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Fragmented QRS complexes are not hallmarks of myocardial injury as detected by cardiac magnetic resonance imaging in patients with acute myocardial infarction ☆

Min-Soo Ahn [a], Jin-Bae Kim [b,*], Byung-Su Yoo [a], Jun-Won Lee [a], Ji Hyun Lee [a], Young Jin Youn [a], Sung Gyun Ahn [a], Jang-Young Kim [a], Seung-Hwan Lee [a], Junghan Yoon [a], Kyung-Hoon Choe [a]

[a] Cardiology Division, Department of Internal Medicine, Yonsei University Wonju College of Medicine, Wonju, South Korea
[b] Cardiology Division, Department of Internal Medicine, Kyung Hee University College of Medicine, Seoul, South Korea

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ABSTRACT

Background: Q waves on a 12-lead electrocardiography (ECG) are considered to be classic hallmarks of prior myocardial infarction. However, one study suggested that the fragmented QRS complex (fQRS) on ECG is a highly sensitive and specific marker of myocardial scarring on a nuclear stress test. The study aimed to investigate the diagnostic accuracy of fragmented QRS complexes compared with Q waves for myocardial injury detected by delayed contrast-enhanced cardiovascular magnetic resonance imaging (DE-CMRI) in subjects with acute myocardial infarction.

Methods: Electrocardiograms of 190 subjects with myocardial infarction who underwent DE-CMR were analyzed. fQRS was defined by the presence of an additional R wave (R″), or notching of the S wave, or more than one R′ in two contiguous leads.

Results: Delayed enhancement was observed in 180 (94.7%) patients. Transmural enhancement was noted in 78 (43.3%) and subendocardial enhancement in 102 (56.7%) patients. The sensitivity and specificity of Q waved and fQRS for diagnosing delayed enhancement were 59.4% vs. 66.7% and 90.0% vs. 40.0%. The area under the receiver–operator characteristics curve of delayed enhancement was 0.75 for Q waves and 0.53 for fQRS ($p = 0.04$). The areas under the ROC curves of the transmurality of delayed enhancement were 0.44 for fQRS and 0.58 for Q waves ($p = 0.73$).

Conclusions: fQRS has poor accuracy for the detection of myocardial injury compared with Q waves. fQRS and Q waves are not valuable tools for the diagnosis transmural irreversible myocardial injury in acute myocardial infarction.

1. Introduction

Pathological Q waves on 12-lead electrocardiography (ECG) signify a prior transmural myocardial infarction (MI). However, the Q wave may regress (or even disappear) over time in 25–63% of patients with a history of a Q-wave MI by ECG (especially in patients treated by reperfusion therapy) despite there being continued evidence of myocardial scarring [1,2]. Studies using contrast-enhanced magnetic resonance imaging (MRI) have shown that Q waves have low sensitivity for prediction of the overall location of myocardial scars [3]. The overall sensitivity of a Q wave for prior MI is limited by ECG, and is as low as 25% for a lateral MI [4,5]. With widespread use of early reperfusion, the incidence of Q-wave MIs has decreased in recent years. These practices have resulted in a decrease in the incidence of Q-wave MIs from 66.6% to 37.5%, and a reciprocal increase in the incidence of non-Q-wave MIs [6,7]. Furthermore, there is no established ECG sign for a remote non-Q-wave MI. Various studies have suggested that the region of a myocardial scar is associated with inhomogeneous activation of the left ventricle, leading to terminal conduction delay or fragmentation of QRS complexes (fQRS) on 12-lead ECG [8,9]. One study has suggested that the fragmented QRS complex on ECG is a highly sensitive and specific marker of myocardial scarring as detected by regional perfusion abnormalities on a nuclear stress test [10]. However, other studies employed to define the sensitivity and specificity of fQRS in the detection of myocardial scarring by use of nuclear stress testing reported that the fragmented QRS complex was not superior to the Q wave for the detection of fixed or mixed myocardial defects [11]. Studies have defined myocardial scarring by regional perfusion abnormalities with use of the nuclear stress test. Delayed enhancement-cardiac magnetic resonance imaging (DE-CMRI) is the "gold standard" for assessment of myocardial viability in patients

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* Corresponding author at: Cardiology Division, Department of Internal Medicine, Kyung-Hee University Medical Center, #1, Hoegi-dong, Dongdaemun-gu, Seoul, South Korea 130-702. Tel.: +82 2 958 8200; fax: +82 2 968 1848.
E-mail address: jinbbai@khu.ac.kr (J.-B. Kim).

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with coronary artery disease (CAD). Numerous studies have demonstrated that late gadolinium hyper-enhancement detected by the DE technique accurately visualizes irreversible myocardial injury [12,13]. We investigated the diagnostic accuracy of fQRS compared with Q waves for myocardial injury detected by DE-CMRI in subjects with myocardial infarction.

2. Methods

2.1. Ethical approval of the study protocol

The study protocol was approved by the Ethics Committee of the Yonsei University Wonju College of Medicine (Wonju, South Korea). All patients provided written informed consent to be included in the study.

2.2. Patient population

One-hundred and ninety patients with MI who underwent cardiac MRI between January 2008 and February 2012 were recruited retrospectively. MI was defined using the universal definition of MI [14]. Demographic and clinical variables were collected retrospectively by a review of medical records. All patients had significant ST deviation, positive biochemical markers, and symptoms suggestive of acute myocardial infarction (AMI). All patients underwent successful percutaneous coronary intervention (PCI).

2.3. Electrocardiographic analyses

The resting 12-lead ECG (filter range, 0.15–100 Hz; AC filter, 60 Hz, 25 mm/s, 10 mm/mV) was analyzed by two independent readers. We used the definition of Q-wave MI from the universal definition of myocardial infarction set by the European Society of Cardiology/American College of Cardiology Foundation/American Heart Association/World Heart Federation (ESC/ACCF/AHA/WHF) Task Force in the primary analysis. A pathological Q wave was defined as: any Q-wave in leads V2–V3 ≥ 0.02 s or QS complex in leads V2 and V3, Q-wave ≥ 0.03 s and ≥ 0.1 mV deep or QS complex in leads I, II, aVL, aVF, or V4–V6 in any two leads of a contiguous lead grouping (I, aVL, V6; V4–V6; II, III, and aVF) [14].

fQRS includes various morphologies of the QRS wave with or without a Q wave [10]. fQRS was defined by the presence of an additional R wave (R′) or notching in the nadir of the R wave or S wave, or the presence of >1 R′ (fragmentation) in two contiguous leads, corresponding to a myocardial territory (Fig. 1). Myocardial territories were defined as: (i) anterior distribution: ECG leads V_1–V_5; (ii) lateral distribution: ECG leads I, AVL, and V_6; and (iii) inferior distribution: ECG leads II, III, and AVF. To define fQRS in wide QRS complexes, we added a criteria of >2 notches in the R wave or S wave because bundle branch block already has 2 notches or peaks present in two contiguous leads [15,16].

2.4. CMR protocol

CMR was undertaken using a 1.5-T imaging unit (Gyroscan Intera; Philips Medical Systems, Best, The Netherlands) equipped with a dedicated cardiac software package, a synergy cardiac coil, and a vectorcardiogram. Cine images were acquired in sequential short-axis slices covering the entire ventricles using a steady-state free precession technique (balanced turbo field echo sequence, TR = 3.3 ms, TE = 1.7 ms, flip angle = 50°, field of view (FOV) 36 cm, matrix size = 256 × 256, slice thickness = 10 mm with no gap, 25 phases/cardiac cycle). Delayed enhancement images were obtained by acquiring an inversion-recovery segmented gradient echo T1-weighted sequence (TR = 2 heart beats, TE = 1.5 ms, flip angle = 15°, FOV = 36 cm, matrix size = 512 × 512, number of signal average = 2) 10–15 min after intravenous injection of 0.2 mmol/kg of gadolinium diethylene triamine pentaacetic acid (DTPA). Sequential short-axis slices (thickness, 10 mm) were obtained. Significant delayed hyper-enhancement was assessed in six segments per slice corresponding to the coronary territory (with the exception of the most apical slice and the basal slice 10 mm below the aortic outflow tract). Significant late gadolinium enhancement (LGE) was assessed in 17 left ventricular (LV) segments according to the recommendations of the AHA [17]. MI transmurality was assessed by analyzing the radial extent of hyper-enhancement between the endocardial and epicardial borders of the myocardial wall at 4.5° intervals around the circumference of LV short-axis-delayed, contrast-enhanced MRI. Regions of the myocardium with abnormally high signals (as determined by two experienced radiologists) were classified as being "positive for LGE". MIs were labeled "transmural" if hyper-enhancement extended throughout the entire LV wall at any point [18]. Infarct size by MRI was determined automatically by computer counting of all hyper-enhanced pixels in the myocardium on each of the 6–8 short-axis images. Infarct size was determined as a percentage of left ventricular mass (%LV) as the sum of hyper-enhanced pixels from each of the 6–8 short-axis images divided by the total number of pixels within the LV myocardium multiplied by 100% [19].

2.5. Statistical analyses

Continuous variables are the mean ± SD; categorical variables are shown as percentages. The unpaired Student's *t*-test and x^2 analyses were used to compare continuous and categorical variables, respectively. The 95% confidence interval (CI) was determined on the basis of the normal distribution of variables. Specificity was defined as the number of true-negative tests divided by the total number of patients without myocardial scarring. Receiver operating characteristic (ROC) curves were used to assess the relationship between the fQRS and the Q wave in the assessment of myocardial scarring. Areas under the ROC curves were compared using a medical statistics software package (MedCalc ver11.0; MedCalc Software, Mariakerke, Belgium). $p<0.05$ was deemed significant. All analyses were undertaken using SPSS ver18 (SPSS, Chicago, IL, USA).

3. Results

3.1. Baseline characteristics

A total of 139 patients (73.2%) were diagnosed with ST segment elevation myocardial infarction (STEMI) and 51 patients (26.8%) had non-ST segment elevation myocardial infarction (NSTEMI). In STEMI patients, Q waves were observed in 88 cases (63.3%) and fQRS in 94 (67.6%). However, 51 patients (36.7%) with STEMI at hospital admission did not show Q waves at hospital discharge. In NSTEMI patients, Q waves were observed in 22 patients (43.1%) and fQRS in 35 (68.6%) (Fig. 2). The baseline characteristics of patients are listed in Table 1.

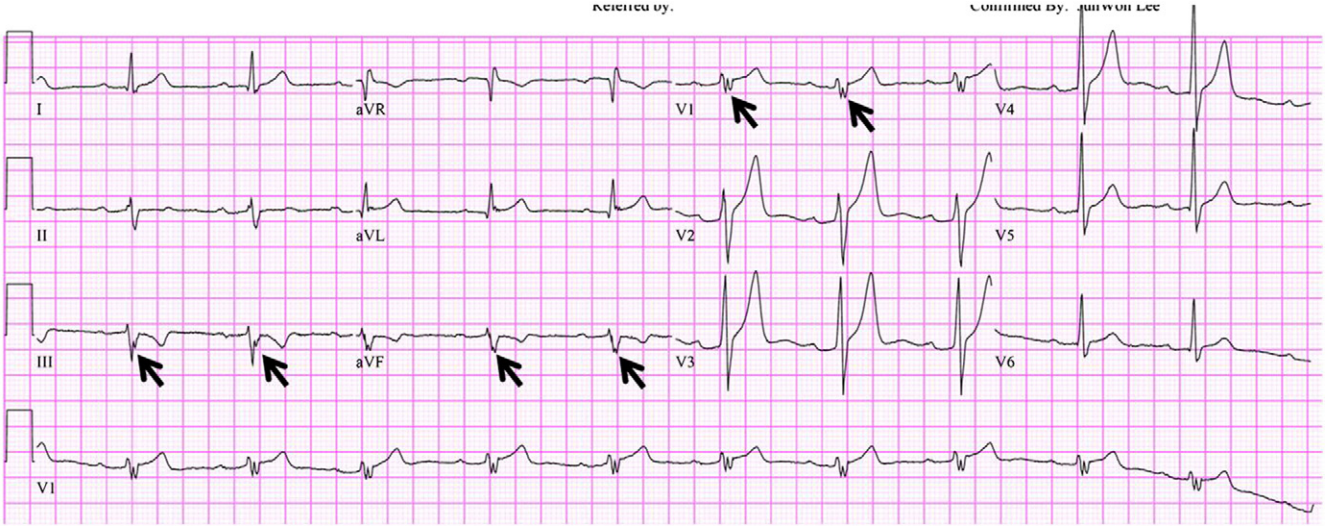

Fig. 1. An example of fQRS with no delayed enhancement of culprit myocardium. Arrow indicated fQRS visible on lead III, aVF and V1; fQRS = fragmented QRS.