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Absence and Resolution of Fragmented QRS Predict Reversible Myocardial Ischemia With Higher Probability of ST Segment Resolution in Patients With ST Segment Elevation Myocardial Infarction

Mustafa Cetin, MD[1], Sinan Altan Kocaman, MD[1], Tuncay Kiris, MD[2], Turan Erdogan, MD[3], Aytun Canga, MD[1], Murtaza Emre Durakoglugil, MD[3], Yüksel Çiçek, MD[3], Sitki Dogan, MD[1], and Omer Satiroglu, MD[3]

[1]Department of Cardiology, Rize Education and Research Hospital, Rize,
[2]Department of Cardiology, Ordu State Hospital, Ordu,
[3]Department of Cardiology, Rize University, Faculty of Medicine, Rize, Turkey

Background and Objectives: Fragmented QRS complexes (fQRS) are associated with increased morbidity and mortality. The causative relationship between fQRS and cardiac fibrosis has been shown, but whether the presence and the number of fQRS on admission of electrocardiogram (ECG) predicts ST segment resolution in patients undergoing primary percutaneous coronary intervention (p-PCI) has not been investigated until now.

Subjects and Methods: This study included one hundred and eighty-four consecutive patients with ST elevation myocardial infarction (STEMI) who underwent p-PCI. The presence or absence of fQRS on pre and post-PCI ECG and their relation with myocardial infarction and reperfusion parameters were investigated.

Results: Patients with fQRS on admission of ECG or newly developed fQRS after p-PCI had increased inflammatory markers, higher cardiac enzyme levels, increased pain to balloon time, prolonged QRS time, more extended coronary involvement and more frequent Q waves on ECG in comparison to patients with absence or resolved fQRS. The presence and higher number of fQRS on admission or post-PCI ECGs were significantly related with low percent of ST resolution and myocardial reperfusion parameters. The area under the receiver operating characteristics curve values for the presence and number of fQRS to detect Thrombolysis in Myocardial Infarction Blush Grade 0 and 1, were 0.682 and 0.703.

Conclusion: In our study, fQRS was significantly related to infarction and myocardial reperfusion parameters before and after p-PCI. Successful myocardial reperfusion by p-PCI caused the reduction in number of fQRS and QRS time with higher ST resolution. fQRS may be useful in identifying the patients at higher cardiac risk with increased ischemic jeopardized or infarcted myocardium, and persistent or newly developed fQRS may predict low percent of ST segment resolution in patients undergoing p-PCI. **(Korean Circ J 2012;42:674–683)**

KEY WORDS: Fragmented QRS; Electrocardiography; Myocardial infarction; Reperfusion; Marker.

Introduction

Fragmented QRS complexes (fQRS) are frequently seen on the surface electrocardiograms (ECGs) with a narrow or wide QRS complex, which includes paced rhythm, bundle branch block or ventricular premature beats.[1] These fragmentations on surface ECG were associated with increased adverse cardiovascular events (CVEs) in previous studies.[2-5] fQRS may be important to determine people at

high risk for CVEs on admission and after ST elevation myocardial infarction (STEMI).

Fragmented QRS complexes on a 12-lead resting ECG are defined as various RSR' patterns (≥1 R' or notching of S wave or R wave) with or without Q waves lacking a typical bundle-branch block in 2 contiguous leads corresponding to a major coronary artery territory.[6] Based on their duration, they are sub-classified into two subgroups as fQRS complexes with QRS duration <120 ms or ≥120 ms (fragmented wide-QRS complexes, f-wQRS) and they can also be found on an ECG with different QRS morphologies. Sometimes, fQRS might be the only ECG marker of myocardial damage in patients with non-Q myocardial infarction and in patients with a resolved Q wave.

The reason for the documented association between fQRS and increased morbidity and mortality, sudden cardiac death, and recurrent adverse cardiac events were investigated by previous studies.[4)5)7-10] In these studies, the main causative mechanism regarding fQRS was cardiac fibrosis.[11)12] Otherwise, fQRS may represent the altered ventricular depolarization, which can be derived from different mechanisms such as the non-homogeneous activation of ischemic ventricles in the STEMI. The causative relationship between fQRS and cardiac fibrosis has been shown, but the possible relation of fQRS on admission and after percutaneous coronary intervention (PCI) with myocardial infarction, reperfusion, and parameters has not been studied until now.

In this study, we investigated whether the presence of fragmented QRS on admission ECG predicts the ST segment resolution in patients undergoing primary PCI (p-PCI) in patients with STEMI.

Subjects and Methods

Patient population and study protocol

The current study includes a prospective observational design. The study was conducted in the cardiology clinics at Rize Education and Research Hospital in Rize, Turkey and Ordu State Hospital in Ordu, Turkey. One hundred eighty four patients with STEMI and no history of coronary artery disease (CAD), who underwent primary PCI at two institutions between January 2010 and December 2010, were enrolled consecutively. An experienced cardiologist examined all patients immediately after hospitalization.

Clinical characteristics, which consisted of multiple descriptors from each patient's history and physical examination, were collected by physicians from cardiology clinics for each patient and were stored in the database of a coronary angiography laboratory at each institute. We recorded the baseline characteristics, which include hypertension, diabetes mellitus, smoking history, family history for CAD, and lipid parameters. Hypertension was defined as the active use of antihypertensive drugs or the documentation of blood

pressure greater than 140/90 mm Hg. Diabetes mellitus was defined as fasting glucose levels over 126 m/dL or glucose level over 200 mg/dL at any measurement or active use of antidiabetic drugs or insulin. Patients who were using tobacco products on admission to our hospital, and those who had quit smoking within the last year were considered as smokers. The family history for CAD was defined as a history of documentation regarding CAD or sudden death in a first-degree relative before the age of 55 for men and 65 for women.

Killip score, which is a system used in individuals with an acute myocardial infarction in order to stratify risk was used to classify patients.[13]

Patients with significant organic valvular heart disease and bundle branch block (LBBB, incomplete or complete RBBB or duration QRS >20 msn), known history of CAD, and those with permanent pacemakers were excluded from the study. Informed consent was obtained from all patients prior to the study. The study was performed in accordance with the principles stated in the Declaration of Helsinki and approved by the Local Ethics Committee.

Presence or absence of fQRS on pre and post-PCI ECGs and their relation with myocardial infarction and perfusion parameters were investigated. In addition, logistic regression analysis was used in order to determine independent predictors for presence of fQRS on pre and post-PCI ECGs.

Laboratory measurements

Cardiac biomarker levels including creatine kinase (CK), creatine kinase-MB fraction (CK-MB) and Troponin-I and inflammatory markers including leukocytes and other baseline parameters were measured at our emergency department and used in the analyses as admission values. The lipid samples were drawn by venipuncture in order to perform routine blood chemistry after fasting for at least 8 hours. Plasma blood glucose, total cholesterol, high density lipoprotein-cholesterol, low density lipoprotein-cholesterol, and triglyceride levels and other parameters were recorded to our hospital database. Glucose, creatinine, and lipid profile were determined by standard methods. White blood cell (leukocyte) counts were obtained from an automated cell counter (Coulter Gen-S, COULTER Corp, Miami, FL, USA).

Electrocardiogram

A 12-derivations surface ECG was obtained from all patients in the supine position immediately after their admission to the emergency care unit (ECU). The 12-lead ECG (Nihon Kohden-cardiofax S ECG-1250 K, filter range 0.5 Hz to 150 Hz, alternating current (AC) filter 60 Hz, 25 mm/s, 10 mm/mV) was analyzed by two independent clinicians who were blinded to study design and data.

The fQRS was defined as the presence of various RSR' patterns

(QRS duration <120 ms) with or without a Q wave, which included an additional R wave (R' prime), notching of the R wave or S wave, or the presence of more than one R prime (fragmentation) without a typical bundle branch block in two contiguous leads corresponding to a major lead set for major coronary artery territory (Fig. 1). Any QRS morphology with a QRS duration >120 ms, including bundle branch block or intra-ventricular conduction delay were excluded from the current study. Analysis of the standard 12-lead ECG was performed without using any magnification, and fragmentations were considered to be present if a visually identifiable signal was demonstrated in all complexes of a particular lead. Thus, for statistical analysis, fQRS was defined to be present if found in ≥2 contiguous anterior leads, lateral leads, or inferior leads. The QRS duration was determined by the longest QRS in any lead.[6] There was a 99% concordance for ECG interpretation for the presence of fQRS, non-fQRS, and wide QRS. In case of a disagreement, the final diagnosis was achieved by mutual agreement. We also used the concept of "number of fQRS", which represents the number of fQRS because

"one fQRS complex" on its own was not accepted to be representative of the presence of fQRS.

The diagnosis of acute STEMI was made according to an ECG obtained during admission to ECU in the presence of clinical symptoms and findings. Patients with chest pain that continued for longer than 30 minutes and with the presence of new or presumed new ST-segment elevation at the J point in ≥2 contiguous leads of ≥0.2 mV in leads V1, V2, or V3 and ≥0.1 mV in other leads. Marked ST depression, which was maximal in leads V1 through V3, without ST segment elevation in other leads, was designated as posterior wall myocardial infarction (MI).[14] The diagnosis of acute STEMI was also confirmed by demonstrating the responsible lesion on the coronary angiographies of all patients. Infarctions leading to the presence of ST elevation in V 1-5 derivations, the presence of ST elevations in two contiguous leads of I, aVL and V6 derivations, and the presence of ST elevation in two contiguous leads of II, III, aVF derivations were diagnosed as anterior MI, lateral MI and inferior MI, respectively.[15]
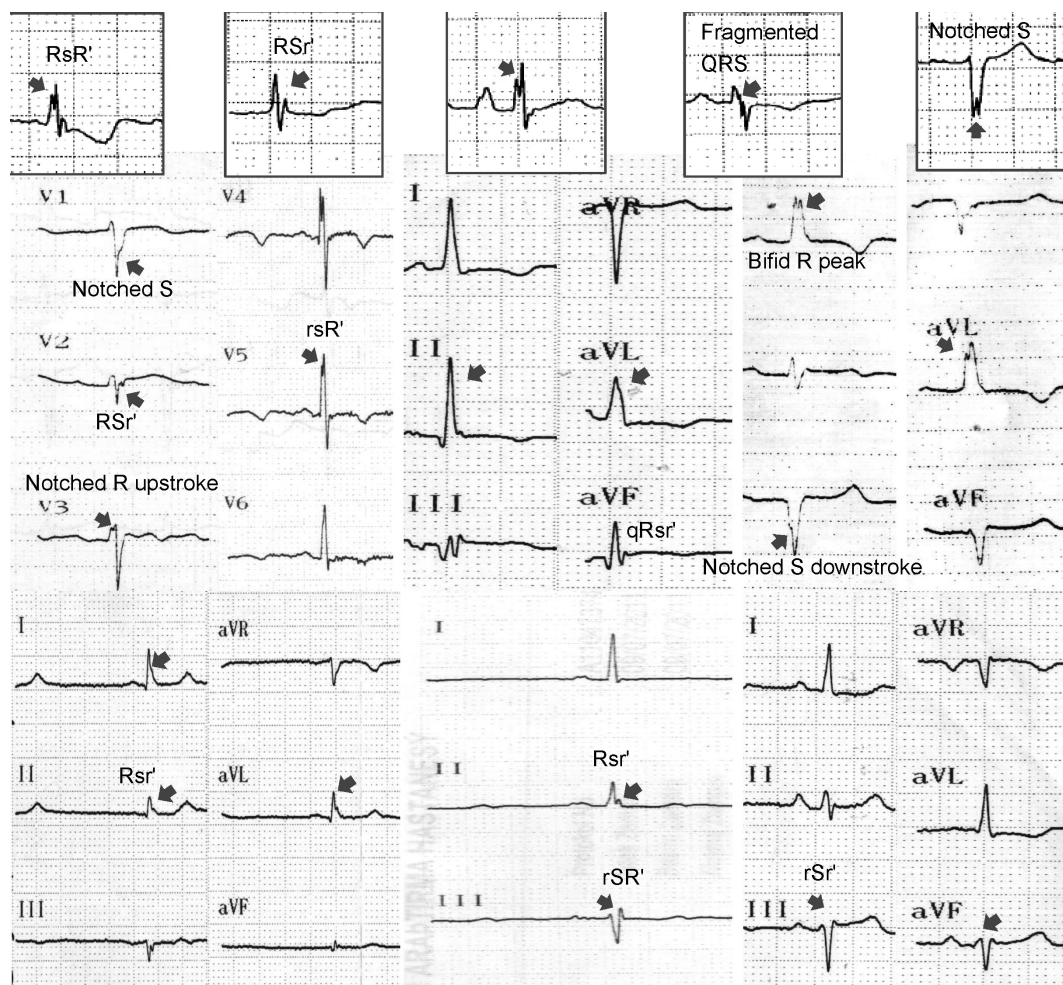

Fig. 1. The various types of notched and fragmented QRS complexes. Different fragmented QRS complexes patterns were shown by arrows including rSr′, rSR′, RSr′, notched R up-stroke, notched S down-stroke, bifid R peak and bifid R nadir.

Pathologic Q wave: Any Q wave in lead V2 or V3 ≥0.02 seconds or the QS complex in leads V2 and V3 with a Q wave ≥0.03 seconds and ≥0.1 mV deep or QS complex in lead I, II, aVL, aVF, or V4 to V6 in any 2 leads of a contiguous lead grouping (I, aVL, and V6; V4 to V6; and II, III, and aVF) was considered as pathologic. An R wave ≥0.04 seconds in lead V1 or V2 and an R/S ratio ≥1 with a concordant positive T wave in the absence of a conduction defect.[14]

Jeopardized myocardium was determined by the sum of ST elevations (in mm) on each ST elevated derivation on pre and post PCI ECG (Total ST elevation score). A repeat ECG was obtained at 60-minute after p-PCI (Fig. 2). Percent of total ST resolution was calculated by the following formula: (Sum of ST elevations on Pre-PCI ECG)-(Sum of ST elevations on Post-PCI ECG)/(Sum of ST elevations on Pre-PCI ECG)×100. Delta QRS time was calculated by the following formula: (Pre-PCI QRS duration)-(Post-PCI QRS duration).

Coronary angiography and primary percutaneous coronary intervention

All patients were administered 300 mg aspirin and 600 mg clopidogrel loading dose prior to the procedure. At the start of the procedure, 10.000 U IV heparin was administered. Coronary stenting directly, or followed by balloon angioplasty, was performed where necessary. Diameters of the vessel and stent, if performed, the dilatation procedure was recorded during PCI. Glycoprotein IIb-IIIa in-

hibitor (tirofiban) was administered at the consideration of the operator. After the operation, all patients were monitored in the intensive coronary unit until stabilization was achieved. All patients were treated based on the recommendations of American College of Cardiology/American Heart Association Guidelines for the Management of Patients With ST-Elevation Myocardial Infarction.[16]

Selective coronary angiography was performed urgently at the hemodynamic laboratory using the Standard Judkins technique through the femoral artery. Multiple views were obtained in all patients, with visualization of the left anterior descending and left circumflex coronary in at least 4 views, and the right coronary artery in at least 2 views. Coronary angiograms were recorded on compact discs in DICOM format. Atherosclerotic coronary involvement was assessed by the number of vessels involved (vessel score) and by a severity score. Significant stenosis was determined visually and defined as a ≥50% reduction in lumen diameter in any view compared with the nearest normal segment. Vessel score ranged from 0 to 3, depending on the vessels involved (0: <50% luminal narrowing, 1, 2 and 3: number of luminal narrowed vessels of ≥50%). Coronary atherosclerotic burden was assessed using the Gensini score.[17]

The Gensini score, which considers both the extent and the severity of the lesions at coronary angiography, was calculated for each patient. This scoring system grades the stenosis in the epicar-
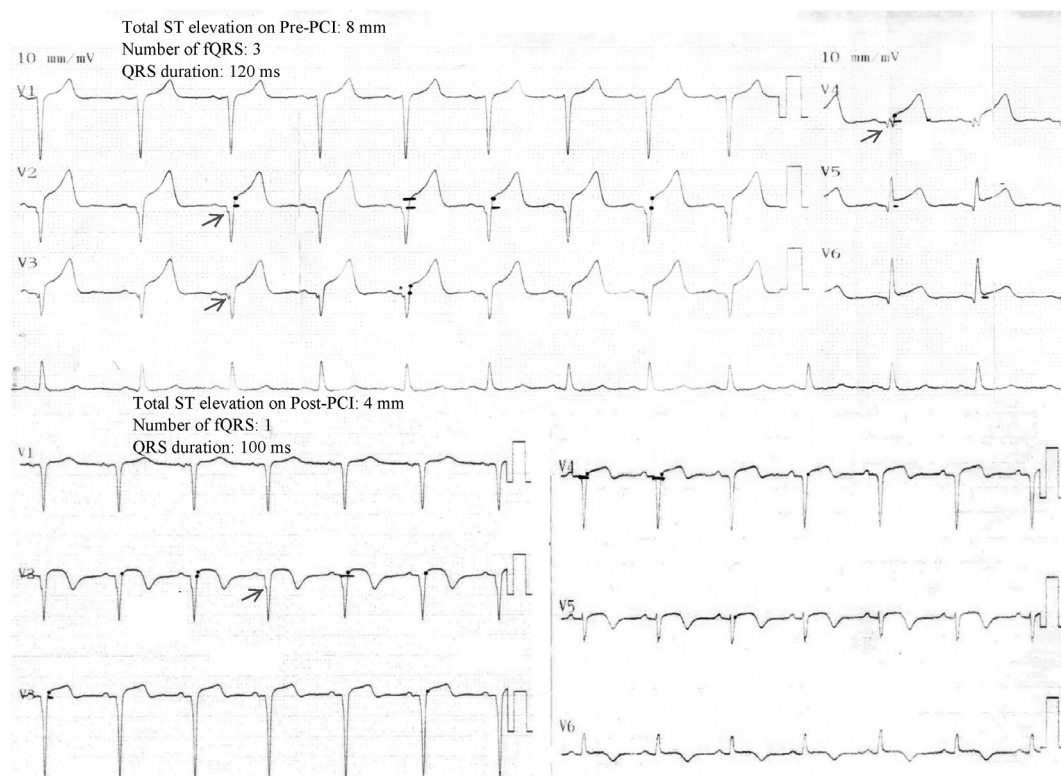

Fig. 2. Changes in fragmented QRS complexes on surface electrocardiogram before and after primary percutaneos coronary intervention.

dial coronary arteries (1 for 1-25% stenosis, 2 for 26-50% stenosis, 4 for 51-75% stenosis, 8 for 76-90% stenosis, 16 for 91-99% stenosis, and 32 for total occlusion) and multiplies this number by a constant number determined according to the anatomical position of the lesion.

The Thrombolysis in Myocardial Infarction (TIMI) Grade Flow,

Table 1. Characteristics of the study population

The fragmentations on surface ECG in patients with STEMI

Parameters	Absence or resolution of fQRS (n=111)	Persistent or newly developed fQRS (n=73)	p
Age (years)	61±13	63±12	NS
BMI (kg/m²)	28±4	27±4	NS
Gender (male) (%)	81	80	NS
Hypertension (%)	28	37	NS
Diabetes mellitus (%)	52	50	NS
Smoking (%)	35	40	NS
Hyperlipidemia (%)	56	56	NS
Family history of CAD (%)	13	27	0.013
Heart rate (bpm)	84±17	84±18	NS
Systolic blood pressure (mm Hg)	128±25	134±26	NS
Diastolic blood pressure (mm Hg)	81±12	82±13	NS
Plasma blood glucose (mg/dL) (Adm.)	156±63	157±68	NS
Creatinine (mg/dL)	0.96±0.3	1.1±0.4	0.048
Total cholesterol (mg/dL)	182±35	186±42	NS
LDL-C (mg/dL)	117±30	122±35	NS
HDL-C (mg/dL)	39±9	37±7	NS
Triglyceride (mg/dL)	130±84	146±75	NS
Leukocytes (10³/mm³)	12±3	14±4	0.004
Neutrophils (10³/mm³)	7.9±2.8	9.9±3.6	<0.001
Lymphocyte (10³/mm³)	2.5±1.8	2.3±1.1	NS
Monocyte (/mm³)	678±513	841±465	0.036
Hemoglobin (mg/dL)	13.8±2.2	14.1±2.0	NS
CK (U/L) (Adm.)	515±783	806±1029	0.044
CK-MB (U/L) (Adm.)	72±69	98±83	0.030
AST (U/L) (Adm.)	56±65	82±95	0.038
LDH (U/L) (Adm.)	447±319	461±414	NS
Troponin I (ng/mL) (Adm.)	3.6±8.7	6.8±13.6	0.097
Pain to balloon time (hours)	4.1±2.1	4.9±3.0	0.046
Killip score (3/4) (%)	7	19	0.016
Number of ST elevated derivations	3.8±1.3	4.7±1.8	<0.001
Total ST elevation on pre-PCI ECG (mm)	9.5±6.0	12.1±7.8	0.014
Total ST elevation on post-PCI ECG (mm)	3.9±3.8	6.7±6.5	0.001
Percent of total ST resolution (%)	63±28	45±48	0.002
Number of obstructed vessels ≥50%	1.9±0.8	1.7±0.8	NS
Q wave on ECG (%)	33	37	NS
QRS duration (ms) pre-PCI (Adm.)	89±14	94±13	0.024
QRS duration (ms) post-PCI	82±14	90±12	<0.001
Post-PCI TIMI score (2 and 3)	2.6±0.8	2.5±0.9	NS
Post-PCI Blush score (2 and 3)	1.7±0.5	1.5±0.5	0.028

ECG: electrocardiogram, STEMI: ST elevation myocardial infarction, fQRS: fragmented QRS complexes, NS: not significant, BMI: body mass index, CAD: coronary artery disease, Adm.: admission value, LDL-C: low density lipoprotein-cholesterol, HDL-C: high density lipoprotein-cholesterol, CK: creatinine kinase, CK-MB: creatinine kinase Muscle/Brain, AST: aspartate aminotransferase, LDH: lactate dehydrogenase, PCI: percutaneous coronary intervention, TIMI: Thrombolysis in Myocardial Infarction

which is a widely adopted scoring system, grades 0-3 referring to the levels of coronary blood flow assessed during percutaneous coronary angioplasty[18] was used to score coronary flow as previously defined. The TIMI Myocardial Blush grade score[19] was used in order to evaluate the microvascular perfusion and was scored as previously defined.

Statistical analysis

Continuous variables were given as mean±standard deviation; categorical variables were defined as percentages. Continuous variables were compared by Student t-test and the χ^2 test was used for the categorical variables between two groups. Linear regression analysis with the stepwise method were used for the multivariate analysis of independent variables, which were included if they were significantly different in the univariate analyses. All tests with regards to significance were two-tailed. Statistical significance was defined as $p < 0.05$.

The Statistical Package for the Social Sciences (SPSS) statistical software (SPSS 15.0 for Windows, Inc., Chicago, IL, USA) was used for all statistical calculations.

Results

Baseline clinical characteristics were shown in Table 1. Patients with persistent or newly developed fQRS had higher leukocyte counts (p=0.004, especially neutrophils, p<0.001), higher CK-MB levels (p=0.030), increased pain to balloon time (p=0.046), higher Killip score (p=0.016), more prolonged QRS time (p=0.025), and more extended coronary involvement (p<0.001) in comparison to patients with absence or resolution of fQRS. Additionally, these patients usually exhibited an infarction on the anterior territory and was often related to a lesion in the proximal left anterior descending artery and the larger jeopardized myocardium (p<0.001).

In Table 2, the study parameters were presented in the groups by determined the presence or absence of fQRS on pre-PCI and post-PCI ECGs.

On the other hand, the presence and higher number of fQRS on admission or post-PCI ECGs were significantly related with the low percent of ST resolution and myocardial reperfusion parameters (Table 3). The presence of fQRS on admission of the ECG, but not on the post-PCI ECG, was significantly related to the post-PCI myocardial reperfusion grade. The relationships between fQRS and re-

Table 2. The infarct related parameters and their relationship with fragmentations on pre and post-PCI ECG

| Parameters | Fragmented QRS before and after PCI | | | | | |
| | Pre–PCI | | | Post–PCI | | |
	nfQRS (n=94)	fQRS (n=90)	p	nfQRS (n=97)	fQRS (n=87)	p
Pain to balloon time (hours)	4±2	5±3	0.004	4±2	5±2	0.046
Killip score (3/4) (%)	3	23	<0.001	7	19	0.016
IRA (%)			0.002			0.044
LAD	38	64		44	62	
CX	35	20		34	20	
RCA	27	16		22	18	
Territory of STEMI (anterior) (%)	38	64	<0.001	44	62	0.017
Number of ST elevated derivations	3.7±1.3	4.9±1.7	<0.001	3.9±1.3	4.7±1.8	<0.001
Total ST elevation on pre-PCI ECG (mm)	8.9±5.9	12.8±7.6	<0.001	9.5±6.0	12.1±7.8	0.014
Total ST elevation on post-PCI ECG (mm)	3.8±4.3	7.0±6.2	<0.001	3.9±3.9	6.7±6.6	0.001
Percent of total ST resolution (%)	62±30	45±46	0.005	63±28	45±49	0.002
Number of obstructed vessels ≥50%	1.9±0.7	1.8±0.8	NS	1.9±0.8	1.7±0.8	NS
Total occlusion in IRA (%)	79	82	NS	83	80	NS
Q wave on ECG (%)	27	41	0.039	33	37	NS
Gensini score	52±23	67±27	<0.001	59±24	60±27	NS
QRS duration (ms) pre-PCI (Adm.)	88±13	96±14	<0.001	89±14	94±13	0.024
QRS duration (ms) post-PCI	83±14	92±13	<0.001	82±14	90±12	<0.001
Post-PCI TIMI score (2 and 3) (%)	90	87	NS	90	86	NS
Post-PCI Blush score (2 and 3) (%)	81	48	<0.001	72	58	0.055

PCI: percutaneous coronary intervention, ECG: electrocardiogram, nfQRS: non-fragmented QRS, fQRS: fragmented QRS complexes, IRA: infarct related artery, LAD: left anterior descending artery, Cx: circumflex coronary artery, RCA: right coronary artery, STEMI: ST elevation myocardial infarction, Adm.: admission value, TIMI: Thrombolysis in Myocardial Infarction Coronary

Table 3. The relationship of percent of total ST resolution after PCI with fQRS

Post-PCI	ST resolution		
Parameters	**<70% (n=121)**	**≥70% (n=63)**	**p**
Gensini score	62±25	55±26	0.088
Total ST elevation on pre-PCI ECG (mm)	11.7±7.1	9.1±6.5	0.018
Total ST elevation on post-PCI ECG (mm)	7.3±5.7	1.4±1.5	<0.001
Delta QRS time (ms)	-2±12	-10±11	<0.001
Presence of fQRS (pre-PCI) (%)	54	37	0.033
Presence of fQRS (post-PCI) (%)	58	36	0.005
Number of fQRS (pre-PCI)	1.7±1.8	1.1±1.5	0.028
Number of fQRS (post-PCI)	1.8±1.7	1.1±1.6	0.012
Localization fQRS (%)			
Anterior	31	10	0.002
Lateral	6	7	NS
Inferior	22	24	NS
Post-PCI	**ST resolution**		
Parameters	**<50% (n=64)**	**≥50% (n=120)**	**p**
Gensini score	65±23	56±27	0.041
Total ST elevation on pre-PCI ECG (mm)	12.8±7.7	9.8±6.4	0.010
Total ST elevation on post-PCI ECG (mm)	10.1±6.4	2.8±2.5	<0.001
Delta QRS time (ms)	0.3±8	-8±13	<0.001
Presence of fQRS (pre-PCI) (%)	62	41	0.007
Presence of fQRS (post-PCI) (%)	67	42	0.001
Number of fQRS (pre-PCI)	1.9±1.7	1.3±1.7	0.020
Number of fQRS (post-PCI)	2.1±1.7	1.3±1.7	0.001
Localization fQRS (%)			
Anterior	33	18	0.023
Lateral	5	7	NS
Inferior	26	20	NS

PCI: percutaneos coronary intervention, ECG: electrocardiogram, fQRS: fragmented QRS complexes

perfusion parameters were presented in Table 4. In the multivariate analysis, only the Gensini score (p=0.027), delta QRS time (p=0.001) and persistent or newly developed fQRS (p=0.035) predicted the percent of total ST resolution (Table 5).

The area under the receiver operating characteristics curve values for the presence and number of fQRS to detect TIMI Blush Grade 0 and 1, were 0.682 and 0.703 (Fig. 3).

Discussion

In this study, we aimed to evaluate the relationship between the presence of fQRS on admission as well as post-PCI ECGs and myocardial reperfusion parameters in patients with STEMI. We found that fQRS was related with inflammatory state, prolonged QRS time, the extent of infarction, and jeopardized myocardium and myocardial perfusion before and after primary PCI. Moreover, although fQRS

might be less valuable in STEMI, compared to acute coronary syndrome whose ECG changes are more nonspecific; the absence and resolution of fragmented QRS and QRS narrowing on ECG showed the diagnostic value as a useful marker of successful myocardial reperfusion, similar to the percent of total ST resolution.

Although fQRS is defined as unexpected deviations in the QRS morphology, the exact cause of QRS complex fractionations on surface ECG is not yet completely known. fQRS predicts cardiac events in different populations. Pathophysiologically, fQRS is generally due to regional myocardial fibrosis/scar and data suggests that ischemia might cause fQRS via nonhomogeneous myocardial electrical activation.[20-24] In patients with ischemic or non-ischemic left ventricular dysfunction, fQRS correlated with myocardial fibrosis.[25] In previous studies in which Gadolinium delayed the enhancement on cardiac magnetic resonance imaging and was used to determine myocardial structure, fQRS has shown a relation with extensive myocardi-

Table 4. The relationship of TIMI myocardial blush perfusion grade score after PCI with study parameters

Post-PCI	Myocardial perfusion		
Parameters	Blush score (0 and 1) (n=64)	Blush score (2 and 3) (n=120)	p
Gensini score	67±25	55±25	0.005
Percent of total ST resolution	41±27	61±44	0.001
Total ST elevation on pre-PCI ECG (mm)	12.3±7.2	10.0±6.8	0.036
Total ST elevation on post-PCI ECG (mm)	7.6±5.5	4.1±5.1	<0.001
Delta QRS time (ms)	-1.3±10.3	-6.7±12.6	0.002
Presence of fQRS (pre-PCI) (%)	72	35	<0.001
Presence of fQRS (post-PCI) (%)	60	45	0.055
Number of fQRS (pre-PCI)	2.4±1.9	1.0±1.5	<0.001
Number of fQRS (post-PCI)	1.9±1.9	1.4±1.6	0.028
Localization fQRS (%)			
Anterior	39	16	<0.001
Lateral	8	6	NS
Inferior	36	16	0.003

TIMI Blush Grade: Thrombolysis in Myocardial Infarction coronary blush perfusion grade, PCI: percutaneos coronary intervention, ECG: electrocardiogram, fQRS: fragmented QRS complexes

Table 5. Linear regression analysis was used for prediction of myocardial reperfusion

Linear regression analysis	Dependent variable: Percent of total ST resolution	
Independent variables	p	Beta (standardized)
Persistent or newly developed fQRS	0.035	-0.165
Gensini score	0.027	-0.173
Delta QRS time (ms) (QRS narrowing)	0.001	0.270
Total ST elevation on pre-PCI ECG (mm)	-0.040	0.613

fQRS: fragmented QRS complexes, PCI: percutaneos coronary intervention, ECG: electrocardiogram

al scar.[11][12] fQRS was also found to be a marker of a prior MI, defined by regional perfusion abnormalities, which has a substantially higher sensitivity and negative predictive value compared with the Q wave.[6][26] It has been shown that regional fQRS patterns denote the presence of a greater corresponding focal regional myocardial scar on stress myocardial perfusion imaging.[27] Additionally, it was known that chronic ischemia could cause myocardial patchy fibrosis without prior MI.[28]

Today, it is well known that myocardial ischemia could cause heart failure and ventricular arrhythmias due to the development of scar tissue, which is related with increased mortality and morbidity.[6][20][27][29] In the setting of acute coronary syndrome, non-homogenous depolarization of myocardium caused by ischemia and infarction may be the main determinant for increased arrhythmic events in hospital course. In our study, the extent of infarcted myocardium on admission was assessed by cardiac biomarkers and, fQRS was found to be related to the extent of infarcted myocardi-
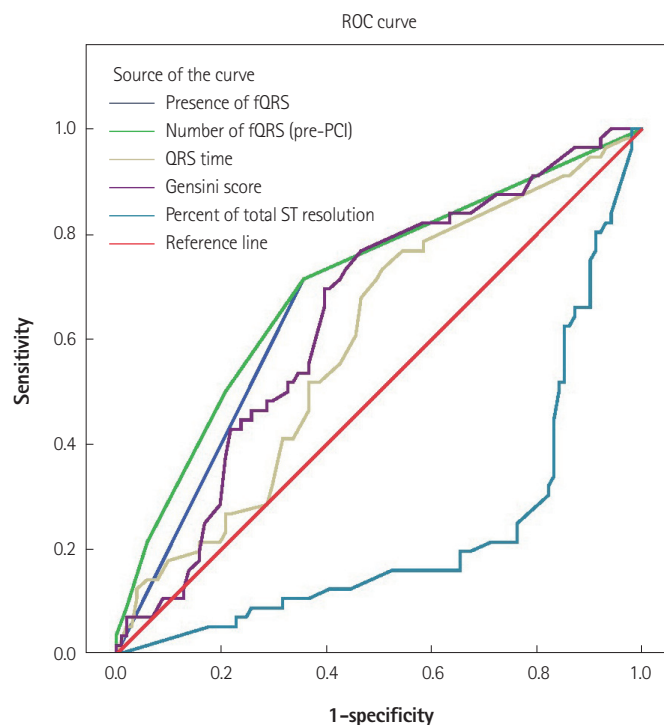
Predictors	AUC	SE	p	95%CI
Presence of fQRS (pre-PCI)	0.682	0.045	0.000	0.595-0.770
Number of fQRS (pre-PCI)	0.703	0.044	0.000	0.616-0.790
QRS time	0.606	0.046	0.029	0.516-0.696
Gensini score	0.644	0.045	0.003	0.556-0.732
Percent of total ST resolution-1	0.767	0.041	0.000	0.687-0.847

Fig. 3. The sensitivity and the specificity of study parameters to detect Thrombolysis in Myocardial Infarction Blush Grade 0 and 1. ROC: receiver operating characteristics, fQRS: fragmented QRS complexes, PCI: percutaneos coronary intervention, AUC: area under the curve, SE: standard error.

um at admission. Especially, this relation was significant for CK and CK-MB, but not for Troponin I for admission values. Possibly, this may be related to the late increase in Troponin levels in the setting for STEMI. Similarly, we also found that fQRS was related with the extent and severity of CAD. This is possibly derived from the extent of jeopardized ischemic myocardium, which may also cause the non-homogenous conduction on the myocardium.[2,23]

In patients with acute coronary syndrome, prolonged QRS time was associated with increased long term mortality due to increased heart failure, arrhythmia and ischemia.[30] In our study, prolonged QRS time was related to fQRS even relatively in the normal range of QRS (<120 ms). This relation may have two possible explanations. Either fragmentation on the QRS complex is induced by the prolongation in QRS time or the fragmentation on the QRS causes an increase in the duration of the QRS complex. However, by our study design, we can only speculate which one is the cause and which one is the result or response in regards to the fragmentation. This interaction should be examined in order to clarify the cause-result relationship in an electrophysiological based study.

Although the presence of fQRS on admission was significantly related with the post-PCI TIMI myocardial perfusion grade, the presence of post-PCI fQRS was not related to myocardial perfusion grade significantly. In our opinion, myocardial stunning and hibernation concepts may explain this gap. At the cellular level, electrical homogeneity can slowly be restored in these situations despite sufficient myocardial reperfusion. In our study, this explanation may also be supported by additional findings. The patients with sufficient perfusion provided by p-PCI had fQRS at a rate of 45% even after PCI. We can speculate that in some patients, the fragmentations were related to the presence of stunned myocardium, which can resolve in the course and in others cannot due to the presence of myocardial scar.

Twelve-lead surface ECG, which is a cheap, non-invasive, and easily apprehensible method, is presently a gold standard in differential diagnosis, determining treatment methods, and performing risk stratification of STEMI. ST elevation, Q wave, and several repolarization abnormalities are commonly used in diagnosis of MI. Additionally, fQRS may also be of great value in predicting the cardiac status as well as short and long term prognosis. fQRS may be useful in identifying patients at higher cardiac risk with ischemic jeopardized or infarcted myocardium, and it can also provide information about the presence of enhanced heterogeneity of myocardial conduction and cardiac electrical instability in an individual patient. fQRS, which may be derived from the effects of individual risk, myocardial infarction and perfusion related factors on myocardial electricity at the cellular level, can represent increased cardiac risk by different causative mechanisms in patients with STEMI.

In conclusion, fragmented QRS may predict a low percent of ST segment resolution and unsuccessful reperfusion in patients undergoing p-PCI. Moreover, the absence and resolution of fQRS may predict reversible myocardial ischemia with a high percent of ST segment resolution in patients with STEMI.

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