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Correlation of left ventricular ejection fraction drop and fragmented QRS with ST-segment elevation myocardial infarction

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Original Article

Abstract

BACKGROUND: Fragmented QRS (fQRS) is an electrocardiographic parameter, which could be assessed easily and non-invasively using surface electrocardiogram (ECG) and may have significant prognostic value. The present study aimed to evaluate the correlation between left ventricular ejection fraction (LVEF) and fQRS in surface ECG.

METHODS: This study was conducted on 186 patients with acute ST-elevation myocardial infarction (STEMI). After primary percutaneous coronary intervention (PCI) and transferring the patients to the cardiac care unit (CCU), the patients were examined using echocardiography, and ejection fraction (EF) was assessed using the Simpson's method by a single cardiologist. Data analysis was performed using SPSS software.

RESULTS: Among 186 eligible patients, 113 cases showed fQRS in the surface ECG. In total, 84.9% of these patients were men, and 15.1% were women ($P < 0.05$). No significant correlation was observed between age and fQRS ($P > 0.05$), as well as coronary artery disease (CAD) severity and fQRS ($P > 0.05$). On the other hand, a statistically significant, reverse correlation was denoted between EF and fQRS in the surface ECG ($P < 0.05$). In addition, significant relations were observed between the rate of ST-segment elevation and depression and fQRS ($P < 0.05$).

CONCLUSION: According to the obtained results, EF significantly decreased in the echocardiography of the patients with STEMI and fQRS in the surface ECG. Considering the cost-efficiency and accessibility of fQRS evaluation, it could be used for the assessment of various parameters in cardiology modalities such as cardiac magnetic resonance imaging (CMRI) and computed tomography (CT).

Keywords: Electrocardiography; Fragmented QRS; Left Ventricular Function; ST Elevation Myocardial Infarction

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Introduction

Electrocardiogram (ECG) is a basic modality that plays a key role in the prognosis of cardiac diseases.[1] Fragmented QRS (fQRS) is an electrocardiographic parameter, which could be assessed easily and non-invasively using ECG. ECG with 12 leads [10 mm/mv, 25 mm/s, alternating current (AC) filter: 60 Hz, filter range: 0.5-150 Hz] should be provided for the evaluation of fQRS.[2] This parameter indicates myocardial tissue scars and previous myocardial infarction (MI) in patients with coronary artery disease (CAD), which is considered to be a major risk factor for the ischemia recurrence.[3] In recent years, several studies have been focused on the association of fQRS with various cardiac diseases. According to the primary studies in this regard, the sensitivity of fQRS in myocardial scars is higher compared to the Q wave.[4]

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Signal-averaged ECG (SAECG), which indicates latent potentials, could cause low-range, high-frequency potentials at the end of the QRS complex in patients with fQRS. Abnormal latent potential indicates a region of slow conduction in the injured myocardium in the proximity of the fibrous tissue, which is caused by previous MI.[5] fQRS is observed due to the altered myocardium activation caused by myocardial scar or fibrosis. In fact, zigzag electric signal conduction in injured myocardial tissue leads to numerous spikes in the QRS complex.[2,6]

Several studies have investigated fQRS in various cardiac diseases, confirming its significant predictive value. Furthermore, studies regarding fQRS in patients with ischemic and non-ischemic cardiomyopathy have demonstrated that the emergence of this parameter in ECG could predict the risk of sudden death and arrhythmia in patients with implantable cardioverter-defibrillator (ICD), as well as the response of these patients to cardiac resynchronization therapy (CRT).[2]

A study conducted in 2014 confirmed a significant association between the presence of fQRS and the wall motion score index (WMSI), as well as the dysfunction of the lateral wall of the left ventricle.[7] Moreover, studies have indicated that the emergence of such waves in the ECG of individuals with ST-elevation MI (STEMI) undergoing primary percutaneous coronary intervention (PCI) is positively associated with in-hospital and yearlong mortality.[8] Some of the key functions of fQRS are to predict and evaluate the rate of cardiac ejection fraction (EF) drop following STEMI. If a relation could be established between this index and the rate of EF drop in patients through case studies, this non-invasive index would be used for optimal, long-term planning for patient management.

In another study, Akgul et al. (2014) evaluated 414 patients diagnosed with STEMI undergoing primary PCI, aiming to assess the correlation between the presence of fQRS and mortality rate in these patients. According to the obtained results, patients with fQRS were older and had higher yearlong mortality rate ($P < 0.001$). Therefore, it was concluded that the presence of fQRS could significantly predict yearlong and in-hospital mortality rate during hospitalization after the intervention.[8]

In a similar study, Das et al. (2009) evaluated 361 patients with CAD and dilated cardiomyopathy (DCM) in order to determine the correlation between the presence of fQRS and mortality rate in these patients. According to the findings, mortality rate without arrhythmia in the patients with fQRS was significantly lower compared to the patients without this wave. Therefore, it was concluded that the presence of fQRS in these patients could significantly predict the risk of arrhythmia, while indicating whether the first arrhythmia would occur earlier in these patients compared to the patients without this wave.[9]

In a study by Onoue et al. (2016), 239 patients with left ventricular diastolic dysfunction (LVDD) were assessed in order to determine the association between the presence of fQRS and LVDD for the differentiation of LVDD from heart failure with preserved EF (HFpEF). The obtained results suggested that the HFpEF affection rate in the patients with fQRS was higher compared to the patients without this wave, while serum troponin and B-type natriuretic peptide (BNP) levels were also significantly higher in these patients. Therefore, it was reported that the presence of fQRS could be used not only to predict the occurrence of HFpEF, but also to differentiate HFpEF from LVDD.[10]

Another research in this regard was performed by Lorgis_et al. (2013) on 113 patients with dropped left ventricular EF (LVEF) in order to assess the correlations between the presence of fQRS, LVEF drop, left ventricular hypertrophy (LVH), and size of the necrotized myocardial area. According to the findings, arterial obstruction and its extent were significantly higher in patients with fQRS. In addition, the emergence of this wave could indicate the extent of myocardial tissue necrosis, myocardial drop rate, and rearrangement status, while it could not significantly predict the systolic blood pressure (SBP) in these patients.[11]

In another study, Nakamura et al. (2016) examined 137 patients with hypertrophic cardiomyopathy (HCM) in order to investigate the correlation between the presence of fQRS and HCM outcomes in terms of the associated cardiac markers and utilizing cardiac magnetic resonance (CMR). According to the obtained results, prolonged QRS was positively correlated with left ventricular (LV) rearrangement and heart failure (HF) in the patients with HCM, while fQRS was not considered to be a significant predictor in these cases.[12]

In a meta-analysis conducted by Rosengarten et al. (2015), the association between the mortality rate and presence of fQRS was evaluated in patients with CAD or non-ischemic cardiomyopathy. According to the obtained results, the rates of mortality and sudden death in the patients with fQRS were significantly high. Therefore, it was concluded that this variable could predict the rate of sudden death in these patients.[13]

In this regard, Zhao et al. (2015) assessed 49 patients with DCM, aiming to evaluate the correlation between the presence of fQRS and LV functional characteristics in these patients. The obtained results indicated that the rate of LV dyssynchrony in the patients with fQRS was significantly higher compared to the patients with normal QRS (P < 0.01), while the mortality rate was significantly higher in the patients with fQRS compared to the other group. Furthermore, LV dyssynchrony in the patients with fQRS significantly deteriorated within two years. Therefore, it could be concluded that fQRS is a proper index to evaluate the prognosis of patients with DCM and predict the rate of LV dyssynchrony in these patients.[14]

Materials and Methods

In this cross-sectional study, an ECG was obtained from all the patients who had chief complaints of chest pain between August 2017 and August 2018 referring to Mousavi Hospital, Zanjan Province, Iran. We included patients who had at least two of the following criteria: 1) electrocardiographic changes in favor of STEMI, 2) characteristic severe chest pain lasting over 30 minutes, and 3) elevation of the cardiac biomarkers in serum. In our study, exclusion criteria were supraventricular tachycardia (SVT) such as atrial fibrillation (AF) and atrial flutter, ventricular tachycardia (VT), previous MI, history of HF and congenital heart diseases. The patients who had MI with ST-segment elevation, based on the clinical definition, referred to the angiography department and underwent coronary artery angioplasty. Patients with normal coronary arteries in current angiography were excluded. Demographic data of the patients including age and gender were collected through enquiries with the patients or their companions. Following that, the patients were referred to the intensive care unit (ICU) for monitoring and underwent echocardiography within 24 ± 6 hours after admission in order to assess their cardiac function. In addition, a cardiologist evaluated the EF rate of the patients using the Simpson and M-mode modalities.

Statistical analysis: Data analysis was performed in the SPSS software (version 24.0, IBM Corporation, Armonk, NY, USA). Qualitative nominal variables were presented in frequency distribution tables in the form of number (percent), and continuous variables were expressed as mean ± standard deviation (SD). The chi-square statistic was used for testing relationships between categorical variables. The Kolmogorov-Smirnov normality test was used to examine if variables were normally distributed. Quantitative variables with normal distribution were compared with the t-test and one-way analysis of variance (ANOVA). Mann-Whitney U and Kruskal-Wallis tests were used when the variables were not normally distributed. Linear regression analysis was used to determine the relation between the EF drop and algebraic sum of ST-segment elevation, depth of inverted T wave, and Q wave depth. The significance level was set at 0.05 for all analyses. Written informed consent was obtained from all patients and patient information was kept confidential. The study was approved by the Ethical Committee of Zanjan University of Medical Sciences, Zanjan, with an ethical code of IR.ZUMS.REC.1397.104.

Results

The mean age of the patients in the present study was 63.4 ± 11.9 years. In total, 186 patients referred to the hospital, including 147 men (79%) and 39 women (21%). Among these patients, 79 cases (42.5%) were aged less than 60 years, 43 cases (23.1%) were aged 60-70 years, and 64 cases (34.4%) were aged more than 70 years.

In the present study, the involvement of one coronary artery was observed in 67 of the patients, while the involvement of two coronary arteries was denoted 63 patients, and involvement of three coronary arteries was observed in 56 patients. Table 1 provides data regarding the mean rate of EF, ST-segment elevation, depth of the inverted T wave, and the Q wave depth according to the gender. There were no significant differences in these paraclinical features and gender (P > 0.05). As is presented in table 1, there were no significant age differences in the mean rate of EF, ST-segment elevation, and depth of T wave (P > 0.05). There was a statistically significant difference in mean depth of the Q wave and age (P = 0.026). Therefore, it could be concluded that Q wave depth was less in the 60-70-year-old patients than other age groups.

According to the information in tables 2 and 3, a statistically significant correlation was observed between gender and the presence of fQRS (P = 0.014). However, no significant correlation was observed between age and the presence of fQRS (P = 0.237). No statistically significant correlation was denoted between the number of the involved coronary arteries and presence of fQRS (P = 0.106).

Table 1. Paraclinical manifestations according to gender and age (n = 186)

Variables		Frequency	Mean ± SD*	P**
EF (%)	Men	147	41.6 ± 10.5	0.511
	Women	39	42.9 ± 11.6	
	Under 60 years old	79	42.1 ± 10.7	0.496
	60-70 years old	43	43.2 ± 11.5	
	Older than70 years	64	40.8 ± 10.3	
ST-segment elevation (mm)	Men	147	4.7 ± 2.5	0.482
	Women	39	4.4 ± 2.5	
	Under 60 years old	79	4.8 ± 2.7	0.760
	60-70 years old	43	4.6 ± 2.7	
	Older than70 years	64	4.5 ± 2.0	
Depth of inverted T wave (mm)	Men	147	1.8 ± 1.7	0.409
	Women	39	1.6 ± 1.2	
	Under 60 years old	79	1.7 ± 1.6	0.896
	60-70 years old	43	1.8 ± 1.6	
	Older than 70 years	64	1.9 ± 1.7	
Depth of Q wave (mm)	Men	147	4.1 ± 4.0	0.255
	Women	39	3.3 ± 3.3	
	Under 60 years old	79	4.5 ± 4.3	0.026
	60-70 years old	43	2.6 ± 3.5	
	Older than 70 years	64	4.3 ± 3.5	

*Continuous variables are expressed as mean ± standard deviation (SD); **T-test and one-way analysis of variance (ANOVA)
EF: Ejection fraction; SD: standard deviation

Table 2. Frequency distribution of presence of fragmented QRS (fQRS) according to gender and age (n = 186)

Variables		fQRS		P*
		Yes [n (%)]	No [n (%)]	
Gender	Men	96 (65.3)	51 (34.7)	0.014
	Women	17 (43.6)	22 (56.4)	
Age (year)	< 60	46 (58.2)	33 (41.8)	0.237
	60-70	23 (53.5)	23 (46.5)	
	> 70	44 (68.8)	20 (31.3)	

*Chi-square test
fQRS: Fragmented QRS

As shown in table 4, we found evidence of significant correlation between gender and the number of the involved coronary arteries (P = 0.015). As such, the risk of multi-vessel disease incidence was higher in the male patients compared to the female patients. However, there was no significant association between age and the number of the involved coronary arteries (P = 0.130).

The mean rate of EF in the patients with fQRS was 37.2 ± 9.9%, while it was 49.2 ± 7.4% in the patients without fQRS, and the difference in this regard was considered statistically significant (P = 0.0005). Therefore, it could be concluded that EF was higher in the patients without fQRS compared to those with fQRS.

Table 3. Frequency distribution of presence of fragmented QRS (fQRS) according to severity of coronary artery stenosis (n = 186)

Variable	SVD	2VD	3VD	P*
	[n (%)]			
fQRS				0.106
Yes	34 (30.0)	41 (36.0)	38 (34.0)	
No	33 (45.0)	22 (30.0)	18 (25.0)	

*Chi-square test
SVD: Single-vessel disease; 2VD: Two-vessel disease; 3VD: Triple-vessel disease; fQRS: Fragmented QRS

Table 4. Severity of coronary artery stenosis according to gender and age (n = 186)

Variable	SVD [n (%)]	2VD [n (%)]	3VD [n (%)]	P*
Gender				
Men	51 (34.7)	55 (37.4)	41 (27.9)	0.015
Women	16 (41.0)	8 (20.5)	15 (38.5)	
Age (year)				
< 60	32 (40.5)	31 (39.2)	16 (20.3)	0.130
60-70	9 (20.9)	13 (30.2)	21 (48.8)	
> 70	26 (40.6)	19 (29.7)	19 (29.7)	

*Chi-square test
SVD: Single-vessel disease; 2VD: Two-vessel disease; 3VD: Triple-vessel disease; fQRS: Fragmented QRS

Table 5. The relation between the ejection fraction (EF) drop, ST-segment, T wave, and Q wave (n = 186)

Variables	Regression coefficient	SE	95% CI		P
			Low limit	High limit	
ST-segment elevation	-2.04	0.27	-2.59	-1.49	< 0.05
Depth of inverted T wave	-2.00	0.46	-2.92	-1.08	< 0.05
Depth of Q wave	-1.02	0.18	-1.38	-0.65	< 0.05

CI: Confidence interval; SE: Standard error

The mean rate of ST-segment elevation was 5.0 ± 2.6 mm in the patients with fQRS, while it was 4.0 ± 2.0 mm in the patients without fQRS, and the difference was statistically significant (P = 0.003). Therefore, it could be concluded that the ST-segment elevation was higher in the patients with fQRS compared to those without fQRS. The mean rate of ST-segment depression was 2.0 ± 1.5 mm in the patients with fQRS and 1.5 ± 1.7 mm in the patients without fQRS, and the difference in this regard was considered statistically significant (P = 0.042). Therefore, it could be deduced that the rate of ST-segment depression was higher in the patients with fQRS compared to those without fQRS. The mean depth of the Q wave was 4.3 ± 3.7 mm in the patients with fQRS and 3.5 ± 4.2 mm in the patients without fQRS. We found no significant differences in depth of the Q wave between patients with and without fQRS (P = 0.139).

According to the information in table 5 and table 6, per every one millimeter of ST-segment elevation, the EF value dropped by an average of 0.0158%. However, the correlation was considered statistically significant (P = 0.0005), and it could be concluded that ST-segment elevation led to EF drop. Moreover, per every one millimeter of ST-segment depression, the EF rate dropped by an average of 0.67%, while this correlation was not considered statistically significant. On the other hand, per every one millimeter of increase in the Q wave depth, the EF rate dropped by an average of 0.43%, and this relationship was statistically significant (P = 0.045). Therefore, the result indicated that the increased depth of Q wave led to the EF drop.

Discussion

The current research was conducted on 186 patients diagnosed with acute MI (AMI), who were examined based on the inclusion and exclusion criteria of the study. According to the obtained results, the mean EF was 41.6 ± 10.5% and 42.9 ± 11.6% in the male and female patients, respectively, and the difference was not statistically significant (P = 0.511). In addition, no statistically significant differences were observed in the mean ST-segment elevation, mean inverted T wave depth, and mean Q wave depth between the male and female participants.

According to the results in the present study, the emergence of fQRS in the male patients was significantly more common compared to the female patients (P < 0.05). In a survey conducted by Terho et al. (2014) on a population of approximately 11000 regarding the prevalence and predictive value of fQRS, this parameter was reported to be more prevalent in men compared to women.[15] In another research performed in South Korea in 2012, evaluation of the correlation between the presence of fQRS and CMR findings indicated that the emergence of fQRS was not higher in men compared to women.[16] Similar studies have often been conducted on small sample sizes, denoting no significant association between gender and the prevalence of fQRS.[4,9,17] Evidently, the findings of the current research are consistent with the study by Terho et al., which was conducted on a significant sample size.

We found that the prevalence of fQRS did not increase with age. In researches by Park et al.,[18] Ma et al.,[19] and other similar studies, no significant correlation has been reported between age and the prevalence of fQRS.

The results of the present study indicated no significant association between the severity of coronary artery involvement and presence of fQRS. In a study by Pietrasik et al. regarding the importance of fQRS in patients with AMI, coronary angioplasty had no correlation with the presence or absence of fQRS.[20]

Table 6. The relation between the ejection fraction (EF) drop and algebraic sum of ST-segment, T wave, and Q wave (n = 186)

Variables	Regression coefficient	SE	95% CI		P
			Low limit	High limit	
ST-segment elevation	-0.15	0.31	-0.960	-2.200	0.0005
Depth of inverted T wave	-0.67	0.49	0.300	-1.600	0.1730
Depth of Q wave	-0.43	0.21	-0.009	-0.840	0.0450

CI: Confidence interval; SE: Standard error

In another similar research performed in 2016, the emergence of fQRS in patients with triple-vessel disease (3VD) was reported to be significantly high.[21] According to the findings of Tanriverdi et al. (2018) in Turkey, the incidence of CAD was significantly higher in the patients with AMI with the evidence of fQRS in the ECG compared to those without this pathological finding.[22] Furthermore, the results obtained by Korkmaz et al. demonstrated that the presence of fQRS was significantly higher in the patients with reduced fractional flow reserve (FFR), so that the presence of fQRS in ECG could predict the presence of reduced FFR.[23] In another study performed on patients with the ECG criteria for left bundle branch block (LBBB) criteria, the correlation between the severity of CAD and fQRS was evaluated. According to the findings, the incidence of obstructive CAD was higher in the patients with fQRS. In addition, these patients had higher Gensini scores.[24] In this regard, the discrepancy between the findings of the current research and other studies could be due to the inadequate sample size and differences in the evaluation methods of stenosis severity.

The most important finding of the current research was that the EF rate was significantly higher in the patients without fQRS compared to those with fQRS. In a similar study, Yan et al. professionally evaluated 176 patients with the history of CAD using the two-dimensional speckle-tracking (2DST) technique. In the mentioned research, the EF rate was observed to be significantly lower in the patients with fQRS compared to those without fQRS.[25] Another study was conducted in 2012 to assess the correlation between the presence of fQRS and systolic and diastolic LV function in the outpatients referring to heart clinics. According to the obtained results, the EF rate was 61% in the patients without fQRS and 44% in the patients with fQRS, and the difference was statistically significant.[26] Another similar research aimed to evaluate the correlation of fQRS with non-compaction cardiomyopathy (NCC) in 2016, and the EF rate was reported to be significantly lower in the patients with fQRS compared to the patients without this finding in their ECG.[27]

According to a study by Lorgis et al. (2013), the presence or absence of fQRS had no correlation with the EF rate in the patients with AMI.[28] In this regard, the findings of Das et al. demonstrated that the presence of fQRS in the superficial ECG was an independent prognostic factor for cardiac diseases in the patients with CAD. Furthermore, Torigoe et al. (2011) reported that the number of the leads with fQRS in the superficial ECG could independently predict cardiac mortality and hospitalization rates in the patients with LV dysfunction.[29]

A secondary objective of the current research was to evaluate the correlations between ST-segment, T wave, and Q wave changes with the EF rate in the patients with AMI. Data analysis indicated a strong, significant, inverse correlation between ST-segment elevation from the isoelectric line and EF rate. Moreover, an inverse, significant correlation was denoted between Q wave depth and EF drop, while no significant association was denoted between the depth of the inverted T wave and EF rate.

In another research, Murkofsky et al. evaluated the changes in the ECG and ventricular dysfunction, reporting a significant, inverse correlation between the presence of Q wave and EF drop.[30] In another study conducted on the patients with AMI, changes in the ST-segment and T wave were reported to predict mortality, while the emergence of the Q wave in the ECG could not be helpful in this regard.[31] It is also notable that few studies have been focused on the associations between fQRS and other diagnostic methods in cardiovascular diseases (CVDs). For instance, Hekmat et al. (2018) claimed that the presence of fQRS in the superficial ECG of the patients without a known history of CAD was correlated with abnormal findings in the myocardial perfusion scan.[32]

Limitations: The present study was conducted to evaluate the correlation between LVEF and fQRS in surface ECG in patients referring to Mousavi Hospital, Zanjan Province. Nevertheless, the study had several limitations. First, this was a single-center urban-based study and as such, these data may not be representative of the whole population of Iran. Second, it did not consider other variables involved in ventricular function, such as chronic HF (CHF) and history of CAD. Another limitation was the failure to record ECG and echocardiography at one time due to the prevention of delay in revascularization.

Conclusion

The results of the present study indicated that the prevalence of fQRS was higher in the male patients compared to the female patients, and this rate did not increase with age. Furthermore, the presence of fQRS was not correlated with the severity of CAD. The most important finding of the current research was the significant, inverse correlation between the evidence of fQRS in the superficial ECG and ventricular EF in echocardiography.

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Conflict of Interests

Authors have no conflict of interests.

Authors' Contribution

AB, KM, and HA were involved in the conception and design of the study. HA and SVAP were involved in the data collection. HA and RF were involved in the analysis and interpretation of the collected data. SVAP and AB were involved in the drafting of the paper and critical revision. All the authors have read and approved the manuscript.

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