Significance of a Fragmented QRS Complex Versus a Q Wave in Patients With Coronary Artery Disease

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Background—Q waves on a 12-lead ECG are markers of a prior myocardial infarction (MI). However, they may regress or even disappear over time, and there is no specific ECG sign of a non-Q-wave MI. Fragmented QRS complexes (fQRSs), which include various RSR’ patterns, without a typical bundle-branch block are markers of altered ventricular depolarization owing to a prior myocardial scar. We postulated that the presence of an fQRS might improve the ability to detect a prior MI compared with Q waves alone by ECG.

Methods and Results—A cohort of 479 consecutive patients (mean±SD age, 58.2±13.2 years; 283 males) who were referred for nuclear stress tests was studied. The fQRS included various morphologies of the QRS (≥120 ms), which included an additional R wave (R’) or notching in the nadir of the S wave, or >1 R’ (fragmentation) in 2 contiguous leads, corresponding to a major coronary artery territory. The Q wave was present in 71 (14.8%) patients, an fQRS was present in 191 (34.9%) patients, and an fQRS and/or a Q wave was present in 203 (42.3%) patients. Sensitivity, specificity, and the negative predictive value for myocardial scar as detected by single photon emission computed tomography analysis were 36.3%, 99.2%, and 70.8%, respectively, for the Q wave alone; 85.6%, 89%, and 92.7%, respectively, for the fQRS; and 91.4%, 89%, and 94.2%, respectively, for the Q wave and/or fQRS.

Conclusions—The fQRS on a 12-lead ECG is 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.

Key Words: electrocardiography ■ myocardial infarction ■ scintigraphy

The presence of pathological Q waves on the 12-lead ECG signifies a prior transmural myocardial infarction (MI).1 However, the Q wave may regress or even disappear over time in as many as 25% to 63% of patients with a history of a Q-wave MI by ECG.2,3 The overall sensitivity of a Q wave for prior MI is limited by the ECG and is as low as 25% for a lateral MI.4,5 This situation is probably due to recent improvements in the management of acute MI, including aggressive medical therapy, the use of thrombolytic agents, and early coronary revascularization. These practices have resulted in a decrease in the incidence of Q-wave MI from 66.6% to 37.5% and a reciprocal increase in the incidence of non–Q-wave MI.6,7 Furthermore, there is no established ECG sign for a remote non–Q-wave MI.6 Therefore, clinicians have to depend on various noninvasive and invasive studies, such as echocardiography, nuclear imaging, or cardiac catheterization, to confirm the presence of obstructive coronary artery disease (CAD).

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Various prior studies have suggested that the region of a myocardial scar is associated with alteration in QRS morphology, leading to a terminal conduction delay or a fragmentation of QRS complexes on the 12-lead ECG.8,9 We have also demonstrated that the presence of an RSR’ pattern, without evidence of a typical bundle-branch block (QRS ≥120 ms), is associated with ventricular aneurysm by left ventriculography.10,11 In addition, during that study, we anecdotally found that the RSR’ pattern was not limited to the precordial leads, and when present in inferior leads, it was often associated with inferior wall motion abnormalities. This novel observation led us to evaluate this ECG sign of a prior MI in patients referred for cardiac stress testing by nuclear perfusion analysis. Myocardial single photon emission tomography (SPECT) stress studies have previously demonstrated the ability to identify regional perfusion abnormalities from a prior myocardial scar. Cardiac SPECT studies are currently routinely performed to identify the extent of ischemia or the presence of a previous MI and the size of the...
The goal of the present study was to evaluate the significance of a fragmented QRS (fQRS) on the 12-lead ECG (which includes the RSR pattern and all its variants; Figure 1) as a predictor of a regional myocardial scar pattern detected by cardiac SPECT myocardial perfusion abnormalities.

We hypothesized that in patients with known or suspected CAD, the presence of an fQRS on the ECG would significantly improve the ability to detect the presence of a regional myocardial scar, as compared with the presence of a Q wave alone.

**Methods**

Five hundred seven consecutive patients who were referred for myocardial SPECT stress testing at the Krannert Institute of Cardiology, Indianapolis, Ind, from June 2003 to July 2004 were included in the study. These patients were either being evaluated for CAD or had a history of CAD. The study protocol was approved by the institutional review board of Indiana University.

The authors had full access to the data and take full responsibility for its integrity. All authors have read and agree to the manuscript as written.

**ECG Criteria for fQRS (RSR’ Pattern and Its Variants)**

The resting 12-lead ECG (GE, Marquette, Wis; model Mac 5000; filter range, 0.16 to 100 Hz; AC filter, 60 Hz, 25 mm/s, 10 mm/mV) was analyzed by 2 independent readers blinded to the myocardial SPECT findings. There was 99.5% concordance for the ECG signs. The RSR’ pattern includes various morphologies of the QRS interval (QRS duration <120 ms) with or without the Q wave. It was defined by the presence of an additional R wave (R’) or notching in the nadir of the S wave, or the presence of >1 R’ (fragmentation) in 2 contiguous leads, corresponding to a major coronary artery territory (Figure 1). Typical bundle-branch block pattern (QRS >120 ms) and incomplete right bundle-branch block were excluded from the study.

The fQRS may also be seen in >1 coronary region in the same patients (Figures 2 and 3). The presence of an fQRS in ≥2 contiguous anterior leads (V1 to V5) was assigned to myocardial scar in anterior segments or in the left anterior descending territory. The presence of an fQRS in ≥2 contiguous lateral leads (I, aVL, and V6) was assigned to lateral segments or left circumflex territory myocardial scar. Similarly, the presence of an fQRS in ≥2 contiguous inferior leads (II, III, and aVF) was assigned to myocardial scar in the inferior segments or in the right coronary artery territory.

Although we recognize that there is often considerable overlap in the

**Figure 1.** Different morphologies of an fQRS on a 12-lead ECG.

**Figure 2.** Twelve-lead ECG, showing an fQRS (various RSR’ patterns; QRS duration <120 ms) in inferior leads that is correlated with an inferior wall MI on a myocardial perfusion study (QRS complexes are enlarged in the lower row). The fQRS (a variant of the RSR’ pattern) is present in lead aVF. There is no Q wave. Nuclear imaging revealed a fixed inferior defect. Stre indicates during stress.
ECG Criteria for Pathological Q Waves
A pathological Q wave was considered present when it was ≥0.04 seconds in duration or deeper than one fourth of the following R wave in voltage.13 The 3 major infarct regions (anterior, lateral, and inferior) were defined in this study according to the location of the Q waves; an anterior MI was defined by the presence of pathological Q waves in 2 precordial leads (V1 to V4) or any Q wave in lead V2. A lateral MI was defined by the presence of pathological Q waves in at least 2 of 3 lateral leads (I, aVL, or V6). A posterior wall MI was defined by the presence of an R wave V1 (≥5 mV) and ≥40 ms in lead V4. The presence of lateral or posterior infarct was assigned to represent scar in the posterolateral segments or in the left circumflex region by SPECT. An inferior infarct was identified by the presence of pathological Q waves in ≥2 inferior leads (II, III, or aVF).

Gated SPECT Acquisition and Analysis
All patients underwent a rest/stress (low-dose/high-dose) Tc-99m sestamibi single-day stress protocol. The ECG-gated acquisition was performed on poststress images at 8 frames per R-R interval, acquired within 20 to 45 minutes after peak stress Tc-99m administration. Gated SPECT images were obtained with a rotating, 90° fixed dual-head gamma camera (Cardio MD-Philips, Andover, Mass). Transaxial tomograms were reconstructed by filtered back-projection in vertical long-axis, horizontal long-axis, and short-axis planes. Motion correction software was used when needed, as determined by the reader. An independent blinded reader evaluated the SPECT images. A semiquantitative sum stress score, sum rest score, and sum difference score were calculated on a standard 17-segment, 5-point scale (0=normal, 1=equivocal or mildly abnormal, 2=moderately abnormal, 3=severely abnormal, and 4=absent tracer uptake). Individual epicardial coronary artery regional segments of the left anterior descending artery (7 segments) represented by leads V1 to V6 (anterior segments); the left circumflex artery (5 segments) represented by leads I, aVL, and V6 (lateral or posterolateral segments); and the right coronary artery (5 segments) represented by leads II, III, and aVF (inferior segments) were scored according to standard nomenclature.14,15 A myocardial scar was defined by a total regional sum stress score and sum rest score ≥2, corresponding to a major coronary artery region. Gated SPECT regional wall motion was obtained by a regional total sum motion score.

Statistical Analysis
Two-tailed t tests were used to compare continuous variables, which are expressed as mean±SD. Comparisons of proportions for dichotomous data were performed by x² analysis. Sensitivity was defined as the number of true-positive tests divided by the total number of patients with myocardial scar defined by SPECT. Specificity was defined as the number of true-negative tests divided by the total number of patients without myocardial scar. Receiver operating characteristic (ROC) curves were used to assess the relation between the fQRS and the Q wave in the assessment of myocardial scar. Areas under the ROC curves were compared with the technique described by DeLong et al.16 For all tests, a probability value <0.05 was considered significant. SPSS 13.0 was used for analysis.

Results
Of the 507 consecutive patients who underwent the myocardial SPECT stress test, 28 (5%) patients were excluded from our analysis because of complete or incomplete right bundle-branch block (n=14), left bundle-branch (n=11), and paced rhythm (n=3). The data for the final cohort of 479 patients (mean±SD age, 58±13 years; 283 males [56%]) were analyzed in this study. Examples of various morphologies of the RSR’ pattern (fQRS) on the ECG are shown in Figures 1 through 3. Two hundred thirty-four patients had a history of CAD, including 36% (n=173) of patients with a history of MI. A demographic comparison of the 2 groups (fQRS present versus absent) is outlined in Table 1. The Q wave was present in 1 or more coronary artery territories in 71 patients (14.8%); the fQRS was present in 191 (40%) patients; the fQRS and Q wave were present in 59 (12%) patients; and the fQRS and/or Q wave was present in 203 (42.4%) patients (Table 2).

Prevalence of ECG Signs and Regional Myocardial Scar
The incidence of Q waves in anterior, posterolateral, and inferior segments was 10 (2.1%), 6 (1.3%), and 59 (12.3%), respectively (Table 2 and Figures 4 and 5). Whereas the fQRS was present in 46 (9.6%) of the anterior leads, 33 (7%) of the lateral leads, and 172 (35.9%) of the inferior leads, the Q wave and/or fQRS was present in 52 (10.9%) of the anterior leads, 35 (7.5%) of the posterolateral leads, and 185 (38.6%) of the inferior leads. The cohort with fQRS demonstrated a significantly higher sum stress score as well as a sum rest score and other perfusion abnormalities diagnostic of regional myocardial scar compared with the non-fQRS cohort (P<0.0001; Figure 4). Additionally, this cohort had a significantly higher sum wall motion score and a lower ejection fraction (P<0.001).

Sensitivity of ECG Signs for Myocardial Scar
The sensitivity of the Q wave for diagnosing myocardial scar was very low (22.2%, 17.1%, and 50% for anterior, posterolateral, and inferior segments, respectively), whereas it was...
substantially higher for fQRS (72.7%, 62.9%, and 82.7% for anterior, posterolateral, and inferior segments, respectively; Table 2 and Figure 5). When the data for the Q wave and/or fQRS were analyzed for myocardial scar, there was an additional increment in sensitivity, to 76.4%, 68.6%, and 90.5% for anterior, posterolateral, and inferior segments, respectively. Furthermore, the overall sensitivity of fQRS (85.6%) was substantially higher than that of the Q wave (36.3%) when the data were analyzed for myocardial scar, independent of the regional correlation with SPECT analysis. This means that myocardial scar is present; however, ECG signs may or may not represent the corresponding assigned coronary artery territory. Of note, there was another increment in sensitivity (91.4%) when the Q wave and/or fQRS was used as a criterion for diagnosing myocardial scar independent of regional correlation.

**Specificity of ECG Signs for Myocardial Scar**

The specificity of ECG signs for a myocardial scar as tested with the Q wave, fQRS, and the Q wave and/or fQRS was high for anterior segments (99.7% versus 98% versus 98.4%, respectively) and lateral segments (99.7% versus 90.5% versus 97.5%, respectively; Table 2 and Figure 5). However, there was a compromise in specificity for ECG signs of inferior myocardial scar (98.9% versus 90.5% versus 91% for the Q wave, fQRS, and Q and/or fQRS, respectively). When the data were analyzed to compare the pathological Q wave with the fQRS for myocardial scar, independent of regional correlation, the specificity of the Q wave was 99.2%, of the fQRS was 89%, and of the Q wave and/or fQRS was 89%.

**Predictive Value and Posttest Probability of ECG Signs for Myocardial Scar**

The posttest probability of the fQRS and/or the Q wave was 85.2%, of the fQRS alone was 77.6%, and of the Q wave alone was 82% (Table 2). The negative predictive value of the fQRS and/or the Q wave was 94.2%, of the fQRS was 87.6%, and of the Q wave was 70.0%.

**ROC Curves of ECG Signs for Myocardial Scar**

The areas under the ROC curves were 0.82 (95% confidence interval, 0.78 to 0.86) for the fQRS and 0.65 (95% confidence interval, 0.59 to 0.70) for the Q wave (Figure 6; *P*<0.001).

**Discussion**

Our study demonstrates that the 12-lead ECG is a very valuable tool for diagnosing regional myocardial perfusion...
patterns suggestive of a prior MI, especially in the present era of thrombolytic and revascularization therapy, in which the incidence of Q-wave MI has declined and the incidence of non-Q-wave or non-ST-segment-elevation MI has increased reciprocally.\textsuperscript{5} The fQRS is associated with significantly greater perfusion and function abnormalities than is the Q wave. In fact, the fQRS may be the only evidence of a prior silent MI, which has a significantly high incidence in women with atypical chest pain, diabetes mellitus, and dementia and in the elderly. Our results shows that in the current era of aggressive risk factor modification and therapy for CAD, the sensitivity of the Q wave for diagnosing a remote MI is very low (36.3%), whereas the fQRS has a substantially higher sensitivity (84.6%), and there is further increment in sensitivity (91.4%) for the Q wave and/or fQRS. However, there is a slight compromise in specificity when using he fQRS alone or the Q wave and/or fQRS compared with the Q wave for diagnosing myocardial scar in the anterior (98.1% versus 98.4% versus 99.7%) and lateral (90.5% versus 97% versus 99.7%) leads. Of note, the specificity is lower in the inferior leads (90.5% versus 92.5% versus 99%), which may be the result of a higher nonspecific conduction abnormality in this region. The study also revealed that the presence of an fQRS is associated with a significantly high posttest probability of myocardial scar.

Our findings are consistent with prior ECG studies on myocardial scar. Fragmentation of QRS complexes has been shown to be associated with a previous myocardial scar in smaller studies as well as in computer models.\textsuperscript{9,17–19} Spectral analysis of high-frequency electrogram has revealed increased notches and or “slurring” in the electrogram after myocardial injury.\textsuperscript{20} In addition, wide-band recording in patients with CAD revealed an increased number of notches in the R wave and slurs in the S wave in those with a myocardial scar.\textsuperscript{21} The study also confirmed the prior angiographic correlation of the RSR’ pattern with MI scar.\textsuperscript{10,11} Autopsies of patients with MI and left ventricular aneurysm have also confirmed significant myocardial necrosis, with “islands” of viable myocardial tissue interspersed in abundant fibrous tissue. The islands of chronically ischemic myocardial scar.

Detection of MI by SPECT: Q wave vs. fQRS

![Graph showing detection of MI by SPECT: Q wave vs. fQRS](image_url)

Figure 4. Bar graph showing the SPECT variables, including left ventricular ejection fraction, in the presence and absence of an fQRS.

![ROC Curve](image_url)

Figure 5. Sensitivity and specificity of the Q wave and fQRS are shown for each myocardial segment as well as any segment (overall).

![Graph showing ROC curve analysis](image_url)

Figure 6. ROC curve analysis of ECG patterns as a predictor of myocardial scar for the fQRS (solid line) and Q wave (dashed line).
dium display slow activation as a result of partially depolarized and depressed action potential upstroke velocities. This feature is responsible for inhomogeneous activation of the left ventricle. This alters ventricular depolarization, which probably represents fragmentation in the QRS complex on the surface 12-lead ECG. Furthermore, endocardial mapping of scar tissue in these patients also revealed fractionated electrograms over a wide area surrounding the myocardial scar.

It has been suggested that the initial R-wave deflection observed is due to shifting of the QRS vector to the right and posterior as a result of early depolarization, with relatively normal conduction through the upper septum and the right ventricle in left ventricular aneurysm that has a high scar load. Similarly, notching or slurring in the S wave may represent the activation pattern in precordial leads (leftward to the transition zone) similar to the activation pattern in left bundle-branch block. Thus, the terminal conduction delay of QRS forces arising from the area of conduction block or slowing results in an fQRS of ventricular activation. Therefore, different morphologies of the QRS on the surface electrograms (various RSR’ patterns) may represent various directions of myocardial activation pattern, depending on the extent and location of scar tissue in the left ventricle.

Therefore, the fQRS is associated with the presence of greater regional fixed perfusion patterns that are likely to improve identification of prior MIs, and in combination with the Q wave, it shows improved detection of regional infarct/scar SPECT patterns. More important, the fQRS has a significantly high negative predictive value for myocardial scar compared with the Q wave; therefore, absence of the fQRS signifies a low likelihood of prior MI in these patients.

**Limitations**

Our study population comprised patients with at least a low to moderate risk of CAD, and therefore, the data cannot be applied to the general population as well as to patients with cardiomyopathy or various non-CAD diseases. This study has shown that the fQRS may be present without CAD and therefore that it may be a normal variant in a few patients. The fQRS has also been shown to be present in patients with dilated cardiomyopathy when wavelet analysis was performed on averaged QRS complexes obtained from the left precordial leads. Similarly, myocardial scar may be present in patients with valvular heart disease, congenital heart disease, myocarditis, and rarer myocardial diseases (eg, Chagas disease, Kawasaki disease). The Q wave (without MI) may also be present in many of these conditions; therefore, we selected only those patients who underwent myocardial SPECT stress testing for evaluation of CAD. Further study is needed to determine the incidence of the fQRS in normal populations and in non-CAD patients with various myocardial diseases. The other limitation of our study is that many patients with bundle-branch block or intraventricular conduction delays with a QRS ≥ 120 ms may have had scar but were not included in the study owing to the lack of identifying criteria.

**Conclusions**

Our study demonstrates that the fQRS (RSR’ pattern and its variants) without typical bundle-branch block on the 12-lead ECG represents remote MI in patients with known or suspected CAD. The fQRS has a substantially higher sensitivity than the Q wave. The specificity of fQRS is also comparable to that of Q wave in anterior ECG leads but is lower than that in lateral and inferior leads. More important, the fQRS has a higher negative predictive value for myocardial scar than does the Q wave.

**Disclosures**

None.

**References**


Pathological Q waves on the 12-lead ECG are markers of a prior myocardial infarction (MI). However, the Q wave has a low sensitivity for a prior MI, and there is no specific sign for a prior non-Q-wave MI. Fragmented QRS complexes (fQRS) on a 12-lead ECG have been shown to be associated with myocardial conduction block due to myocardial scar. This study has defined the fQRS as various morphologies of the QRS interval (QRS duration <120 ms), such as an additional R wave (R') or notching in the nadir of the S wave, or >1 R' (fragmentation) in 2 contiguous leads corresponding to a major coronary artery territory. The sensitivity, specificity, and negative predictive value for myocardial scar as detected by SPECT analysis are 36.3%, 99.2%, and 70.8%, respectively, for the Q wave alone; 85.6%, 89%, and 92.7%, respectively, for the fQRS; and 91.4%, 89%, and 94.2%, respectively, for the Q wave and/or the fQRS. Thus, the fQRS on a 12-lead ECG is likely to improve identification of prior MIs in patients who are being evaluated for coronary artery disease. More important, the fQRS has a significantly high negative predictive value for detection of myocardial scar compared with the Q wave, and therefore, the absence of an fQRS signifies a low likelihood of a prior MI in these patients. This study has emphasized the utility of the 12-lead ECG, a relatively inexpensive and preliminary test, for detection of MI scar in patients with known or suspected coronary artery disease.
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