Early Resolution of ST-Segment Elevation Correlates With Myocardial Salvage Assessed by Tc-99m Sestamibi Scintigraphy in Patients With Acute Myocardial Infarction After Mechanical or Thrombolytic Reperfusion Therapy

Jun Dong, MD; Gjin Ndrepepa, MD; Claus Schmitt, MD; Julinda Mehilli, MD; Sebastian Schmieder, MD; Markus Schwaiger, MD; Albert Schömig, MD; Adnan Kastrati, MD

Background—Early resolution of ST-segment elevation is an indicator of final infarct size and clinical outcomes. Whether this correlation is an expression of initial infarct characteristics or degree of myocardial salvage achieved with reperfusion therapy is unclear.

Methods and Results—We prospectively included 243 patients with acute myocardial infarction (AMI) treated with either coronary stenting (122 patients) or thrombolysis (121 patients). Serial 12-lead electrocardiograms (ECG) were performed at baseline and 90 minutes after initiation of therapy. ST-segment resolution was defined as complete (>70%), partial (70% to 30%), or no resolution (<30%). Paired technetium-99m sestamibi scintigraphic studies were performed to calculate the initial perfusion defect, final infarct size, and the proportion of initial defect salvaged with reperfusion (salvage index). ST-segment resolution correlated significantly with salvage index (P=0.008), final infarct size (P<0.001), and 6-month mortality (P=0.03). In the groups with complete, partial, and no resolution, salvage index was 0.54±0.32, 0.39±0.36, and 0.33±0.60; final infarct size was 12.5±12.0%, 20.0±13.9%, and 22.7±19.4% of the left ventricle; 6-month mortality was 2.4%, 6.2%, and 12.8%, respectively. After adjustment for baseline characteristics, ST-segment resolution was the second strongest predictor of salvage index (P=0.007) after the type of reperfusion, stenting, or thrombolysis (P=0.001); it was greater after stenting than after thrombolysis (P<0.001).

Conclusion—Early resolution of ST-segment elevation in surface ECG correlates with myocardial salvage as assessed by scintigraphy in patients with AMI after reperfusion therapy. These data provide an explanation for the favorable prognostic value of the ST-segment resolution and support the use of this parameter to compare the efficacy of different reperfusion strategies. (Circulation. 2002;105:2946-2949.)

Key Words: electrocardiography ▪ myocardial infarction ▪ scintigraphy ▪ stents ▪ thrombolysis

Myocardial salvage is the principal mechanism by which patients with acute myocardial infarction (AMI) benefit from various reperfusion therapies.¹ Technetium (Tc)-99m sestamibi scintigraphy is considered a reliable method to assess myocardial salvage achieved by reperfusion therapy.² Early resolution of ST-segment elevation has been demonstrated to be a simple and useful predictor of final infarct size, left ventricular function, and clinical outcomes after both thrombolytic and coronary interventional approaches.³,⁴ Whether this predictive value is the expression of the degree of myocardial salvage achieved with reperfusion therapy remains unclear.

The objective of this study was to evaluate the correlation between extent of early ST-segment resolution and myocardial salvage assessed by Tc 99m sestamibi scintigraphy in patients with AMI treated with thrombolysis or primary coronary stenting.

Methods

Study Patients
Between December 1997 and February 2001, 302 patients with AMI within the first 12 hours from symptom onset were randomized to receive either stenting or thrombolysis in the context of the Stent versus Thrombolysis for Occluded Coronary Arteries in Patients with Acute Myocardial Infarction (STOPAMI) 1 and 2 trials.³,⁶ Stenting was accompanied by abciximab as an adjunct therapy, and thrombolysis was applied as alteplase alone or as half-dose alteplase plus abciximab. More detailed information about the enrolled patients and randomly assigned treatment has been published previously.³,⁶

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Correspondence to Dr Adnan Kastrati, Deutsches Herzzentrum München, Lazarettstr 36, 80636 Munich, Germany. E-mail kastrati@dhm.mhn.de
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Baseline Characteristics in the Three ST-Segment Resolution Groups

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Complete Resolution (n=85)</th>
<th>Partial Resolution (n=80)</th>
<th>No Resolution (n=78)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>60±11</td>
<td>61±14</td>
<td>60±13</td>
<td>0.83</td>
</tr>
<tr>
<td>Female</td>
<td>22 (26)</td>
<td>20 (25)</td>
<td>17 (22)</td>
<td>0.82</td>
</tr>
<tr>
<td>Current smoker</td>
<td>48 (56)</td>
<td>49 (49)</td>
<td>310 (40)</td>
<td>0.10</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>12 (14)</td>
<td>22 (27)</td>
<td>15 (19)</td>
<td>0.10</td>
</tr>
<tr>
<td>Hypercholesterolemia</td>
<td>66 (78)</td>
<td>62 (78)</td>
<td>53 (68)</td>
<td>0.27</td>
</tr>
<tr>
<td>Arterial hypertension</td>
<td>53 (62)</td>
<td>52 (65)</td>
<td>49 (63)</td>
<td>0.93</td>
</tr>
<tr>
<td>Previous myocardial infarction</td>
<td>10 (12)</td>
<td>8 (10)</td>
<td>11 (14)</td>
<td>0.73</td>
</tr>
<tr>
<td>Previous bypass surgery</td>
<td>5 (6)</td>
<td>2 (3)</td>
<td>4 (5)</td>
<td>0.55</td>
</tr>
<tr>
<td>Killip class &gt;2</td>
<td>6 (7)</td>
<td>7 (9)</td>
<td>2 (3)</td>
<td>0.51</td>
</tr>
<tr>
<td>Anterior infarction</td>
<td>20 (24)</td>
<td>47 (59)</td>
<td>48 (62)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Peak CK, IU/L</td>
<td>1069±1393</td>
<td>1104±918</td>
<td>997±966</td>
<td>0.83</td>
</tr>
<tr>
<td>Time-to-treatment interval, min</td>
<td>220±131</td>
<td>266±170</td>
<td>272±174</td>
<td>0.07</td>
</tr>
<tr>
<td>Initial perfusion defect, % of LV</td>
<td>27±17</td>
<td>34±20</td>
<td>34±22</td>
<td>0.04</td>
</tr>
</tbody>
</table>

Data presented as mean±SD or number (%) of patients. LV indicates left ventricle; and CK, creatine kinase.

The ST-segment resolution analysis was added to the protocol in July 1998, after the enrollment of the first 37 patients. Of the 265 patients, 7 had ECGs technically inadequate for the assessment and 15 patients were excluded because of left bundle-branch block (10 patients) or idioventricular rhythm (5 patients). Therefore, 243 patients who underwent either primary coronary stenting (122 patients) or thrombolysis (121 patients: 50 patients without and 71 patients with abciximab) formed the population for this analysis. A 6-month visit to the outpatient clinic was carried out in all eligible patients.

**Electrocardiographic Analysis**

A 12-lead ECG was performed before and 90 minutes after initiation of therapy. The sum of ST-segment elevation was measured 20 ms after the end of the QRS complex in leads I, aVL, and V<sub>6</sub> through V<sub>6</sub> for anterior, and leads II, III, aVF, and V<sub>6</sub> through V<sub>6</sub> for nonanterior infarction. The ST-segment elevation resolution was calculated as the initial sum of ST-segment elevation minus the sum of ST-segment elevation on the second ECG divided by the initial sum of ST-segment elevation and expressed as a percentage. Two cutoff points of ST-segment resolution (70% and 30%) were applied, which defined 3 groups of ST-segment resolution: complete (≥70%), partial (<70% to 30%), and no resolution (<30%). ECG measurements were performed in the ECG core laboratory by operators blinded to the scintigraphic and clinical outcome data.

**Tc-99m Scintigraphy**

Patients received an intravenous injection of technetium Tc-99m sestamibi before the initiation of reperfusion therapy. Single-photon emission computed tomography was performed within 6 to 8 hours after the injection of the radionuclide. A follow-up scintigraphy was performed 7 to 14 days after reperfusion treatment. The methods for assessment of myocardial salvage using Tc-99m sestamibi scintigraphy were described in detail previously. The following 3 parameters were calculated: initial perfusion defect and final infarction size (perfusion defect at follow-up studies), both expressed as a percentage of the left ventricle, as well as salvage index, calculated as the proportion of the initial perfusion defect that was salvaged (initial perfusion defect minus final infarction size divided by initial perfusion defect). All measurements were conducted in the scintigraphic core laboratory by investigators who were blinded to the reperfusion therapy received, ST-segment data, and clinical outcomes. Paired scintigraphic studies were available in 89% of the patients.

**Statistical Analysis**

The data are presented as mean±SD, counts, or percentages. Monovariate analyses of differences were conducted by using 1-way analysis of variance (ANOVA) for continuous variables and Pearson χ² test or Fisher’s exact test for categorical variables. Differences in 6-month mortality were analyzed by the log-rank test. The relation between ST-segment resolution and salvage index or final infarct size was assessed by linear regression analysis. The relation between ST-segment resolution and 6-month survival was assessed by the Cox regression analysis. The independence of the main relation of this study between ST-segment resolution and salvage index was checked after adjustment for the influence of other factors by multiple linear regression analysis. Differences were considered significant with a value of P<0.05.

**Results**

Complete resolution (≥70%) was present in 85 patients (35%), partial resolution (<70% to 30%) in 80 patients (33%), and no resolution (<30%) in 78 patients (32%). The comparison of the characteristics between these groups is shown in the Table.

**ST- Segment Resolution, Myocardial Salvage, and Clinical Outcome**

ST-segment resolution as a continuous variable correlated significantly with salvage index (P=0.008), final infarct size (P<0.001), and mortality at 6 months (P=0.03). As shown in Figure 1, salvage index was 0.54±0.32 in the group with complete ST-segment resolution, 0.39±0.36 in the group with partial ST-segment resolution, and 0.33±0.60 in the group with no resolution (P=0.01). Final infarct size was 12.5±12.0% of the left ventricle in the group with complete ST-segment resolution, 20.0±13.9% in the group with partial ST-segment resolution, and 22.7±19.4% in the group with no resolution (P<0.001).
Six-month mortality was 2.4% in the group with complete ST-segment resolution, 6.2% in the group with partial ST-segment resolution, and 12.8% in the group with no ST-segment resolution (P=0.03; Figure 1). The relation between ST-segment resolution and salvage index was also assessed in a multivariate model including all baseline characteristics listed in the Table as well as the type of reperfusion therapy. After adjustment, ST-segment resolution was the second strongest predictor of salvage index (P=0.007, β-coefficient=0.20) after the type of reperfusion regimen, stenting, or thrombolysis (P=0.001, β-coefficient=0.26). No interaction was seen in the model between ST-segment resolution and reperfusion regimen (P=0.26).

Reperfusion Therapy and ST-Segment Resolution

The extent of ST-segment resolution was significantly different between the 2 forms of reperfusion therapy, stenting versus thrombolysis (P<0.001; Figure 2). Complete ST-segment resolution was achieved in 47% of the patients in the stent group versus 23% of those in the thrombolysis group; partial ST-segment resolution was achieved in 32% versus 34% of the patients; and 21% of the stent patients and 43% of the patients with thrombolysis showed no ST-segment resolution. Salvage index was also significantly greater in the stent group, 0.54±0.31 versus 0.30±0.53 in the thrombolysis group (P<0.001; Figure 2). Six-month mortality was 3.3% among patients treated with stenting and 10.7% among those treated with thrombolysis (P=0.02; Figure 2). Within the group of patients who received thrombolysis, there were no significant differences in ST-segment resolution (P=0.1), salvage index (P=0.4), and 6-month mortality (P=0.7) associated with the administration of abciximab.

Discussion

To our knowledge, the present study represents the first prospective investigation of the correlation between the extent of early ST-segment resolution and myocardial salvage determined by Tc-99m sestamibi scintigraphy in patients with AMI treated with either mechanical or thrombolytic reperfusion therapy. In this study, we found that patients with complete ST-segment resolution were more likely to achieve greater myocardial salvage and, consequently, better survival rates at 6 months. In addition, the extent of ST-segment resolution was a sensitive parameter to identify the superiority of stenting over thrombolysis as reperfusion strategy in patients with AMI.

Previous studies in patients treated with thrombolysis or primary percutaneous coronary intervention for AMI showed that the extent of the early ST-segment resolution correlates with the angiographic flow to the infarct area,7,8 the enzymatic9 and scintigraphic final infarct size,10 the left ventricular function, and clinical outcome.7,8,11 We also found a good correlation between a greater ST-segment resolution and a smaller scintigraphic final infarct size and better survival rate at 6 months. The group of patients with a greater ST-segment resolution had, in addition, a lower proportion of anterior infarctions and a smaller initial scintigraphic perfusion defect. The finding of less ST-segment resolution in anterior infarctions has also been reported previously.12 However, the association between ST-segment resolution and salvage index remained significant even after adjustment for initial infarct characteristics and reperfusion regimen. These data underscore the value of paired scintigraphic studies to better evaluate the mechanisms underlying the favorable prognostic value of ST-segment resolution. They also show that the greater ST-segment resolution achieved with stenting compared with thrombolysis is concordant with the higher degree of myocardial salvage and lower 6-month mortality rate observed with the same reperfusion regimen. Therefore, ST-segment resolution may serve as a simple marker of the extent of myocardial salvage achieved with reperfusion therapies.

Acknowledgment

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