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ST-Segment Deviation Analysis of the Admission 12-Lead Electrocardiogram as an Aid to Early Diagnosis of Acute Myocardial Infarction With a Cardiac Magnetic Resonance Imaging Gold Standard

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Objectives The purpose of this study was to validate existing 12-lead electrocardiographic (ECG) ST-segment elevation myocardial infarction (STEMI) criteria in the diagnosis of acute myocardial infarction (AMI) and the application of similar ST-segment depression (STEMI-equivalent) criteria with contrast-enhanced cardiac magnetic resonance imaging (ceMRI) as the diagnostic gold standard.

Background The admission ECG is the cornerstone in the diagnosis of AMI, and ceMRI is a new diagnostic gold standard that can be used to validate existing and novel 12-lead ECG criteria.

Methods One hundred fifty-one consecutive patients with their first hospital admission for chest pain underwent ceMRI. The 116 patients without ECG confounding factors were included in this study, and AMI was confirmed in 58 (50%). The admission ECG was evaluated on the basis of the lead distribution of ST-segment deviation according to current American College of Cardiology/European Society of Cardiology (ACC/ESC) guidelines.

Results A sensitivity of 50% and specificity of 97% for AMI were achieved with the currently applied ST-segment elevation criteria. Consideration of ST-segment depression in addition to elevation increased sensitivity for detection of AMI from 50% to 84% ($p < 0.0001$) but only decreased specificity from 97% to 93% ($p = 0.50$). There were no significant differences in AMI location or size between patients meeting the 12-lead ACC/ESC ST-segment elevation criteria and those only meeting the ST-segment depression criteria.

Conclusions In patients admitted to hospital with possible AMI, the consideration of both ST-segment elevation and depression in the standard 12 lead-ECG recording significantly increases the sensitivity for the detection of AMI with only a slight decrease in the specificity. (J Am Coll Cardiol 2007;50:1021–8) © 2007 by the American College of Cardiology Foundation

It is important to achieve a rapid and accurate diagnosis regarding acute myocardial infarction (AMI) in patients with symptoms suggestive of an acute coronary syndrome (ACS), and the initial electrocardiogram (ECG) is the cornerstone of this decision-making process.

Troponin T or I are very sensitive markers for AMI and are now part of routine clinical practice in the diagnosis of patients with symptoms suggesting ACS. However, the infarction is in progress by the time the current routine biomarkers are detectable in venous blood. In addition, the noncardiac causes for troponin release are well documented (1). Contrast-enhanced magnetic resonance imaging (ceMRI) with its high spatial resolution for clinical detection of AMI provides a unique gold standard for evaluation of more universally available diagnostic methods (2). Indeed, location, transmurality, and size of AMI can also be determined with precision and reproducibility (3).

Clinical decisions for initiating reperfusion therapy are typically based on ECG criteria developed in the GUSTO (Global Utilization of Streptokinase and Tissue Plasmino-

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Abbreviations and Acronyms

ACC = American College of Cardiology
ACS = acute coronary syndrome
AMI = acute myocardial infarction
ceMRI = contrast-enhanced magnetic resonance imaging
ECG = electrocardiogram/electrocardiographic
ESC = European Society of Cardiology
LAD = left anterior descending coronary artery
LCx = left circumflex coronary artery
LV = left ventricle/ventricular
LVEF = left ventricular ejection fraction
MVO = microvascular obstruction
NSTEMI = non–ST-segment elevation myocardial infarction
RCA = right coronary artery
STEMI = ST-segment elevation myocardial infarction

gen Activator for Occluded Arteries) series of trials (4); slightly revised criteria have more recently been introduced by the American College of Cardiology and the European Society of Cardiology (ACC/ESC) (5). However, it is well recognized that the sensitivities of these sets of 12-lead ECG criteria are suboptimal (6,7) An example of this deficiency is the routine underdetection of acute posterolateral myocardial infarction (MI) that is the typical result of occlusion of the left circumflex coronary artery (LCx) (8). The adverse risk associated with non–ST-segment elevation myocardial infarction (NSTEMI) is well documented (9), but many trials have failed to demonstrate the benefits of thrombolysis on the basis of alternative non–ST-segment elevation criteria (10–13). With the emergence of more targeted treatments such as percutaneous coronary intervention, the potential role of the admission ECG as a triage tool is increased.

Acute transmural ischemia caused by occlusion of a major coronary artery produces an epicardial injury current that can be detected as a deviation of the ST-segment toward the involved myocardial region (14). This deviation is ST-segment elevation when a region is "viewed" by the positive pole of an ECG lead but ST-segment depression when "viewed" by the negative pole. Acute occlusion of the left anterior descending (LAD) or the right coronary artery (RCA) therefore typically causes ST-segment elevation in chest leads V_1 to V_4 or in limb leads II, aVF, and III, respectively, and therefore the resulting myocardial infarcts are termed STEMI. However, acute occlusion of the nondominant LCx typically produces only ST-segment depression in the 12 standard ECG leads, and therefore, the resulting myocardial infarcts could be termed "STEMI equivalent" (15). This ST-segment depression in the standard leads would appear as ST-segment elevation in the negative counterparts of these leads (7,16).

The primary aim of this study is to demonstrate that the currently accepted GUSTO (4) and ACC/ESC ST-segment elevation criteria (5) from the 12-lead ECG have high specificity but low sensitivity for the diagnosis of acute myocardial infarcts and to investigate the diagnostic benefits of considering STEMI-equivalent ST-segment depression criteria. The secondary aim is to determine the incidence and extent of infarcts meeting ACC/ESC biochemical marker criteria that are not detected by ceMRI.

Methods

Patient population. All patients admitted to the Western Infirmary Glasgow with symptoms suggesting an ACS between August 2002 and May 2003 were considered for this study. This hospital is the primary medical center for a population of 300,000 located in a metropolitan area in a surrounding mixed suburban/rural region in Western Scotland. Patients were excluded if they: had a past medical history of chest pain; had significant comorbidity; were unable or refused to consent for the study; had contraindications to ceMRI (ferrous implants, severe claustrophobia, pregnancy, were unable to remain supine for >45 min); or were transferred from another hospital.

Thirty-five patients (23%) were excluded from this study because of confounding factors in the admission ECG. These ECG factors include diagnostic evidence of prior AMI (n = 17); left ventricular (LV) hypertrophy (n = 9); atrial fibrillation with high ventricular rate (n = 1); Wolff-Parkinson-White syndrome (n = 1); bundle branch block (n = 5); right ventricular hypertrophy (n = 1); and excessive artifacts (n = 1). The study of the remaining 116 patients complies with the Declaration of Helsinki. The Ethics Committee of the North Glasgow University Hospitals NHS Trust approved the protocol for study, and all participants gave their written informed consent.

The diagnosis of STEMI for final analysis was made according to the stated criteria on the basis of the findings of the ECG core lab. The diagnosis of NSTEMI included all those patients with evidence of myocardial infarction as indicated by the presence of delayed hyperenhancement rather than by the biomarkers. All except 4 patients had positive biomarkers and a rise and fall over 3 separate time points (admission, 12 h, and at the time of ceMRI). Of the 4 with negative biomarkers (false positive by cardiovascular magnetic resonance [CMR] for AMI) 3 had no ST-segment deviation on the admission ECG. The 4th patient met the STEMI-equivalent criteria (ST-segment depression had resolved on the repeat ECG the following day) and had a diffuse pattern of delayed hyperenhancement associated with an inferior and posterolateral hypokinetic regional wall motion abnormality; coronary angiography was not performed.

ECGs. The admission ECG was quantitatively evaluated in a core laboratory by 2 of the investigators, who were blinded to all other study data. The ST-segment measurements were made at the J point to the nearest 0.05 mV, and all differences were adjudicated in conference. Regarding "contiguity," the spatial consideration of the 6 chest leads and the spatially based orderly sequence of the 6 standard limb leads were considered (17). The ECGs were classified according to the following 3 criteria:

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