 28.0
Intragroup ANOVA P Value	0.08	0.74	0.55	0.13	0.38	0.22

* denotes $P < 0.05$ with intragroup comparison vs baseline across time periods; ^γ denotes $P < 0.05$ for intergroup comparison (reflow vs no reflow) at specified time point.

study, we had an ample population to evaluate the acute effects of successful or unsuccessful reflow at the 24-hour time period. Finally, this is the first study we are aware of evaluating QT and QTc disp with primary PCI as the reperfusion strategy in acute myocardial infarction.

Among patients with stable angina pectoris without history of myocardial infarction, the impact of coronary angioplasty on QT and QTc disp was evaluated in three trials.¹²⁻¹⁴ In the first trial, 15 patients with proven coronary disease but without ischemia at the start of the angioplasty were evaluated before balloon inflation, at the end of the first inflation, and at 30 and 60 seconds after the first inflation.¹² The QTc disp significantly increased at the 30- and 60-second time periods as compared to the time before balloon inflation.¹² Similarly, in a second trial of 43 patients, the QT disp was significantly increased during balloon inflation as compared to before inflation.¹³ These studies show that in stable angina pectoris, the blockage of coronary arteries by the angioplasty balloon can cause or enhance momentary ischemia and increase QT(c) disp.^{12,13} A final study in this population shows that angioplasty can reduce QT disp at 4 hours and 24 hours postprocedure as compared to the preprocedure value.¹⁴ That study suggests that subjects with stable angina pectoris have elevations in QT disp as compared to control subjects even when they are not having symptomatically or electrocardiographically noted ischemia.¹⁴

Secondarily, we found that QT and QTc disp is significantly reduced in the LAD and RCA groups at the 24-hour and 3-day time point versus baseline regardless of whether successful reflow occurred. However, when each of these infarct related artery groups were separated by successful or unsuccessful reflow, it becomes clear that successful reflow patients have a continuous and significant improvement in QT disp but the unsuccessful reflow patients do not. We are not aware of any studies evaluating this relationship previously.

CONCLUSIONS

Primary PCI reduces QT and QTc disp immediately after the procedure and these variables pro-

gressively decrease over the next 24 hours and 3 days if successful reflow (TIMI III blood flow) is established. This is not seen with unsuccessful reflow. Finally, this same relationship for successful reflow and unsuccessful reflow occurs for QT disp when each of the infarct related arteries are evaluated separately.

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