Comparison of the correlation of the Selvester QRS scoring system with cardiac contrast-enhanced magnetic resonance imaging–measured acute myocardial infarct size in patients with and without thrombolytic therapy

Walther C.M. Rovers, MD,a,* Marit C. van Boreen, MD, a Madeleine Robinson, MD, b Thomas N. Martin, MD,b Charles Maynard, PhD,c Galen S. Wagner, MD, d Anton P.M. Gorgels, MD a

aDepartment of Cardiology, University Hospital Maastricht, 6229 HX Maastricht, The Netherlands
bDepartment of Cardiology, Glasgow University Hospital, Western Infirmary, G11 6NT Glasgow, United Kingdom
cDepartment of Health Services, University of Washington, Seattle, WA 98101, USA
dDuke University Medical Center, Durham, NC 27705, USA

Received 17 August 2007

Abstract

Background: After an acute myocardial infarction (MI), it is important to define the infarct size because it is related to mortality and morbidity. The Selvester QRS Score is an electrocardiographic (ECG) method that has been developed for estimating MI size. It has been shown to correlate well with postmortem anatomically measured sizes of single MI in patients who did not receive thrombolytic therapy. The aim of this study was to test the hypothesis that correlation between Selvester QRS Score–estimated MI size and contrast-enhanced magnetic resonance imaging (ceMRI)–measured MI size is equivalent in patients who did vs those who did not receive thrombolytic therapy.

Methods: Thirty-six patients with MI (24 with thrombolytic therapy and 12 without) received ceMRI and ECG at admission and at 1 or 6 months after admission. Indeed, in 23 of the patients, the therapy was intravenous only. The Selvester QRS Score was calculated using the 1-month ECG or, if not available, the 6-month ECG. The correlation between the 2 measures of MI size was determined for all patients and for the 2 groups separately.

Results: The mean MI size in the group that did not receive thrombolytic therapy was 8.5% ± 6.4% estimated by the Selvester QRS Score and 11.7% ± 10.2% measured by ceMRI. For the group that received thrombolytic therapy, Selvester QRS Score was 13.9% ± 11.1% and ceMRI was 20.2% ± 11.3%. The mean MI size in both groups combined was 12.1% ± 10.0% estimated by the Selvester QRS Score and 17.3% ± 11.5% measured by ceMRI. The Spearman rank correlation coefficient between Selvester QRS Score and ceMRI was 0.74 (P < .0001) for all patients, 0.74 (P < .0001) for the group that received thrombolytic therapy, and 0.64 (P = .024) for the group that did not receive thrombolytic therapy.

Conclusions: The associations between Selvester QRS Score and ceMRI-based MI were statistically significant and similar in both groups.

Keywords: Selvester QRS score; Contrast-enhanced magnetic resonance imaging; Thrombolytic therapy

Introduction

Since the introduction of reperfusion therapy after acute myocardial infarction (MI), there has been a decrease in mortality and morbidity. Therapeutic reperfusion increases the proportion of the myocardium that survives the ischemic process, producing a patchy distribution of necrosis with irregular borders. However, irregular borders make it more challenging to measure infarct size (MI) by contrast-enhanced magnetic resonance imaging (ceMRI), and therefore potentially diminish the reliability of this method as a standard for testing more generally available methods of

* Corresponding author. 4904 XM Oosterhout, The Netherlands. Tel.: +31 647684801. E-mail address: wrovers@gmail.com

0022-0736/$ – see front matter © 2009 Elsevier Inc. All rights reserved.
estimating MI size. Therefore, there is a possibility that a ceMRI method either overestimates or underestimates actual infarct size in infarcts with a patchy distribution.2

It is important to determine the MI size because of its relationship to mortality and morbidity (eg, development of arrhythmias and hemodynamic dysfunction) and, therefore, to guide therapeutic decisions.3 Previous studies have documented the capability of clinically available electrocardiographic (ECG) methods for estimating MI size in the pre-reperfusion era,4 and it is now necessary to determine the correlation with MI size after reperfusion therapy has been administered. It is not clear what effect the patchiness of the reperfused MI has on ECG methods for estimating its size.

The Selvester QRS Score is an ECG method that has been developed for estimating MI size. It has been shown to correlate well with postmortem anatomically measured sizes of single MI in the anterior (r = 0.80), inferior (r = 0.74), and posterolateral regions of the left ventricle (LV) (r = 0.72).5–7 Sevilla et al8 found a significant but lower correlation between QRS-estimated and anatomically documented sizes of multiple MIs (r = 0.44). Thus, in the pre-reperfusion era, the Selvester QRS Scoring system has been established as a clinical method for estimating the size of a single MI in the distribution of the 3 major coronary arteries based on quantitative QRS changes in the standard 12-lead ECG.9 An advantage of the QRS scoring system is that it requires only an adequately obtained 12-lead ECG, which is universally available, inexpensive, safe, and noninvasive.10 The ECGs can be scored reproducibly with only slight variability among trained individuals.11,12

The aim of this study is to test the hypothesis that the Selvester QRS Score achieves a similar correlation in estimating ceMRI-measured MI size in patients who received thrombolytic therapy as in those who did not.

Methods

Patient selection

The Magnetic Anatomical and eLecTrical (MALT) study was performed at the University of Glasgow (the Western Infirmary, Scotland, UK) on patients admitted with acute coronary syndromes between August 2002 and May 2003. Patients were excluded if they had a history of pre-event chest pain, had significant comorbidity, were unable or refused to consent for the study, had contraindications to ceMRI, or were transferred from another hospital. After exclusion of these patients, there were 148 remaining in the MALT database. All study patients received cardiac ceMRI and standard 12-lead ECGs at 1 and 6 months after hospital admission if possible, regardless of the presence of an acute MI by clinical diagnosis.

Because this version of the Selvester QRS scoring system should be applied only to patients with a single MI who do not have confounding ECG factors, patients were excluded from this MALT substudy if they had no evidence of MI on ceMRI and an elevated troponin level (≥0.02 ng/ml), did not undergo ceMRI at either 1 or 6 months, had LV or RV hypertrophy or fascicular or bundle branch block on ECG, or had reinfarction after the first ceMRI. Patients were also excluded if they had confounding ceMRI evidence of previous MI or myocarditis. The included patients were divided into 2 groups: those who received and those who did not receive thrombolytic therapy.

Of the 148 patients in the database, 80 were documented as having an MI by both ceMRI and a transiently elevated troponin level. Thirteen patients were excluded because either the ceMRI or the ECG at both 1 and 6 months was not obtained. Of the remaining 67 patients, 31 were excluded because of ECG confounding factors: prior MI (22), recurrent MI before 1 month (1), LV hypertrophy (4), left bundle branch block (2), left anterior fascicular block (1), or right ventricular hypertrophy (1). A total of 36 patients were available for this study. For 31, the ceMRI and ECG at 1 month were considered because the acute changes due to thrombolytic therapy would have resolved and ventricular remodeling would not have been completed. However, in 5 patients, the ECG and the ceMRI at 6 months were used because either of these studies were not obtained at 1 month. Of the 36 patients, 12 did not receive acute thrombolytic therapy. Of the remaining 24 patients, 23 received intravenous thrombolytic therapy and one received percutaneous coronary intervention. This is considered the thrombolytic therapy group.

Electrocardiographic analysis

For all patients, the ECGs were evaluated in a core laboratory. The MI size was estimated using the 50-criteria/31-point Selvester QRS scoring system on the standard 12-lead ECG.13 Two investigators evaluated the location and Selvester QRS Score–estimated size of MI, and adjudicated the differences blinded to ceMRI results.

The patients’ initial ECGs were classified according to the following criteria:

1. American College of Cardiology/European Society of Cardiology ST-elevation MI (STEMI): ST-segment elevation at the J point in 2 or more anatomically contiguous leads, with thresholds of 0.2 mV in leads V1, V2, or V3 and 0.1 mV in other leads.14
2. STEMI equivalent: ST-segment depression at the J point in 2 or more anatomically contiguous leads or in one lead

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Admission ST-segment deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>ST elevation (n = 19)</td>
<td>ST depression (n = 12)</td>
</tr>
<tr>
<td>STEMI (n = 19)</td>
<td>I, aVL, II, III, aVF</td>
</tr>
<tr>
<td>STEMI equivalent (n = 12)</td>
<td>V1 through V6</td>
</tr>
<tr>
<td>Non-STEMI (n = 5)</td>
<td>V3 through V6</td>
</tr>
</tbody>
</table>

Ant indicates anterior; Inf, inferior; Lat, lateral; SE, subendocardial.
that is anatomically contiguous to a lead with ST-segment elevation criteria; with thresholds of $-0.05 \text{ mV}$ in $V_2$ and $V_3$, and $-0.1 \text{ mV}$ in other leads. 


The region supplied by the left circumflex coronary artery previously termed posterior is now termed lateral, as suggested by a consensus panel to coincide with imaging terminology. 

**Contrast-enhanced MRI analysis**

With the introduction of ceMRI, the myocardium can be directly visualized, and by using delayed ceMRI, it is possible to distinguish infarcted from noninfarcted myocardium. 

Short-axis slice positions were used for the ceMRI investigations. Measurement of LV mass was evaluated with manual planimetry on commercial available Argus software (Siemens) by an observer blinded to all other clinical data. The ceMRI data were analyzed with Cardiac Magnetic Resonance Tools (Imperial College, London, UK). Regions of MI by ceMRI were defined as those with hyperenhancement involving at least the subendocardium. The signal intensities of gadolinium-enhanced myocardium and normal myocardium were measured with computer-assisted planimetry and over-read manually. The method for ceMRI analysis used in this study has been fully described by Martin et al. 

The MI location was determined with the 12-segment method described by Ideker et al. The location was defined as the region of the LV containing the highest percentage infarction; patients were classified as having multiple infarcts if there were 2 or more separate areas of delayed enhancement. 

**Statistical analysis**

All MI size measurements (in percentage LV) were expressed as mean ± SD. To determine if there was a difference in MI sizes estimated by Selvester QRS Score and measured by ceMRI within the nonthrombolytic and thrombolytic therapy groups, we used the Wilcoxon matched-pairs signed-ranks test. To determine if Selvester QRS Score or ceMRI size differed between the 2 groups, we used the Wilcoxon rank-sum test. The nonparametric Spearman rank correlation coefficient ($r$) was used to measure the correlation between ECG and ceMRI measurements. This statistic measures the correlation of the ranks of the 2 variables rather than the actual values, and is advantageous for small sample sizes.

**Results**

As seen in Table 1, 53% of patients had STEMI, 33% STEMI equivalent, and 14% non-STEMI. In the STEMI group, 74% had inferior MI, whereas in the STEMI equivalent group, location was more evenly distributed, with 58% occurring in the lateral wall. Patients in the nonthrombolytic and thrombolytic therapy groups were similar with respect to age and sex (Table 2). As expected, all patients with STEMI received thrombolytic therapy, and no patients with non-STEMI received thrombolytic therapy; although 5 of the 12 (42%) individuals with STEMI equivalent did receive thrombolytic therapy. In the group that did not receive thrombolytic therapy, there was no patient with STEMI criteria (Fig. 1). Only half of patients...
who received thrombolytic therapy for inferior MI had STEMI criteria on the initial ECG.

Fig. 2 provides MI sizes in both groups for both methods, and the $P$ values of the statistical analyses which were used to compare the groups. The mean MI size in the group that did not receive thrombolytic therapy was $8.5\% \pm 6.4\%$ estimated by the Selvester QRS Score and $11.7\% \pm 10.2\%$ measured by ceMRI. For the group that received thrombolytic therapy, Selvester QRS Score was $13.9\% \pm 11.1\%$ and ceMRI was $20.2\% \pm 11.3\%$. For both groups combined, the mean infarct size estimated by Selvester QRS Score was $12.1\% \pm 10.0\%$ and the mean infarct size measured by ceMRI was $17.3\% \pm 11.5\%$.

The Selvester and ceMRI infarct sizes were similar in the nonthrombolytic therapy group ($P = .23$), whereas the ceMRI size was larger in the thrombolytic therapy group ($P < .0001$ by Wilcoxon matched-pairs signed-ranks test). The infarct size estimated by Selvester QRS Score was similar in both therapeutic groups ($P = .21$), but the ceMRI size was larger in the thrombolytic therapy group ($P = .032$ by Wilcoxon rank-sum test).

The infarct size estimated by the Selvester QRS Score was plotted against the infarct size measured by ceMRI for both therapeutic groups (Fig. 3). There were statistically significant correlations between the infarct size estimated by the Selvester QRS Score and the infarct size measured by ceMRI for the patients who did not receive intravenous thrombolytic therapy ($r = 0.64$, $P = .024$), and for the patients who did ($r = 0.74$, $P < .0001$). For both groups combined, the correlation was 0.74 ($P < .0001$).

**Discussion**

In this study, the correlation between Selvester QRS Score and ceMRI was similar in patients with and without thrombolytic therapy. There was, however, a lower Selvester QRS Score–based MI size than ceMRI-based MI size. For the patients in the thrombolytic therapy group, this difference was statistically significant. It is possible that the Selvester QRS Score underestimates MI size, but it is also possible that the ceMRI method overestimates size because of the challenge of boundary delineation. In a study from a different MRI laboratory, the results were opposite in direction to those from the current study.\(^{19}\) There is therefore a need for standardization of how to delineate the region of hyperenhancement for accurate MI sizing as indicated in the editorials by Gibbons et al.\(^{23}\) and Engblom et al.\(^{3}\) The measurement of infarct size by ceMRI is influenced by the software used to determine infarct size from in vivo images acquired with the ceMRI technique,\(^{3}\) relative contrast and brightness used with different image display systems, contrast dose,\(^{24,25}\) time between injection of the contrast agent and image acquisition,\(^{25,26}\) myocardial perfusion,\(^{27}\) and the timing of image acquisition in relation to the acute MI. It will be important to know the relationship between MI size estimated by the Selvester...
QRS scoring system and ceMRI when standardization of ceMRI interpretation has been accomplished. It is for now sufficient to know that the correlations between the 2 measures were similar in the 2 groups. Because the Selvester QRS scoring system shows only slight variability among trained readers, these differences may be due to ceMRI interpretation.

The patients who received thrombolytic therapy had much larger MI sizes than those who did not. This can be explained by the consideration that there were some patients who showed such small MI sizes on ceMRI that the ECG did not show characteristic changes (false-negative on ECG). In the clinical setting, patients receive reperfusion therapy based on their presenting ECG changes. So, those patients with small MI sizes, which were undetectable on ECG, would be as expected in the group that did not receive acute thrombolytic therapy. Another explanation is that the patients with ST depression did not receive thrombolytic therapy. Infarctions characterized by ST depression tend to be smaller than those with ST elevation. It is, of course, unlikely that the larger MI sizes were due to thrombolytic therapy.

These results must be considered in regard to several limitations. Only 12 of the 36 patients did not receive thrombolytic therapy, because it is currently difficult to find patients with MI who are not treated with some type of reperfusion therapy. There was also a difference in MI size between the patients who received thrombolytic therapy and the patients who did not. The overall study population was limited because exclusion of those with prior MI or ECG confounders was necessary to compute the Selvester QRS Score. In both treatment groups, there are patients whose ECG and ceMRI at 6 months were used. This is not considered a major limitation because it is assumed that MI size is relatively stable during that period.

Despite these limitations, there is a similarly moderate correlation between Selvester QRS Score and ceMRI in both treatment groups. Further investigation of the Selvester QRS Score is needed in patients receiving reperfusion therapy with either thrombolytic drugs or percutaneous coronary intervention, particularly those with early complete restoration of blood flow. More importantly, more collaborative method development is needed to improve ceMRI analysis so that it can be used as a criterion standard for future studies that involve ECG methods that estimate MI size.

References


The underlying rhythm in the 12-lead electrocardiogram (ECG) recorded in double standard shown above is sinus bradycardia with a single premature ventricular complex. After the first P wave, there is a truncated QRS complex seen in lead I with no ST segment or T wave; there are no visible QRS complexes in leads II or III. An apparent 2.4-second pause (shaded area) follows. Upon careful inspection of the baseline in the simultaneously recorded leads I, II, and III, the ECG signals are completely attenuated, leading to a flat line. Signal attenuation almost always represents a disconnection between the ECG lead(s) and/or the cable connections to the recording equipment. Electrocardiographic lead disconnection is common and can occur at the chest wall, the individual recording electrode being disconnected, or at the cable connection to the ECG machine. In this case, because all leads in the first recording panel display the flat line, the latter, transient cable disconnection, is more likely and indeed is what occurred in this patient. The computer interpretation, seen in the lower right-hand corner of the ECG, has even given the interpretation of “electrode: off”; the computer cannot distinguish between electrode and cable disconnections.

Kurt S. Hoffmayer, PharmD, MD, and Nora Goldschlager, MD

E-mail address: kurt.hoffmayer@ucsf.edu

doi:10.1016/j.jelectrocard.2008.11.007