The Usefulness of Intracoronary Electrocardiography during Primary Percutaneous Coronary Intervention in Patients with Acute Myocardial Infarction

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ABSTRACT

Background and Objectives: Measurements obtained using an intracoronary electrocardiogram (IC-ECG) reflect the electrical activity in various regions of the myocardium. This technique can be easily used in the catheterization laboratory during percutaneous coronary intervention (PCI) procedures. Furthermore, IC-ECG could be used to evaluate myocardial viability in patients with acute myocardial infarction (AMI). The aim of this study was to evaluate the usefulness of IC-ECG in predicting the microvascular integrity and late improvement of left ventricular (LV) function after primary PCI in patients with AMI.

Subjects and Methods: A total of 78 patients (62 male, 16 female) who underwent primary PCI with stent implantation were enrolled in this study. After the implantation of the stent, IC-ECG was recorded from the tip of an insulated angioplasty guidewire before and after balloon occlusion of the infarct-related artery. The IC-ECG was obtained from the inferior and inferolateral areas in inferior wall MI, or apex and apical anterior wall regions in anterior wall MI. Significant ST segment elevation was defined as a further ST segment elevation of ≥0.2 mV at 80 msec after the J-point in comparison to the baseline value. The microvascular integrity of the myocardium was evaluated by myocardial contrast echocardiography (MCE) one day after the PCI was performed. Six months later, all of the patients were followed up by echocardiography and the wall motion score index (WMSI) and ejection fraction (EF) were measured.

Results: Significant ST elevation was noted in 47 patients (Group A) after coronary occlusion. There was no significant change in the other 31 patients (Group B). MCE showed microvascular perfusion in 41 patients in group A (87%) and in four patients in group B (13%) (p<0.05). The six-month follow-up echocardiography showed that group A had a lower WMSI (1.20±0.18 vs 1.56±0.34, p<0.05) and higher EF (57.6±7 vs 47±11, p<0.05) than group B. The LV end diastolic dimension (LVEDD) in group B was increased compared to group A (p=0.021). The LV end systolic dimension (LVESD) was also increased in group B; however, the LVESD in group A was decreased after six months (p=0.002).

Conclusion: IC-ECG during PCI is a simple and useful method for assessing the microvascular integrity of the myocardium and for predicting the long-term improvement of LV function.

KEY WORDS: Myocardial infarction; Ventricular function; Electrocardiography.

Introduction

Differentiating viable myocardium from necrotic tissue in patients with acute myocardial infarction (MI) has both prognostic and therapeutic significance, especially when a revascularization procedure is being considered. The identification of nonviable myocardium during percutaneous coronary intervention (PCI) in the catheterization laboratory provides additional information that can be used to guide the procedure and subsequent patient follow-up.

Intracoronary ECG (IC-ECG) was first developed by Meier et al.,4) Meier and Rutishauser,5) and Friedman.6) IC-ECG determines the regional myocardial electrical activity and can easily detect myocardial ischemia during PCI with greater sensitivity than surface ECG. IC-ECG...
ECG has been used as a tool for detecting myocardial viability. Myocardial contrast echocardiography (MCE) has emerged as a relatively new and non-invasive echocardiographic tool for the assessment of myocardial perfusion. MCE is another useful method for assessing microvascular integrity and myocardial viability in patients with MI.11-13

We hypothesized that if the local myocardium were viable after MI, the ST segment on the IC-ECG would be elevated from the baseline value. Based on the data collected on the IC-ECG, we evaluated the viable myocardium as determined by MCE, and used echocardiography to compare the left ventricular (LV) function between two groups after six months. The goal was to determine whether IC-ECG could be used to assess the microvascular integrity of the myocardium during the acute phase of MI, and to predict the improvement of LV function at a later date after the MI.

Subjects and Methods

Population and study protocol

A total of 78 patients (62 male, 16 female) with acute ST segment elevation MI who were referred to our catheterization laboratory for primary PCI within 12 hours of symptom onset between March 2005 and January 2006 were enrolled in this study. The diagnosis of acute MI was based on the presence of ischemic chest pain lasting >30 minutes, ST elevation ≥0.1 mV in ≥2 contiguous leads on standard ECG and a ≥three-fold increase in serum levels of creatine kinase. All patients underwent coronary angiography within 60 minutes of admission. The coronary angiography was then followed by stenting of the infarct-related artery (IRA). The exclusion criteria included: contraindication to the coronary angiogram, >50% stenosis in the left main coronary artery, >75% stenosis in another major coronary artery, prior MI, cardiacogenic shock, cardiomyopathy, and right or left bundle branch block detected on the ECG. Each patient provided written informed consent prior to catheterization in accordance with the hospital guidelines. Echocardiography was performed prior to PCI and MCE was performed one day after the PCI. All patients were followed up with echocardiography six months after PCI in order to measure the wall motion score index (WMSI) and ejection fraction (EF).

Coronary angiography and angioplasty

All patients received an intravenous bolus injection of 5000 U of heparin, and 5 mg/h of isosorbide dinitrate was continuously administered intravenously soon after the diagnosis was established. Emergency coronary angiography was performed by the femoral approach according to the standard procedure. An insulated angioplasty guidewire (Wizdom, Cordis, USA) was placed at the distal portion of the target coronary artery. The guidewire served as a unipolar electrode placed distal to the lesion. The external end was connected to the chest lead terminal of a CardioLab® system (Prucka Engineering, Inc. USA) using an alligator clamp. The surface and IC-ECGs were simultaneously recorded on the CardioLab® system. The initial dilatation was performed with an angioplasty balloon catheter of small diameter (2.0 mm) to recanalize and obtain a Thrombolysis in Myocardial Infarction (TIMI) grade 3 flow prior to conducting the study. The baseline level was defined as the ST segment level on the IC-ECG following the improvement of the reperfusion arrhythmia and injury. The IC-ECG and balloon occlusion were recorded in regular sequence ten minutes after the stent implantation.

The balloon diameters used for occlusion were chosen according to the stent size and a short balloon, usually less than 15 mm, was used in all patients. The balloon pressure could not be elevated over 6 atmospheres. Each patient’s balloon was inflated for 120 sec. The IC-ECG was obtained from the inferior and inferolateral wall in cases of inferior wall MI and from the apex and apical anterior wall in cases of anterior wall MI.

Any further ST segment elevation greater than 0.2 mV on the IC-ECG occurring during the balloon occlusion inflation was considered to be a significant change. All ST segment deviations were measured manually at 80 ms after the J-point using the PR interval as the isoelectric point of reference.

Echocardiography

All patients underwent a complete transthoracic study before PCI, which included the analysis of images taken from multiple viewpoints using a commercially available imaging system (Vivid 7, GE Healthcare, USA). Systolic wall thickening and inward wall motion were visually assessed offline by two experienced operators. Investigators who were blinded to the results of the intracoronary and surface electrocardiograms interpreted the results of the echocardiograms. Three apical views (four- and two-chamber and long axis) were analyzed, and the left ventricle was divided into 16 segments. A four point segmental wall motion scoring system was used (1, normal; 2, hypokinesia; 3, akinesia; 4, dyskinesia). Each zone included nine segments, and the apical inferior and apical-lateral segments were considered to be overlapping segments. The infarct zone WMSI was obtained by averaging the sum of the scores of all of the visualized segments in the infarct zone divided by the number of the scored segments. Biplane measurements of LV volumes and EF were also obtained as previously reported.14

Myocardial contrast echocardiography (MCE)

MCE was performed using perfluorocarbon-enhanced sonicated dextrose albumin (PESDA) as the contrast
After the onset of biplane echocardiography, 60 mL of saline was mixed with 40 mL of PESDA and the mixed fluids were then slowly infused intravenously at a rate of 1 mL/min in order to examine uniformly perfused myocardium by microbubbles. High-energy ultrasound was injected to eliminate microbubbles in the myocardium. The refilling pattern of the microbubbles in the myocardial wall was examined and recorded by S-VHS video. The refilling pattern of the microbubbles was analyzed in the apical four-chamber view, the apical three-chamber view and the apical two-chamber view and the presence of reperfusion was evaluated in each view. Myocardial reperfusion abnormalities were identified when microbubbles did not refill through the tenth end-systole after the removal of the high-energy ultrasound. MCE was performed using a digital ultrasound system (Vivid 7, GE Healthcare, USA) and real time MCE was performed using low mechanical index Power Modulation imaging (MI<0.1). The optimal gain was adjusted to the best level prior to the examination and was maintained at that level throughout the examination.  

Statistical analysis
Statistical analysis was performed using SPSS 12.0 for Windows (SPSS Inc. Chicago, Illinois, USA). All quantitative data are presented as the means ± standard deviation. A paired t-test was used to compare the recorded variables within the same group, while the unpaired t-test was used to compare another group [AH3]. Statistical significance was defined at p<0.05.

Table 1. Comparison of the baseline characteristics between the two groups

<table>
<thead>
<tr>
<th></th>
<th>Group A (n=47)</th>
<th>Group B (n=31)</th>
<th>P</th>
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<tbody>
<tr>
<td>Age (years)</td>
<td>57±14</td>
<td>58±10</td>
<td>NS</td>
</tr>
<tr>
<td>Male, n (%)</td>
<td>38 (81)</td>
<td>24 (77)</td>
<td>NS</td>
</tr>
<tr>
<td>HTN, n (%)</td>
<td>20 (43)</td>
<td>11 (35)</td>
<td>NS</td>
</tr>
<tr>
<td>DM, n (%)</td>
<td>16 (34)</td>
<td>10 (32)</td>
<td>NS</td>
</tr>
<tr>
<td>Dyslipidemia, n (%)</td>
<td>19 (40)</td>
<td>12 (39)</td>
<td>NS</td>
</tr>
<tr>
<td>Smoking, n (%)</td>
<td>31 (66)</td>
<td>17 (55)</td>
<td>NS</td>
</tr>
<tr>
<td>Peak CK-MB (ng/mL)</td>
<td>119±123</td>
<td>204±182</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>LVEF (%)</td>
<td>51±7</td>
<td>46±8</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>WMSI</td>
<td>1.35±0.2</td>
<td>1.55±0.3</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Onset to balloon time (hr)</td>
<td>4.6±3</td>
<td>4.8±2</td>
<td>NS</td>
</tr>
<tr>
<td>Door to balloon time (min)</td>
<td>83±17</td>
<td>85±16</td>
<td>NS</td>
</tr>
</tbody>
</table>

HTN: hypertension, LVEF: left ventricular ejection fraction, WMSI: wall motion score index, DM: diabetes mellitus, CK-MB: creatine kinase-MB

Results

Patient characteristics
Emergency angiography revealed that 47 patients (61%) had significant ST segment elevation as shown in Fig. 1, patient 2 (group A), and that there were 31 patients (39%) who did not have significant ST segment elevation (Fig. 1) (patient 1, group B). The patient characteristics for the two groups are summarized in Table 1. There were no significant differences with regard to age, gender, diabetes, hypertension, smoking and dyslipidemia. However, the peak creatine kinase, MB levels were greater in group B than in group A (p=0.012). LVEF was greater in group
In the Table 2, the comparison of the angiographic findings between the two groups is shown.

<table>
<thead>
<tr>
<th>Culprit lesion, n (%)</th>
<th>IRA, Group A</th>
<th>IRA, Group B</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proximal</td>
<td>12 (26)</td>
<td>16 (52)</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Middle</td>
<td>30 (64)</td>
<td>10 (32)</td>
<td></td>
</tr>
<tr>
<td>Distal</td>
<td>5 (10)</td>
<td>5 (16)</td>
<td></td>
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Table 3: A comparison of myocardial contrast echocardiogram (MCE) findings between the two groups.

<table>
<thead>
<tr>
<th>Microvascular perfusion, n (%)</th>
<th>Group A</th>
<th>Group B</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>+, n (%)</td>
<td>41 (87%)</td>
<td>4 (13%)</td>
<td></td>
</tr>
<tr>
<td>-, n (%)</td>
<td>1 (13%)</td>
<td>26 (87%)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>47</td>
<td>31</td>
<td></td>
</tr>
</tbody>
</table>

Results of MCE

The sensitivity and specificity of IC-ECG and its relationship to the findings of microvascular perfusion are shown in Table 3. The IC-ECG had an 87% sensitivity and specificity.

Angiographic findings

Table 2 shows the features observed during coronary angiogram in the two groups. There were no differences in the IRA or final TIMI 3. However, significant differences were found in the culprit lesions and the pre TIMI score. Group B had more proximal lesions (p=0.001) and lower pre-TIMI scores than group A (p=0.004).

In-hospital and out-of-hospital prognosis

There was no difference in the frequencies of recurrent MI, restenosis or death between the two groups (Table 4). Two patients in group A and one patient in group B showed target lesion restenosis at the six-month angiographic follow-up following PCI. Although one patient did show restenosis on the coronary angiogram at six months after PCI, this patient had no symptoms of ischemia and showed no evidence of ischemia in the non-invasive test. Therefore, revascularization was not performed. However, PCI was performed in two patients. There were no cases of recurrent MI or of in-hospital or out-of-hospital death.

Left ventricular function by echocardiography six months after PCI

The differences in LV function according to TTE were compared between the two groups six months after PCI and the results are shown in Table 4. Group A showed greater improvement in LV function than group B: group A had a decreased WMSI (p=0.002) and an increased LVEF (p=0.007) compared to group B. The LV end diastolic dimension (LVEDD) in group B was greater than that of Group A (p=0.021), and the LV end systolic dimension (LVESD) in group B was increased; however, the LVESD in group A decreased after six months (p=0.002).
Discussion

Acute ST elevation myocardial infarction (STEMI) is a critical condition that requires prompt and accurate treatment. Time is one of the most important factors in the successful treatment of STEMI. Early reperfusion allows the residual myocardium to survive, which prevents mechanical and electrical complications that can develop from an acute MI. Therefore, the occluded coronary vessel must be recanalized and treated as soon as possible. It is important to consider the amount of viable myocardium because residual myocardium determines long-term LV function and survival. Therefore, the detection of viable myocardium is useful for post-myocardial risk stratification and patient prognosis. Several diagnostic tools for the detection of viable myocardium are employed such as thallium-201 myocardial scintigrams, dobutamine stress echocardiography, myocardial contrast echocardiography and positron emission tomography. However, imaging studies cannot adequately distinguish between infarcted, irreversibly damaged and stunned or hibernating myocardium. In addition, each of these techniques can only be performed during the post-infarction time period. No studies have been easily performed during PCI. Therefore, IC-ECG is likely to be a very useful method for validating myocardial viability.

A patient’s prognosis can be predicted based on the detection of viable myocardium by IC-ECG, and the prognosis of STEMI is closely correlated with LV function, which can be predicted by the detection of viable myocardium. Both short term and long term survival after STEMI depend on three factors: resting LV function, residual potentially ischemic myocardium and susceptibility to serious ventricular arrhythmias. The most important of these factors is the state of LV function. Therefore, IC-ECG can be used to predict long-term LV function.

In this study, we found good correlation between ST elevation detected on IC-ECG during balloon occlusion performed during the acute stage and an improvement in LV function by echocardiography at the chronic stage. The sensitivity and specificity of significant ST elevation on the IC-ECG performed during PCI to assess viability based on the MCE, and the improvement of LVEF and WMSI on TTE at six months after PCI were very high. Therefore, IC-ECG may provide a very useful method for validating myocardial viability.

The peak CK-MB was significantly higher in patients in group B during PCI and in cases of culprit lesions and pre-TIMI 0; group B had more proximal and pre-TIMI 0 lesions than group A.

Patients with TIMI 0 have a totally occluded coronary artery and must have a larger infarct area or severe reperfusion injury. Furthermore, the remaining viable myocardium is smaller in patients with TIMI 0 than in patients with high-grade TIMI scores. These findings were significant in patients with no significant ST segment elevation.

Therefore, the presence of significant ST segment elevation on the IC-ECG suggested the presence of viable myocardium. Our findings showed that IC-ECG can detect viable myocardium, and could therefore be used as a prognostic tool. Measurements can be easily performed in the catheterization laboratory during PCI. Aggressive unloading therapy may be provided in cases where the IC-ECG shows no significant ST segment elevation. The variables affecting the results of the IC-ECG, including more proximal site, TIMI 0 flow, were interrelated, which might be affect the results of the IC-ECG. However, we can only predict the fate of the myocardium diffusely about whether myocardium is alive or not. In this situation, IC-ECG can provide additional information regarding the viable myocardium and prognosis with high sensitivity and specificity.

This study had several limitations. Our analysis followed patients for six months, which is a relatively short period of time. The survival and quality of life over a longer period of time should be taken into consideration in future studies. Another limitation of our study was that we did not consider the impact of collateral channels during balloon occlusion. The opening of the collateral vessels with severe coronary artery stenosis during PCI might have obscured the ST segment changes in the IC-ECG during the occlusion of the IRA. However, there was no angiographic evidence of preexisting collateral circulation in any of the patients studied, but the possibility remains that collateral circulation could have confounded the results. Another limitation of our study was that although the guidewire was positioned at the most distal part of the vessel, it was not possible to cover all corresponding regions of interest with the guidewire. This may have resulted in discordant findings and may have introduced a certain degree of error in the assessment of myocardial viability based on the ST elevation. It is possible that our results underestimated the diagnostic accuracy of IC-ECG. It is also possible that balloon occlusion for IC-ECG itself might affect the peak CK-MB level. However, the effects of short balloon time and low pressure could be small and may not have altered our results from the IC-ECG.

In conclusion, IC-ECG during PCI is a simple and useful method for assessing the microvascular integrity of the myocardium and for predicting the long-term improvement of LV function in patients with acute MI.

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