Comparative Study of Dobutamine Stress Echocardiography and Dual Single-Photon Emission Computed Tomography (Thallium-201 and I-123 BMIPP) for Assessing Myocardial Viability After Acute Myocardial Infarction

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Discordance between the $^{123}$I-labelled 15-iodophenyl-3-R, S-methyl pentadecanoic acid (BMIPP) and $^{201}$Tl findings may indicate myocardial viability (MV). This study compared dobutamine stress echocardiography (DSE) and single-photon emission computed tomography (SPECT) using the dual tracers for assessment of MV and prediction of functional recovery after acute myocardial infarction (AMI). DSE and dual SPECT were studied in 35 patients after AMI, of whom 28 underwent percutaneous coronary intervention in the acute stage. Dual SPECT was performed to compare the defect score of BMIPP and $^{201}$Tl. The left ventricular wall motion score (WMS) was estimated during DSE and 6 months later to assess functional recovery of the infarct area. The rate of agreement of MV between dual SPECT and DSE was 89% (p<0.01), and the sensitivity and specificity of DSE for dual SPECT in MV assessment was 86% and 93%, respectively. The positive and negative predictive values for functional recovery by dual SPECT were 76% and 67%, respectively, and by DSE were 90% and 79%, respectively. Four of 5 patients with positive MV by dual SPECT, but without functional recovery, had residual stenosis of the infarct-related artery. The WMS and defect scores of BMIPP and $^{201}$Tl were significantly smaller in patients with functional recovery than in those without. Assessment of MV using DSE concords with the results of dual SPECT in the early stage of AMI. DSE may have a higher predictive value for long-term functional recovery at the infarct area. However, a finding of positive MV by dual SPECT, without functional recovery, may indicate residual stenosis of the infarct-related artery, although the number of cases was small. Combined assessment by dual SPECT and DSE may be useful for detecting MV and jeopardized myocardium. Furthermore, the results suggest that functional recovery of dysfunctional myocardium may depend on the size of the infarct and risk area.

Key Words: Acute myocardial infarction; Dobutamine stress echocardiography; Myocardial viability; SPECT
greater than 0.1 mV in at least 2 leads on the admission 12-lead electrocardiogram (ECG) and characteristic rise and fall in plasma creatine kinase isoenzyme MB activity. Twenty-eight of the patients underwent percutaneous coronary intervention (PCI) at the acute stage of myocardial infarction: 18 underwent primary percutaneous transluminal coronary angioplasty (PTCA) and stenting, and 10 had PTCA only. No patient received coronary thrombolytic therapy. The institutional review board of National Kyushu Medical Center approved the study and written informed consent was obtained from all patients.

**Dobutamine Stress Echocardiography**

DSE was performed 7–14 days after the AMI using a Hewlett Packard SONOS 5500 equipped with a 2.5-MHz transducer with the backup of second harmonic imaging. Two-dimensional precordial echocardiograms were acquired from the parasternal long- and short-axis views and from apical 4- and 2-chamber views. Beta-adrenergic blocking agents were discontinued for at least 24 h before testing. After baseline echocardiography, intravenous dobutamine infusion was started at 5 g/kg per min for another 5 min, followed by 10 g/kg per min for another 5 min. We then administered high-dose dobutamine at 20, 30 and, where possible, 40 g/kg per min, for 3 min at each dose, if patient had no major complications, such as frequent arrhythmia, congestive heart failure or post-infarction angina. The ECG was recorded every minute, as was blood pressure by automatic sphygmomanometer. The echocardiography images were digitized on-line to obtain a continuous loop, multi-screen display, and the transferred images were analyzed relative to the baseline images. All images were backed up on VHS videotape.

**Regional Wall Motion Analysis**

Two experienced observers who were unaware of the angiographic and scintigraphic data reviewed all echocardiographic images. Differences in interpretation were resolved by consensus. For wall motion analysis, the left ventricle was divided into 16 segments as recommended by the American Society of Echocardiography. The left ventricle in the basal and the mid-ventricular short axis images was divided to anteroseptal, anterior, lateral, posterior, inferior and inferoseptal segments, and the apex was divided to anterior, lateral, inferior and septal segments. We assessed inward endocardial motion and systolic wall thickening visually to estimate the degree of wall motion abnormality. Each segment was graded on a 4-point scoring system: normal motion (score 0), hypokinesia (score 1), akinesia (score 2) and dyskinesia (score 3). The left ventricular wall motion score (WMS) was calculated by summing the segment score of the infarct area before and after dobutamine infusion. Myocardial viability in the asynergic segment was considered positive if there was improvement equal to or more than 1 grade after low-dose dobutamine compared with the baseline echocardiograms. When worsening or a biphasic response of regional function was induced by high-dose dobutamine, that was also defined as viable myocardium? Because the aim of the study was to evaluate the MV of the infarct area, the WMS of the remote ischemic area was not included. Evaluation of the wall motion abnormality was performed at least 1 cm from the adjacent normal segment to avoid misinterpretation from tethering effects.
Coronary Angiography

Coronary angiography was performed in 28 of the 35 patients in the acute stage of myocardial infarction. Follow-up angiograms were obtained from all those patients before hospital discharge to estimate the extent of coronary artery disease and the patency of the infarct-related vessels. The angiograms were evaluated by more than 3 investigators who quantitatively determined the degree of coronary artery stenosis with calipers on selected coronary angiograms in multiple views. We considered significant coronary arterial disease was present when the luminal diameter of the stenosed vessel was greater than 75% of the normal reference segment. Restenosis of the target vessel was defined as the luminal diameter of stenosis increasing by more than 75%.

Follow-up Study

Follow-up echocardiograms were obtained 6 months (average, 23.4±7.2 weeks) after the first echocardiographic studies. When the wall motion abnormalities of the infarct area had definitely improved in comparison with the initial resting echocardiograms, we considered that those segments showed functional recovery. If the wall motion was persistently dysfunctional, functional recovery was graded as negative. We performed follow-up coronary angiography 3 or 6 months after AMI.

Statistical Analysis

Continuous variables were expressed as the mean±standard deviation. Chi-square analysis or Fisher’s exact test was used to determine differences in the categorical variables of the studies of dual SPECT, DSE and long-term follow-up echocardiography. Two-way analysis of variance for repeated measures were used to assess differences in continuous variables between patients with and without functional recovery. p<0.05 was considered to be statistically significant.

Results

During the follow up period, cardiac events occurred in 5 patients: 3 had coronary bypass surgery and 2 had PTCA. There were no deaths. Two patients were omitted from the follow-up study because they later underwent coronary bypass surgery and a complete follow-up echocardiographic study could not be obtained.

Comparison of DSE With Dual SPECT for MV Assessment in the Early Stage of AMI

The relationship between the assessment of MV by dual SPECT and the comparison of wall motion improvement by DSE is shown in Table 1. We hypothesized that a heart with a normal or mismatched region on the dual SPECT images would have functional reserve of the infarct area identified by low-dose dobutamine. Of the 35 patients with AMI, 21 had mismatched uptake of the dual SPECT tracers and the remaining 14 had a matched defect. In all those with mismatched uptake, the BMIPP score was greater than that of 201Tl.

High-dose dobutamine echocardiography was performed in 29 of the 35 patients and the other 6 patients underwent low-dose dobutamine echocardiography only because of heart failure, ventricular arrhythmia or anginal pain. There were 4 patterns of wall motion response: (1) no significant response (ie, no viability) was observed in 16 patients, (2) improvement only in 14 patients, (3) biphasic response in 4 patients and (4) worsening in 1 patient. On this basis, we assessed MV to be positive in the 19 patients showing patterns 2–4.

The rate of agreement between the assessment of viability by DSE and dual SPECT was 89 % (p<0.001). Of the 21 patients with mismatch on dual SPECT, 18 (86 %) showed improvement of wall motion by DSE, and of the 14 patients with matched defect on SPECT, 13 (93 %) showed no myocardial viability by DSE and all 13 did not show worsening of wall motion with high-dose dobutamine (Table 1).

The relationship between the assessment of MV by dual SPECT (201Tl, BMIPP) and that by DSE in terms of each myocardial segment is shown in Table2. Of the total 560 segments in all patients, normal or mismatched uptake on dual SPECT was observed in 436 (78%), and the remaining 124 (22%) showed matched defect. The rate of agreement between the DSE and dual SPECT findings was 91 % (P<0.01). Of the 436 segments with normal or mismatched uptake by SPECT, 407 (93%) showed MV by DSE, whereas in the 124 segments with matched defect by SPECT, 102 segments (82%) did not show myocardial viability by DSE.

Response to DSE According to Area of Myocardial Infarction

We evaluated the response to DSE in different areas of infarction: 18 cases of anterior infarction, 14 of inferior infarction and 3 of lateral infarction. Of these, a positive response was shown in 11 (61%), 7 (50%) and 2 (66%) cases of anterior, inferior and lateral infarction, respectively (p=NS). Therefore, the DSE response was not related to the site of infarction.

Predictive Value of DSE and Dual SPECT for Long-Term Functional Recovery of the Infarct Area

Functional recovery of the infarct area was assessed 6 months later in 33 patients and the wall motion response to DSE was compared with long-term functional recovery (Table 3). Of 19 patients with a positive response to DSE, functional recovery was recognized in 17 (positive predictive value=90%), and of 14 patients with a negative

<table>
<thead>
<tr>
<th>Table 1 Assessment of Myocardial Viability by Dual SPECT in Comparison With Dobutamine Stress Echocardiography (DSE)</th>
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<tbody>
<tr>
<td>BMIPP/thallium</td>
</tr>
<tr>
<td>Mismatch</td>
</tr>
<tr>
<td>Match</td>
</tr>
<tr>
<td>Total (%)</td>
</tr>
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<td>BMIPP, single-photon emission computed tomography; DSE, dobutamine stress echocardiography; thallium, 201Tl.</td>
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<th>Table 2 Assessment of Myocardial Viability by Dual SPECT in Comparison With DSE: Myocardial Segments</th>
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<tbody>
<tr>
<td>BMIPP/thallium</td>
</tr>
<tr>
<td>Normal/mismatch</td>
</tr>
<tr>
<td>Match</td>
</tr>
<tr>
<td>Total (segments)</td>
</tr>
<tr>
<td>BMIPP, single-photon emission computed tomography; DSE, dobutamine stress echocardiography; BMIPP, 123I-labelled 15-iodophenyl-3-R, S-methyl pentadecanoic acid.</td>
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Table 3  Assessment of Myocardial Viability by Dual SPECT and DSE in Comparison With Long-Term Functional Recovery

<table>
<thead>
<tr>
<th>Group</th>
<th>DSE (+)</th>
<th>DSE (-)</th>
<th>SPECT (+)</th>
<th>SPECT (-)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>17</td>
<td>3</td>
<td>16</td>
<td>4</td>
</tr>
<tr>
<td>Group 2</td>
<td>2</td>
<td>11</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>Total</td>
<td>19</td>
<td>14</td>
<td>21</td>
<td>12</td>
</tr>
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| Group 1; wall motion recovery (+); n=20; group 2; wall motion recovery (-); n=13; total patients: n=33. | DSE, dobutamine stress echocardiography.

Table 4  Assessment of Myocardial Viability by Dual SPECT and DSE in Comparison With Long-Term Functional Recovery in Patients With a History of Percutaneous Coronary Intervention Without Residual Stenosis

<table>
<thead>
<tr>
<th>Group</th>
<th>DSE (+)</th>
<th>DSE (-)</th>
<th>SPECT (+)</th>
<th>SPECT (-)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>15</td>
<td>1</td>
<td>13</td>
<td>3</td>
</tr>
<tr>
<td>Group 2</td>
<td>0</td>
<td>7</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Total</td>
<td>15</td>
<td>8</td>
<td>15</td>
<td>8</td>
</tr>
</tbody>
</table>

ange of DSE for wall motion recovery was 85% and 85%, respectively.

The assessment of MV by dual SPECT compared with long-term functional recovery is shown in Table 3. In 21 patients with positive viability, functional recovery was recognized in 16 (positive predictive value=76%), and 8 of 12 patients with negative viability showed no functional recovery (negative predictive value=67%). The rate of agreement between dual SPECT and long-term functional recovery was 73% (p<0.01) and the overall sensitivity and specificity of DSE for wall motion recovery was 85% and 85%, respectively.

We assessed the prediction of long-term functional recovery by the combination of dual SPECT and DSE. A combined positive DSE and positive SPECT finding had 89% positive predictive value, whereas a negative DSE response associated with a negative SPECT finding had 80% negative predictive value. These values were similar to those of DSE alone.

Predictive Value of DSE and Dual SPECT for Long-Term Functional Recovery of Infarct Area in Patients With Successful PCI

We compared the assessment of MV by dual SPECT and DSE in terms of long-term functional recovery in patients with a history of successful PCI without residual stenosis performed during the acute phase (Table 4). All 15 patients with a positive response to DSE had functional recovery (positive predictive value=100%); 7 of 8 patients with a negative response to DSE did not show functional recovery (negative predictive value=87.5%). The rate of agreement between the response to DSE and wall motion recovery was 96% (p<0.0001).

Of 15 patients with positive response to SPECT, functional recovery was recognized in 13 patients (positive predictive value=87%). Seven of 8 patients with negative response to SPECT did not show functional recovery (negative predictive value=63%). The rate of agreement between response to SPECT and wall motion recovery was 78% (p=0.026).

Changes in the Wall Motion Score

Changes in the WMS on echocardiograms at rest, during low-dose dobutamine and at the long-term follow-up study were analyzed between patients with (group 1) and without (group 2) functional recovery of asynergic wall motion (Fig 2). It was evident that the WMS in group 2 was significantly greater than that in group 1 (p<0.01). In group 1 patients, WMS decreased significantly from baseline (5.1±4.4), during the low-dose dobutamine study (3.6±4.5) to the follow-up study (2.6±3.5) (p<0.01). WMS, however, was unchanged in group 2 patients: 12.9±4.3 at rest, 13.2±3.9 during low-dose dobutamine and 12.7±4.7 at the follow-up.

Difference of SPECT Score

The SPECT score of patients with group 1 and group 2 were compared. Both 201Tl and BMIPP scores were smaller in group 1 than group 2 (5.8±5.1 vs 14.8±5.8, 10.7±5.7 vs 16.4±6.2, respectively, p<0.001). However, the difference of the 2 scores (the extent of viable tissue) was greater in group 1 than in group 2 (4.9±3.5 vs 1.7±2.4, p<0.001).

Discussion

Our studies have demonstrated that the findings from DSE and dual SPECT of 201Tl and BMIPP were concordant for the assessment of MV in the early stage of AMI. DSE had a higher predictive value for the long-term functional recovery of the infarct area than dual SPECT, but because patients with positive MV by dual SPECT, but without functional recovery, had residual stenosis of the infarct-related artery, a combined assessment with dual SPECT and DSE can be useful for detecting both MV and jeopardized myocardium.
Assessment of MV in the Early Stage of AMI: Comparison of DSE With Dual SPECT

Viable myocardium after myocardial infarction can be assessed by DSE, which has a sensitivity for MV ranging from 71% to 97% and specificity from 63% to 96%. In our present study conducted during the early stage of AMI, the sensitivity and specificity of DSE were 85% and 85%, respectively, which are similar diagnostic values for MV to most of the previous studies.

Recent studies report that improvement of wall motion during low-dose dobutamine echocardiography followed by worsening during high-dose dobutamine infusion provides the most accurate information regarding MV. We also evaluated ischemic wall motion by both low-dose and high dose DSE in the present study and after increasing to high-dose dobutamine, 4 patients showed a biphasic response and 1 had worsening of wall motion at the infarct area. Of these 5 cases, 4 appeared to have a significant coronary lesion in the infarct-related vessels. Our results confirm that high-dose dobutamine in addition to low-dose studies can assess viable but jeopardized myocardium.

Thallium imaging is widely used for assessing MV because stress-redistribution images, followed by a second injection of thallium or thallium rest followed by late redistribution imaging, are a sensitive method of identifying viable but dysfunctional myocardium. However, these methods are time consuming, and their specificity for the diagnosis of viable myocardium appears to be substantially poor in comparison with low-dose DSE.

Fatty acid oxidation is impaired in the ischemic myocardium and the radiolabeled fatty acids used in BMIPP high-quality SPECT imaging can identify myocardial ischemia and viability. Furthermore, discrepancies between BMIPP uptake and flow tracers have been observed in patients with coronary artery disease. In patients with myocardial infarction, less BMIPP uptake in comparison with 201Tl uptake is found more frequently in areas subtended by revascularized, as opposed to occluded nonrevascularized coronary arteries. Thus, dual SPECT of BMIPP with flow tracers is a useful method to detect MV and we therefore compared it with low-dose DSE for identification of viable myocardium because these methods have rarely been compared in patients with AMI.

Hambye et al compared low-dose DSE with dual SPECT of BMIPP and sestamibi in patients with chronic left ventricular dysfunction and an old myocardial infarction. They reported that the overall global agreement between the 2 approaches was 77%, and the positive and negative predictive values for scintigraphy were 72% and 88%, respectively. Our results were consistent with or better than their results despite conducting our study in patients with AMI.

The extent of MV may decrease with time after AMI and so it is highly possible that discordance between BMIPP and perfusion imaging is influenced by the time delay after the onset of myocardial infarction. Tamaki et al reported that discordance between BMIPP and thallium imaging decreased 4 weeks after the onset of myocardial infarction in comparison with the results from the preceding 4 weeks. All the previous studies assessing myocardial viability by BMIPP and perfusion imaging were carried out in the early to chronic phase of myocardial infarction whereas we performed these tests 5–10 days after AMI in all patients. Thus, the timing of the diagnostic imaging of our study may be appropriate for accurate evaluation of MV.

Prediction of Long-Term Functional Recovery of the Infarct Area

Prediction of long-term recovery of ischemic left ventricular dysfunction is clinically important. Although most studies have evaluated myocardial viability by comparing regional ventricular function in the follow-up period, recovery is influenced not only by the extent of myocardial viability, but by several other factors, including the residual and/or progressive stenosis of the infarct-related arteries, the interval to the follow-up study, the methods used to identify viability and their criteria, and so forth. Therefore, functional recovery is not always the gold standard of MV.

The extent of residual stenosis of the infarct-related coronary artery has an important effect on the outcome of functional recovery. In our study, the majority of the study patients underwent primary PTCA and stenting in the acute phase of infarction. We showed that the positive predictive value of DSE was 90% and negative predictive value was 79% for functional recovery of the infarct area. The positive predictive value was almost similar, but negative predictive value was relatively better, in comparison with previous studies despite those studies having patients with chronic coronary stenosis who did not undergo primary PTCA in the acute stage of myocardial infarction.

The period and extent of recovery vary according to the tests used to identify myocardial viability. Recent reports revealed that the sensitivities for predicting improvement in regional contractile function after revascularization are higher for all nuclear tracer imaging techniques. However, specificity is highest for low-dose DSE and lowest for 201Tl rest-redistribution, thus favoring the former for prediction of recovery of regional left ventricular function. Our study showed that DSE had higher positive and negative predictive values for functional recovery compared with dual SPECT of 201Tl and BMIPP. The combination of the 2 methods did not significantly change the rate of prediction.

Franken et al, however, reported that the accuracy of combined BMIPP and sestamibi SPECT in predicting segmental functional outcome was higher than that of sestamibi uptake or low-dose DSE alone. Although the reason for the difference between their results and ours is not clear, it is possibly related to the patients in our study undergoing primary PTCA in the acute stage, whereas those in Franken’s study had prolonged ischemia (hibernation) after myocardial infarction, and therefore the response to low-dose dobutamine was less prominent. We also used high-dose as well as low-dose dobutamine, which would also account for the difference in the results for DSE from our study.

Relationship Between Functional Recovery and the Extent of Myocardial Infarction

The present study has shown that the WMS is significantly lower in patients with functional recovery of the infarct area than in those without recovery. Furthermore, the extent-of-defect scores of 201Tl and BMIPP were also both lower in patients with functional recovery. The difference between the defect scores of 201Tl and BMIPP indicates the extent of myocardial viability, and the difference was greater in patients with functional recovery. These results suggest that functional recovery of the infarct area may depend on the extent of myocardial infarction or myocardial viability, observations that have not been clearly defined in previous studies.

Experimental studies indicate that the ratio of myocard-
dial infarct area to risk area increases with increased size of infarction; that is, the extent of myocardial viability is greater with a smaller risk area or infarct size. Although we did not accurately measure the risk area, but it has been suggested that area of low uptake of BMIPP in the early phase of infarction is equivalent to the risk area.

Primary PTCA was performed in 28 of the 35 (80%) patients in our study and although there is no definite evidence, reperfusion injury might have occurred, particularly in cases of large infarcts. Reperfusion injury would extend the myocardial damage outside of the infarct area and so the extent of viable myocardium may have been limited in our study.

Study Limitations

There are several limitations in the interpretation of our comparative results for SPECT imaging and DSE assessment of viable myocardium. An important limitation inherent to the comparison of 2 different approaches is the lack of complete anatomical concordance. Although we matched the SPECT segments with the 2-dimensional echocardiogram, according to the recommendations of the American Society of Echocardiography, this could have lead to some discordance in the location of the abnormality. However, as there was good agreement in the identification of viable myocardium between DSE and dual SPECT in terms of segments as well as of patients, the misalignment may not have been problematic and affected our results.

Timing of the different methods is important factor in a comparative study. The area of hypo-activity of BMIPP decreases with time after myocardial infarction and so the delay between perfusion and BMIPP imaging should be minimized. In the previous studies it has been 2–7 days. We injected the 2 tracers simultaneously and the 2 images were also obtained simultaneously. However, DSE was delayed by a few days after dual SPECT and it is possible that the recovery of myocardial contractile elements occurred during the delay and thus the response to dobutamine in the viable tissue might have been augmented.

The response of the lateral border zone of the infarct and the normal area to dobutamine is important to determine myocardial viability. In accordance with the hyperkinetic motion induced by dobutamine in the normal myocardium, the adjacent ischemic myocardium may also show improved wall motion because the motion of the ischemic segments is affected by the surrounding normal segments (the so-called tethering effect). This phenomenon would have resulted in an underestimation of ischemic myocardium in our study. As shown in Table 2, there were 22 segments with a matched defect on dual SPECT with $^{201}$TI and BMIPP, which indicates necrotic area, despite improved segmental wall motion with dobutamine. It is possible that the tethering effect came into play with these segments and DSE could have overestimated viable myocardium, although we made a point of determining ischemic muscle tissue by the absence of, or decrease in, systolic myocardial thickening and endocardial excursion.

Estimation of stress echocardiography is always problematic because poor imaging is inevitable in some patients. The recent development of harmonic imaging has overcome the problem and we used it in our study, which is another reason why low-dose DSE had a better diagnostic value for MV in our study than in the previous studies.

Finally, the number of study patients was not enough to ascertain any discrepancy between dual SPECT and DSE, so it is not conclusive that positive identification of MV by dual SPECT without functional recovery indicates residual stenosis of the infarct-related artery. Further studies are needed to clarify the usefulness of combining dual SPECT and DSE for detecting jeopardized myocardium.

Clinical Implications

The identification of MV following AMI is of great importance for predicting the amount of salvaged myocardium and prognosis. It is relevant in patients with a significant residual coronary artery stenosis suitable for coronary revascularization. The present study demonstrated that DSE has excellent sensitivity, specificity and, more importantly, positive predictive accuracy in identifying MV after AMI. In particular, DSE is an excellent method for assessing MV in patients who undergo primary PTCA. Dual SPECT of TI-BMIPP mismatch was also a good marker of MV after AMI. Both these modalities are non-invasive and safe, even in the acute phase.

Viable but jeopardized myocardium can be estimated by high-dose as well as low-dose dobutamine echocardiography from a biphasic response or worsening of the segment WMSI. However, high-dose dobutamine sometimes has adverse effects and although serious complications rarely occur, it would be safer to avoid its use in the acute stage of AMI. Our results suggest that it is possible to identify viable but jeopardized myocardium by combining low-dose DSE and resting dual SPECT of thallium and BMIPP.

Conclusion

The present study demonstrated that the assessment of MV using DSE concords with that by dual SPECT in patients with AMI, when 80% of them underwent primary PTCA. DSE may have a higher predictive value for long-term functional recovery of the infarct area in comparison with dual SPECT, but positive MV by dual SPECT without functional recovery may reflect residual stenosis at the infarct-related arteries, although the number of cases in the present study was not enough and there was no definite evidence of MV. Therefore, the combined assessment of dual SPECT and DSE may be the most useful method for detecting MV and jeopardized myocardium. Furthermore, the results suggest that functional recovery of dysfunctional myocardium may depend on the size of the infarct.

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