Does the presence of Q waves on the EKG accurately predict prior myocardial infarction when compared to cardiac magnetic resonance using late gadolinium enhancement? A cross-population study of noninfarct vs infarct patients

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BACKGROUND We hypothesize that infarct detection by electrocardiogram (EKG) is inaccurate as compared with detection by magnetic resonance imaging and is potentially independent of infarct vs noninfarct status. This might have implications for societies in which initial cardiovascular testing is uniformly EKG.

OBJECTIVE This study aimed to relate EKG-defined scar to cardiovascular magnetic resonance imaging (CMR)–defined scar *independent* of the underlying myocardial pathology.

METHODS A total of 235 consecutive patients who underwent CMR-late gadolinium enhancement (LGE) with simultaneous EKG were screened for Q waves and compared with patients with a positive LGE pattern. The patients were divided into 3 groups: (1) patients with a positive infarct LGE pattern (LGE+/+; herein defined as LGE+), (2) patients with a noninfarct LGE pattern (LGE+/−), and (3) patients with a negative LGE pattern (LGE−).

RESULTS While 139 of 235 patients (59%) were either LGE+ or LGE+/−, pathological Q waves were present in only 74 of 235 patients (31%). However, of these LGE+ or LGE+/− patients, only 76 (32%) had an infarct LGE pattern representing little overlap between the presence of LGE+ and Q waves. EKG sensitivity and specificity to detect infarct: 66% and 85%, respectively. However, of 24 of 74 patients (32%) with Q waves on the EKG, 66% were LGE+/− and 34% were LGE−. Importantly, 3-dimensional volume of myocardial scar was far more predictive of a Q wave than of scar transmurality.

CONCLUSION EKG-defined scar, while ubiquitous for an infarct, has low sensitivity than CMR-LGE–defined scar. Unexpectedly, a significant number of pathological Q waves had absent infarct etiology, indicating high false positivity. Similarly, underrecognition of bona fide myocardial infarction frequently occurs, while 3-dimensional CMR volume of myocardial scar is far more predictive of a Q wave than of scar transmurality. This suggests that the well-regarded EKG may be a disservice when applied on a population basis, leading to inappropriate over or under downstream testing with wide socioeconomic implications.

KEYWORDS Cardiac magnetic resonance imaging; EKG; Late gadolinium enhancement; Myocardial infarction; Nonischemic heart disease

ABBREVIATIONS **2D** = 2-dimensional; **CAD** = coronary artery disease; **CI** = confidence interval; **CMR** = cardiovascular magnetic resonance imaging; **EKG** = electrocardiogram; **LGE** = late gadolinium enhancement; **LGE+** = positive infarct late gadolinium enhancement pattern; **LGE+/−** = noninfarct late gadolinium enhancement pattern; **LGE−** = negative late gadolinium enhancement pattern; **LV** = left ventricular; **MI** = myocardial infarction; **QW** = Q-wave; **ROC** = receiver operating characteristic

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Introduction

Since its invention by Willem Einthoven in 1913, the electrocardiogram (EKG) has become a valuable tool in clinical practice to assess the presence of many cardiac diseases, especially acute and remote myocardial infarction (MI). For more than 50 years, it has been common clinical practice to divide patients into those with Q-wave (QW) MI and those with non-QW MI on the basis of the EKG. The

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presence of pathological Q waves has been used as a marker of prior MI. However, the accuracy of this definition remains controversial.[1,2] Furthermore, the presence of QW MI and non-QW MI was once thought to be synonymous with transmural infarcts and subendocardial infarcts, respectively,[3] until studies questioning this distinction suggested that this association was more random. Some even suggested that this association was a "myth,"[4] while others found it meaningless.[5] Recently, the presence or absence of Q waves was shown to be more closely correlated with the size of the myocardial infarct than with its transmural extent.[6] However, Q waves may be absent in patients with coronary artery disease (CAD) and/or left ventricular (LV) dysfunction[7] or can be present as a normal variant or represent a noninfarct etiology such as hypertrophic cardiomyopathy. Despite these controversies, the presence of pathological Q waves is still widely used clinically as well as in ACC/AHA guidelines as indicative of prior MI.[8]

In the last 2 decades, cardiac magnetic resonance imaging (CMR) has emerged as a powerful new technology to evaluate a myriad of cardiac diseases using high-resolution magnetic fields and radiofrequency to generate 2-dimensional (2D)/3D/tomographic images with high spatial resolution, modest temporal resolution, and excellent intrinsic and extrinsic contrast. Late gadolinium enhancement (LGE)-CMR has shown to be the accepted "criterion standard" modality for evaluating myocardial infarction and viability. CMR-LGE can also reflect irreversibly damaged myocardium including acute and chronic MI. Scarring has been shown to predispose to ventricular arrhythmias and increases morbidity and mortality. The quantification of LGE allows the precise detection of the total volume, location, and transmural extent of MI to be ascertained with minimal interobserver and intraobserver variability.[9–11] This is due to the T1 effect of gadolinium-based sequences permitting detection of MI, affecting less than 1% of the total myocardial mass.[12] More recently, CMR-LGE has been demonstrated to robustly identify non–ischemic heart diseases.[13–18]

To date, the majority of studies that focus on elucidating the basic pathophysiology of the Q wave have been limited to patients with prior MI. Thus, there has been a strong selection bias favoring those with CAD. Thus, this high pretest probability may have led to the overestimation of the true incidence of QW-defined MI when an unselected population is investigated. We hypothesized that the standard assessment of the presence of an infarct relying on the EKG is inaccurate compared with that relying on CMR-LGE regardless of the LGE pattern. Specifically, we evaluated the accuracy of finding of Q waves in those with CAD and those without CAD.

Methods

We conducted a retrospective, institutional review board–approved analysis of patients who were referred to our institution, a tertiary care center with an admixture of primary care, between August 2006 and December 2009 for CMR evaluation for myocardial viability and/or myocardial tissue characteristics. EKGs were obtained from an unselected admixture of an inpatient and outpatient population (in a ratio of 45:55) referred for cardiac indications who had undergone near-simultaneous CMR examinations (not a specific or focused subgroup). EKGs performed within ±1 day of CMR were screened for the presence of Q waves and were compared with those with a positive LGE pattern regardless of the myocardial post-gadolinium pattern. Reproducibility of the presence or absence of Q waves was performed in those with EKGs within 30 days of incident EKG. Specifically, study patients were selected independently of the presence of CAD, including those patients with a noninfarct etiology, thereby limiting selection bias. The exclusion criteria were as follows: presence of cardiac conditions that may cause Q waves (ie, left bundle branch block, Wolff-Parkinson-White syndrome, or hypertrophic cardiomyopathy) and contraindications to CMR. No patient was scanned within 7 days of acute MI while Q waves may still be dynamic,[19,20] although it is acknowledged that QW stability may require 6 weeks or longer. The average time of an infarct was approximately 17 months (range 3 months to 10.5 years)

The patients were then divided into 3 groups: (1) patients with a positive infarct LGE pattern (LGE+/+; herein defined as LGE+), (2) patients with a noninfarct LGE pattern (LGE+/−), and (3) patients with a negative LGE pattern (LGE−). Furthermore, we divided the infarct patients (LGE+) into patients with transmural and subendocardial infarcts. A representative sample of LGE+ patients underwent 3D scar quantitation for partitioning to define the extent of an infarct necessary to produce a Q wave.

CMR

CMR-LGE was performed as described previously[21,22] with a 1.5-T scanner (GE 1.5T EXCITE, GE Medical Systems, Milwaukee, WI) using 4-element surface coils and prospective ECG triggering. Briefly, after cine imaging in 2 long-axis views and up to 12 contiguous short-axis slices covering the entire myocardium, an intravenous bolus of 0.15 mmol/kg contrast (MultiHance, Bracco Diagnostics Inc, Princeton, NJ) was given. After a 10-minute delay, late enhancement images were acquired in the same views as those used for cine imaging by using an inversion recovery sequence.[23] For infarct assessment, the standard 17-segment model of the left ventricle was used.[24] An *infarct LGE pattern* was defined by either a transmural, a subendocardial, or a mixed pattern of post-gadolinium enhancement subtending a typical coronary artery territory distribution. A *noninfarct LGE pattern* was defined as an atypical post-gadolinium configuration not having a phenotypic pattern for an infarct by virtue of its distribution, location, pattern, or a phenotype representative of an alternative pathology. By using commercial post-processing software (Diagnosoft, Cary, NC), a representative subgroup (33% of the population of each group) of LGE+