Myocardial infarction assessment by surface electrocardiography

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Surface electrocardiography (ECG) is often used clinically for the detection of myocardial infarction (MI). Although prior guidelines used to classify MI as Q-wave and non-Q-wave MIs, current guidelines rely on ST segment shift on the ECG to differentiate ST-elevation MI from non-ST elevation acute coronary syndrome since that has direct impact on clinical management¹. Further, we now realize that transmural MI may occur without Q waves on the ECG and non-transmural MIs may be accompanied by Q waves². Nevertheless, the presence of Q waves on an ECG is helpful to suggest the presence of prior MI. In this regards, not all Q waves on ECG tracings are pathologic; pathologic Q waves are defined in the Fourth Universal Definition of Myocardial Infarction as the presence of Q wave in leads V2-V3 > 0.02 s or QS complex in leads V2-V3; Q wave ≥ 0.03 s and ≥ 1 mm deep or QS complex in leads I, II, aVL, aVF, or V4-V6 in any 2 leads of a contiguous lead grouping (I, aVL; V3-V6; II, III, aVF); or an R wave > 0.04 s in V1-V2 and R/S > 1 with a concordant positive T wave in absence of conduction defect³. Even pathologic Q waves may be present in the absence of MI. Notoriously, lead misplacement can result in the misdiagnosis of MI by ECG. Any condition that induces a shift in the position of the

heart in relation to the surface ECG leads can have similar consequences. Other conditions that have been associated with Q waves in the absence of MI include Wolff-Parkinson-White syndrome, amyloid heart disease, hypertrophic cardiomyopathy, non-ischemic dilated cardiomyopathy, chronic obstructive pulmonary disease, left bundle branch block, and paced rhythm².

The gold standard for diagnosis of MI is the presence of myocardial cell death due to prolonged ischemia on autopsy³. Current imaging studies allow for the diagnosis of MI in a relatively non-invasive manner. The presence of myocardial scar by imaging is known to correlate with poor outcomes^{4,5}. The identification of viable (but non-functional) myocardium on imaging suggests that coronary revascularization to that region of the heart may result in the recovery of myocardial function⁶. In contrast, the restoration of blood flow to scarred myocardium is unlikely to be associated with clinical benefit and may result in harm due to the elevated risk associated with coronary revascularization in these patients. Positron emission tomography (PET) imaging using flow (ex: ¹³N-ammonia) and metabolic (¹⁸F-fluorodeoxyglucose-FDG) tracers is a very accurate method for the identification of scar and myocardial viability⁷.

In this issue of the *Journal*, Markendorf and colleagues evaluated the ability of ECG to predict the presence of myocardial scar using cardiac PET as gold standard⁸. They studied 149 patients known to have ischemic cardiomyopathy defined by evidence of coronary artery stenosis on prior angiography or a history of MI who underwent ammonia and FDG PET at a single institution. They evaluated the correlation of Q and/or QS waves on ECG with scarred myocardium by PET defined as a region of matching defect (<50% uptake) on FDG and ammonia PET images. The presence of Q waves was associated with a higher number of scarred

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segments on PET (2.0 vs 1.7). On a per patient analysis, the sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of Q waves for detecting scar were 70%, 40%, 37%, and 73% respectively. When using only QS complexes, the corresponding values were 46%, 59%, 36%, and 68% respectively. On a per vessel analysis these were 56%, 73%, 25%, and 91%, respectively, for Q waves and 33%, 87%, 30%, and 89%, respectively, for only QS complexes. The authors conclude that although the negative predictive value may be at least modest, the presence of Q or QS complexes on ECG should not be used to determine the presence of myocardial scar or to guide in whom coronary revascularization should or shouldn't be sought⁸.

The utility of an ECG to detect MI has been extensively studied with the consensus that it is relatively unreliable and insensitive in this regard as even those with prior MI could have normal resting ECGs^{9–11}. Jaarsma et al evaluated different scoring systems for the detection of prior MI and found at best modest diagnostic accuracy using late gadolinium enhancement cardiovascular magnetic resonance (CMR) imaging as gold standard. They cautioned against the exclusion of previous MI based on ECG criteria alone¹². In a different study, Kakhi and colleagues reported a sensitivity of only 61% for Q waves on ECG to detect MI with single emission computed tomography (SPECT) myocardial perfusion imaging (MPI) as the gold standard¹³.

The Minnesota Code is a guide to systematically critique an ECG in order to identify pathology. It has gone through multiple revisions and is generally used in studies to standardize the definition of ECG findings. In an interesting study, Asch et al evaluated the accuracy of ECG Q or QS waves to detect prior MI using CMR as gold standard. The Minnesota Code definition of Q or QS waves on ECG had a sensitivity of only 48% for the detection of scar comprising more than 1% of the total ventricular volume by CMR. The specificity was 84%. The positive and negative predictive values were 73% and 64%, respectively. Although the sensitivity increased with increasing size of scar by CMR, the increase was modest at best reaching 64% for scars larger than 30% of left ventricular volume (this decreased the specificity to 73%). Whether the scar is transmural or not, the accuracy of ECG was not altered. When analyzing the results by location of the scar, the sensitivity was lowest for lateral scars with only 14% of those detected by ECG¹⁴. Nadour et al reported similar results (also using CMR as reference) with a sensitivity of 66% and specificity of 85% with a significant number of false positives of Q waves in the absence of CMR scar findings¹⁵.

Sandler et al used thallium SPECT MPI as a reference standard and the Minnesota Code criteria for Q and QS complexes on ECG. They reported a sensitivity of 58% and specificity of 75%. The specificity was improved by using more stringent criteria on the Minnesota Code at the expense of lower sensitivity (sensitivity of 30% for the most stringent criteria)¹⁶. Taneja et al evaluated the accuracy of Q waves on ECG to predict myocardial viability (using dobutamine stress echocardiography as reference) in patients who had recent MI. They reported a sensitivity of 64% and specificity of 70%. Thus, the presence of Q waves did not predict non-viable myocardium¹⁷. Al-Mohammad et al asked a similar question to Markendorf and colleagues, but did so in a smaller patient population, evaluating the ability of Q waves to detect viability based on PET imaging. They reported a sensitivity of 41% and a specificity of 79%. Although they reported a lower sensitivity than specificity (unlike in the current report by Markendorf⁸), both were only modest at best¹⁸.

It is important to recognize that these studies were largely performed in patients suspected of having an MI and undergoing advanced imaging. As detailed above in the study by Markendorf et al⁸, the included patients had a history of ischemic cardiomyopathy and were undergoing imaging with PET for assessment of myocardial viability. The majority of these patients (65%) had a clinical history of MI (if the clinical history of MI is the gold standard, even the most sensitive imaging test has low accuracy for its detection). How these data on the accuracy of the ECG translate to patients not suspected of having an MI is not clear. This is an important question given the prevalence of 'silent MI' using ECG criteria documented in several cohorts. Multiple studies have also confirmed that silent MI by ECG confers a poor outcome that may be comparable to clinical MI^{19–21}. In this regards, Soliman et al highlighted the importance of having a systematic approach to interpreting the ECG for presence of an MI given the wide range of incidence and prevalence reported in the literature when using the ECG alone to determine the presence of prior MI²².

We congratulate Markendorf et al⁸ on the performance of this study and adding to the body of literature on the accuracy of ECG for the detection of MI. The ECG can be obtained quickly, is readily available, and relatively cheap, and its performance is not associated with adverse events, but it has significant limitations. As detailed above (summarized in Table 1) and highlighted by Markendorf et al⁸, the diagnostic accuracy of the ECG for detection of MI is suboptimal. In our opinion, the identification of MI by ECG should alert the clinician for the possibility of prior MI if not otherwise suspected. This should be followed by imaging tests to

Table 1. Summary of studies assessing the ECG vs various imaging modalities

Authors	EKG finding	Imaging modality	Number of patients	Sensitivity (%)	Specificity (%)
Markendorf	Q waves	PET	149	70	40
Jarrasma	Universal definition of previous MI	MRI	114	33	97
Jaarsma	Minnesota ECG code	MRI	114	79	77
Jaarsma	Selvester QRS score	MRI	114	90	71
Jaarsma	Cardiologist assessment	MRI	114	67	74
Kakhi	Q waves	SPECT	476	61	94
Kakhi	Fragmented QRS complex	SPECT	476	78	65
Asch	Q waves	MRI	139	48.4	83.5
Nadour	Q waves	MRI	235	66	85
Sandler	Minnesota ECG code	SPECT	214	58	75
Al-Mohammad	Q waves	PET	58	41	79
Taneja	Q waves	Echo	176	64	70

confirm or refute that assumption. As stated earlier, ST segment shift on the ECG has direct impact on current management of acute coronary syndrome. However, in the modern era, the ECG should not be used in isolation for the diagnosis of prior MI and the presence or absence of ECG criteria for MI should not alone dictate clinical management.

Disclosure

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