Prediction of Functional Recovery After Revascularization in Coronary Artery Disease Using $^{18}$F-FDG and $^{123}$I-BMIPP SPECT*

Hideki Sato, MD; Tsutomu Iwasaki, MD; Takuji Toyama, MD; Yoshiaki Kaneko, MD; Tomio Inoue, MD; Keigo Endo, MD; and Ryozo Nagai, MD

**Study objectives:** Clinical studies comparing fatty acid and glucose metabolism in relation to functional recovery of ischemic myocardium after coronary revascularization are scarce. This study evaluated the recovery of regional and global left ventricular function after coronary revascularization in relation to uptake patterns of $\beta$-methyl-iodophenyl-pentadecanoic acid (BMIPP) and fluorodeoxyglucose (FDG) in patients with ischemic myocardial dysfunction.

**Methods:** Patients with ischemic regional wall motion abnormality underwent baseline viability imaging with $^{18}$F-FDG, $^{123}$I-BMIPP, and $^{99m}$Tc-methoxyisobutylisonitrile, and the regions with evidence for maintained tissue viability were revascularized. Mismatch of uptake score between two different single-photon emission CT (SPECT) images in the same myocardial region was graded as low or high mismatch. Regional and global left ventricular functional changes after revascularization were analyzed in relation to mismatch severity and difference of total uptake score in each SPECT image pair. A total of 33 vessels in 30 patients related to the asynergic regions were revascularized, and a total of 100 myocardial segments perfused by the revascularized vessels were analyzed.

**Results:** Segments showing high metabolic mismatch (FDG/BMIPP) had lowest regional wall motion score at baseline, representing the most severely impaired ischemic myocardium, and had highest improvement in regional wall motion score after revascularization. Difference of total uptake score between FDG and BMIPP showed a significant positive correlation with difference of ejection fraction between pre- and postrevascularization ($r = 0.774$, $p < 0.0001$).

**Conclusions:** Combined metabolic SPECT imaging with FDG and BMIPP has the potential to identify severely impaired ischemic myocardium leading to more efficient therapeutic management of patients with coronary artery disease.

(CHEST 2000; 117:65–72)

**Key words:** coronary artery disease; $^{18}$F-fluorodeoxyglucose; functional recovery; $^{123}$I-$\beta$-methyl-iodophenyl-pentadecanoic acid; single-photon emission CT

**Abbreviations:** BMIPP = $\beta$-methyl-iodophenyl-pentadecanoic acid; CABG = coronary artery bypass grafting surgery; EF = ejection fraction; FDG = fluorodeoxyglucose; MIBI = methoxyisobutylisonitrile; PET = positron emission tomography; PTCA = percutaneous transluminal coronary angioplasty; SPECT = single-photon emission CT

With recent improvements in the treatment of acute myocardial infarction, more patients with advanced coronary artery disease and reduced left ventricular function survive the acute event and may present in the postinfarction period with symptoms of either angina pectoris or heart failure. Thrombolytic therapy or acute percutaneous transluminal coronary angioplasty (PTCA) is now more frequent and successful in older patients. Preoperative prediction of the effect and risk/benefit assessment for subsequent elective revascularization have become more important information for an efficient therapeutic management. Positron emission tomography (PET) using $^{18}$F-fluorodeoxyglucose (FDG) is considered the “gold standard” for noninvasive assessment of tissue viability. However, FDG-PET is an expensive and, therefore, not widely used technique. Recently, it has been demonstrated that detection of FDG by single-photon emission CT (SPECT) with ultra-high-energy collimator provides similar clinical information on tissue viability.1–4
Fatty acids are the main energy source for the normoxic myocardium, and there is a long history of investigation on cardiac metabolism using fatty acids.\textsuperscript{5,6} \textsuperscript{123}I-\textbeta-methyl-iodophenyl-pentadecanoic acid (BMIPP) is currently considered to be a suitable tracer for monitoring regional cardiac fatty acid uptake in the human,\textsuperscript{7,8} and it has been recently suggested that BMIPP used in conjunction with flow tracers may also provide information on tissue viability.\textsuperscript{9 –15} Moreover, combined imaging of FDG with scintigraphic flow tracers such as \textsuperscript{201}Tl or \textsuperscript{99m}Tc-methoxyisobutylisonitrile (MIBI) has been reported to be a useful approach for assessment of myocardial viability.\textsuperscript{16 –21} However, clinical studies comparing fatty acid and glucose metabolism in relation to functional recovery of ischemic myocardium after coronary revascularization, the useful "gold standard" for viability, are extremely scarce.

The aim of this study was, therefore, to evaluate the recovery of regional and global left ventricular function after coronary revascularization in relation to uptake patterns of FDG and BMIPP in patients with ischemic myocardial dysfunction.

**Materials and Methods**

**Patient Selection and Subsequent Therapy**

Nuclear imaging for assessment of myocardial flow and viability (\textsuperscript{99m}Tc-MIBI, \textsuperscript{18}F-FDG, \textsuperscript{123}I-BMIPP SPECT) was performed between July 1995 and June 1997 in patients with myocardial infarction and ischemic regional wall motion abnormalities considered for coronary revascularization. Patients with recent myocardial infarction (< 6 weeks), unstable angina, or concomitant heart disease (cardiomyopathy, valve disease) were excluded. Patients with diabetes mellitus were also excluded.

Patients with a cardiac event between baseline studies and planned revascularization and patients with left bundle branch block, atrial fibrillation, or permanent pacemaker were excluded, because these factors would have influenced quantitative assessment of regional wall motion. B-Receptor blocking agents were withdrawn for \textgtrsim 48 h before angiography. Revascularization was performed on the patients if they fulfilled the following inclusion criteria: (1) significant coronary artery disease (diameter stenosis \textgtrsim 70\%) in at least one major vessel proven by recent coronary angiography; (2) reduced contractility in the region perfused by a vessel considered for revascularization; and (3) angina pectoris despite medical therapy. Revascularization was performed on the vessel responsible for asynergic myocardial region considered as viable by scintigraphic finding (scintigraphic viability is defined in the subsequent section on image interpretation).

Physicians were not restricted from assessing the nuclear data for treatment decisions. PTCA was attempted in patients with single-vessel disease. In patients with multivessel disease (undergoing PTCA), only stenoses with evidence for ischemia or preserved viability were dilated, and the patients were revascularized surgically when PTCA was thought to be difficult to perform. Complete revascularization of viable regions was attempted by coronary artery bypass grafting surgery (CABG) if technically feasible.

To minimize a serious influence of differential attenuation of \textsuperscript{18}F vs \textsuperscript{123}I and \textsuperscript{99m}Tc, patients in whom revascularization was performed on the right coronary artery were excluded from analysis. Furthermore, patients with dominant left circumflex artery that perfused both inferior and posterobasal walls were also excluded. The protocol was approved by the local institutional ethical board, and patients gave informed consent before participation.

**Imaging Protocols**

For all acquisitions, a large field-of-view dual-head camera (Multispect 2; Siemens, Hoffman Estates, IL) was used, and a total of 30 views were obtained over 180° taking 60 s per view. Transaxial slices were reconstructed from the raw scintigraphic data filtered backprojection using a Butterworth filter (third-order and a cutoff frequency of 0.5) without attenuation correction. Further reconstruction yielded short- and long-axis slices perpendicular to the heart axis.

**Myocardial Perfusion:** To delineate regional myocardial perfusion, \textsuperscript{99m}Tc-MIBI SPECT was performed under resting conditions on a different day. Fifty minutes after the injection of 600 MBq \textsuperscript{99m}Tc-MIBI, patients were imaged during a fasting state using the same camera and acquisition mode. The same collimator was used for both the BMIPP and the \textsuperscript{99m}Tc-MIBI studies. \textsuperscript{123}I-BMIPP SPECT: Three days after the MIBI SPECT, metabolic imaging with \textsuperscript{123}I-BMIPP was performed at rest during a fasting state of \textgtrsim 12 h. The camera was equipped with a low-energy, high-resolution collimator, and imaging was started 30 to 45 min after the IV injection of 111 MBq of \textsuperscript{123}I-BMIPP.

**FDG SPECT:** Three hours after the completion of BMIPP imaging, 75 g of oral glucose loading was performed. One hour after the glucose loading, 740 MBq of \textsuperscript{18}F-FDG was injected, and the acquisition was initiated 1 h after the injection of \textsuperscript{18}F-FDG using an ultra-high-energy collimator specifically designed for 511-keV photons.

**Coronary and Left Ventricular Angiography**

Cardiac catheterization was performed using the Judkins technique and recorded on cineradiography film at 50 frames/s. Left ventriculography was obtained in the 30° right anterior oblique view and 45° left anterior oblique with 15° cranial view during deep inspiration. Vessels were documented in at least two identical orthogonal projections at baseline and follow-up. Follow-up angiography was performed 3 months after the planned revascularization.

**Myocardial Revascularization**

Successful dilation was defined as > 20\% reduction in luminal diameter stenosis and < 50\% residual stenosis. Restenosis or graft failure was considered to have occurred if the percent diameter stenosis was > 50\% in the dilated lesion or coronary artery bypass grafts.

**Image Interpretation**

Semiaquantitative visual analysis of the SPECT data was performed. Short-axis and vertical long-axis slices of the SPECT images were divided into seven segments (anterobasal, anterior, apical, inferior, posterobasal, septal, and lateral walls) corresponding to the left ventriculographic segments of the American Heart Association criteria (Fig 1). The anterobasal, anterior, septal, and apical walls corresponded to the territory of the left anterior descending artery, the lateral wall to the territory of the
left circumflex artery, and the inferior and posterobasal wall to the territory of the right coronary artery.

In each segment of left ventriculographic image, regional wall motion was graded on a 4-point scoring system (3 = normal; 2 = hypokinetic; 1 = akinetic; and 0 = dyskinetic) and ejection fraction (EF) was calculated by the area-length method. The differences of regional wall motion score and EF between baseline and follow-up were calculated in each patient.

Segmental uptake of the tracer at baseline was graded on a 3-point scoring system by visual assessment (2 = normal; 1 = mild-to-moderate reduction in tracer uptake; and 0 = severe reduction in tracer uptake or absence of tracer uptake). The definition of regional viability was applied for the segment showing score 1 or 2 on FDG or BMIPP or MIBI SPECT image. The following definitions of metabolic or metabolic/perfusion mismatch between two nuclear imaging techniques at baseline were applied: low mismatch, the difference of the uptake score was 1; and high mismatch, the difference of the uptake score was 2. The sum of scores for seven segments at baseline was defined as a total uptake score in each patient. Differences of total uptake score between each SPECT image were calculated.

**Statistical Analysis**

Data were expressed as mean ± SD. Student’s t test for unpaired data or one-way analysis of variance for factorial analysis was used to test the differences between groups. A p value < 0.05 was considered significant.

**Results**

**Patient Baseline Data and Subsequent Therapy**

Thirty-nine consecutive patients (36 with PTCA, 3 with CABG) in whom revascularization was performed only on the left coronary artery were recruited prospectively. Follow-up angiography was performed at 3.9 ± 1.1 months (range, 3 to 7 months) after revascularization in all patients. Of these patients, nine patients who received PTCA were excluded from the study because restenoses were proven in the revascularized vessels by follow-up angiography. The remaining 30 patients (26 men, 4 women; age, 66 ± 10 years) were the final study cohort. Clinical and angiographic data of these 30 patients are summarized in Table 1. All patients were stable during the study, and none presented with unstable angina or myocardial infarction between investigations. Of these patients, all had a history of chronic (≥ 6 weeks) myocardial infarction. Twelve patients (40%) had a history of several infarcts. The interval between baseline catheterization and baseline nuclear imaging was 6 ± 2 days. The interval between baseline viability imaging and subsequent revascularization was 9 ± 4 days, resulting in an overall interval of 14 ± 6 days between recruitment and revascularization.

All patients showed regional asynchrony on baseline left ventriculogram and underwent elective revascularization, with 10% of them undergoing CABG and 90% receiving PTCA with successful dilation at baseline. The right coronary artery was the dominant vessel in all patients. Follow-up angiography confirmed no angiographic evidence of restenosis or graft failure in these 30 patients. A total of 33 vessels (22 left anterior descending artery, 11 left circumflex artery) related to the asynergic regions were revascularized, and a total of 100 myocardial segments corresponding to the territory of the left anterior descending artery or left circumflex artery were analyzed.

**Metabolic Imaging and Regional Wall Motion Changes at Follow-up**

The results of serial changes of regional wall motion score by the revascularization in relation to

---

**Table 1—Baseline Clinical and Angiographic Data of the Patients**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total patients</td>
<td>30</td>
</tr>
<tr>
<td>Mean ± age, yr</td>
<td>66 ± 10</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>26</td>
</tr>
<tr>
<td>Female</td>
<td>4</td>
</tr>
<tr>
<td>Myocardial infarction</td>
<td>30</td>
</tr>
<tr>
<td>Frequent myocardial infarctions</td>
<td>12</td>
</tr>
<tr>
<td>Location</td>
<td></td>
</tr>
<tr>
<td>Anterior</td>
<td>22</td>
</tr>
<tr>
<td>Lateral</td>
<td>11</td>
</tr>
<tr>
<td>Inferior</td>
<td>6</td>
</tr>
<tr>
<td>Coronary anatomy</td>
<td></td>
</tr>
<tr>
<td>One-vessel disease</td>
<td>22</td>
</tr>
<tr>
<td>Two-vessel disease</td>
<td>7</td>
</tr>
<tr>
<td>Three-vessel disease</td>
<td>1</td>
</tr>
<tr>
<td>Mean ± SD ejection fraction, %</td>
<td>46 ± 8</td>
</tr>
</tbody>
</table>

*Data are presented as No. unless otherwise indicated.*
different nuclear imaging patterns are presented in Table 2. Regional wall motion score improved in 79 segments (79%) from 1.6 ± 0.8 to 2.4 ± 0.7 (p < 0.001). There was no change of regional wall motion score in the remaining 21 segments. Ninety-six segments were considered as viable with tracer uptake on at least one SPECT scan. Only four segments showed absent uptake on both FDG and BMIPP SPECT scans and were considered as nonviable. Forty segments showed tracer uptake by FDG, BMIPP, and MIBI. Of these segments, 38 myocardial segments (95%) showed improvement of regional wall motion score at follow-up. It is noteworthy that 22 myocardial segments were considered as nonviable on BMIPP or MIBI SPECT scan, whereas 18 of these 22 segments were considered as viable on FDG scan and 12 of the 18 segments (66%) showed improvement of regional wall motion score at follow-up. A representative case showing improvement of regional wall motion score in the myocardial segments in which only FDG uptake was observed is shown in Figures 2, 3. Three of four segments showing an absence of uptake of FDG as well as of MIBI and BMIPP showed no change of regional wall motion score.

Metabolic and Metabolic/Perfusion Mismatch and Regional Wall Motion Changes

Segments showing match or mismatch of uptake score between two nuclear images at baseline are summarized in Table 3. Mismatch of FDG/BMIPP (FDG uptake greater than fatty acid) was observed in 64 segments. Furthermore, FDG/MIBI mismatch (FDG uptake greater than perfusion) and BMIPP/ MIBI mismatch (BMIPP uptake lower than perfusion) were observed in 38 and 40 segments, respectively. Of these segments, low mismatch was documented in 86 segments (36 segments with FDG/BMIPP mismatch, 30 segments with FDG/MIBI mismatch, 20 segments with BMIPP/MIBI mismatch) and high mismatch was documented in 56 segments (28 segments with FDG/BMIPP mismatch, 8 segments with FDG/MIBI mismatch, 20 segments with BMIPP/MIBI mismatch; Table 3).

There were no significant differences between the regional wall motion score at follow-up in any of the groups (Fig 4). Baseline regional wall motion score was significantly lower compared with that of postrevascularization in all SPECT image pairs. It is striking that high mismatch segments in the set of

Table 2—Frequency of Myocardial Segments Showing Regional Wall Motion Score Improvement in Relation to Different Nuclear Viability Patterns of Combined SPECT Imaging at Baseline*

<table>
<thead>
<tr>
<th>FDG</th>
<th>BMIPP</th>
<th>MIBI</th>
<th>S-RWMI(LAD/LCX)/total seg. (LAD/LCX)</th>
</tr>
</thead>
<tbody>
<tr>
<td>+</td>
<td>+</td>
<td>+</td>
<td>38 (26/10)/40 (28/14)</td>
</tr>
<tr>
<td>+</td>
<td>–</td>
<td>–</td>
<td>28 (25/0)/38 (30/8)</td>
</tr>
<tr>
<td>+</td>
<td>–</td>
<td>–</td>
<td>12 (12/0)/18 (18/0)</td>
</tr>
<tr>
<td>–</td>
<td>–</td>
<td>–</td>
<td>1 (1/0)/4 (4/0)</td>
</tr>
</tbody>
</table>

*+ = viable; – = nonviable; LAD = segments perfused by left anterior descending artery; LCX = segments perfused by left circumflex artery; S-RWMI = regional wall motion score improvement.

Figure 2. Vertical long-axis SPECT images of a 66-year-old man with anterior myocardial infarction and old inferior myocardial infarction. Successful PTCA of the left anterior descending artery was performed and no restenosis was disclosed at the 3-month follow-up angiography. Normal uptake of FDG is evident except for apical and inferior wall with decreased uptake (left). Absence of uptake of BMIPP is observed in the extensive area of anterior to inferior wall with decreased uptake in the inferior wall, indicating viability mismatch in the anteroseptal to inferior wall (center). Decreased uptake of MIBI is observed in the reduced area compared with the defect area of BMIPP with absence of uptake in the apex (right). High mismatch of FDG and BMIPP image pair was observed in myocardium corresponding to left ventriculographic segment 2 (anterior wall).

Figure 3. Baseline left ventriculograms showed akinesis in segments 2, 4, 5, and 6, and dyskinesis in segment 3 (upper panels). Follow-up angiography (lower panels) disclosed substantial improvement of the preoperative asynergic anterior wall, where high mismatch of FDG and BMIPP was observed, after PTCA with improvement of global EF. ED = end diastole; ES = end systole.
FDG/BMIPP showed lowest regional wall motion score, resulting in the most significant difference of regional wall motion score between pre- and post-revascularization (Fig 4). In other words, segments showing high metabolic mismatch of FDG/BMIPP had impressively highest improvement of regional wall motion score after revascularization.

### Total Uptake Score and Functional Changes

Total uptake score of each tracer was correlated with baseline EF (FDG: $r = 0.54$, $p = 0.012$; BMIPP: $r = 0.62$, $p = 0.002$; and MIBI: $r = 0.45$, $p = 0.048$). The difference of total uptake score in the set of FDG and BMIPP was strongly correlated with the difference of EF ($r = 0.74$, $p < 0.0001$) and less strongly correlated in the set of BMIPP and MIBI SPECT image pair ($r = 0.50$, $p = 0.007$; Fig 5). No significant correlation between difference of total uptake score and difference of EF was found in the set of FDG and MIBI ($r = 0.21$, $p = 0.31$).

### Discussion

#### Myocardial Revascularization

In the present study, segmental analysis was not performed on the posterobasal and inferior wall regions (territory of the dominant right coronary artery) to minimize the probable differential attenuation of $^{18}$F vs $^{123}$I and $^{99m}$Tc in the inferoposterobasal wall, which could not be corrected in the present SPECT system.22–25 We studied the revascularized region and analyzed the difference of EF and total uptake score, which reflects the change of the revascularized region because both regional wall motion score and uptake score of the inferior region showed no changes in this study (data not shown). Moreover, patients with anterior wall myocardial infarction exhibited a more-depressed left ventricular function and poorer prognosis than patients with inferior infarction.26,27

#### FDG-SPECT

The spatial resolution of the ultra-high-energy collimator used in this study was somewhat lower than that of a conventional collimator. By means of a phantom study, the full width at half maximum of the ultra-high energy collimator was 12.9 mm when the distance from a line source was 10 cm, whereas full width at half maximum of the conventional collimator used in this study for $^{123}$I-BMIPP and $^{99m}$Tc-MIBI SPECT was 9.2 mm. However, these differences were small enough to be disregarded because the segmental area of the left ventricle studied for viability in this study was about $5 \times 5$ cm, which was more than threefold the full width at half maximum of the ultra-high energy collimator used for $^{18}$F-FDG SPECT. Thus, the limited spatial resolution of
FDG SPECT is not considered to be a major handicap for viability assessment in this study.

**Myocardial Viability**

In this study protocol, only patients with evidence for preserved viability underwent revascularization. This nonrandomized recruitment accounts for a biased high sensitivity. This seemed to be a limitation of the interventional clinical study. However, serial analysis of regional wall motion score revealed that 12 of 18 segments (67%) with FDG uptake but without BMIPP and MIBI uptake exhibited regional wall motion score improvement at follow-up. These 12 segments (12% of total segments) would not have been revascularized if the viability decision had been based on results of BMIPP and MIBI. These facts proved that FDG SPECT was useful in identification of residual viable myocardium.

**Metabolic Mismatch and Functional Change**

It has been demonstrated that detection of FDG by SPECT with ultra-high-energy collimators provides a clinical information on tissue viability. Recent studies reported that combined metabolic SPECT imaging using FDG with scintigraphic perfusion markers such as 99mTc-MIBI might be a useful approach in the assessment of myocardial viability. More recently, it has been suggested that BMIPP/perfusion imaging may also provide information on tissue viability. Preservation of oxidative metabolism, as assessed by 11C-acetate using PET, has been found to be necessary for functional recovery after revascularization. Although 11C-acetate showed a higher positive and negative predictive value for functional recovery than did FDG PET, metabolism of 11C-acetate cannot be assessed by conventional gamma camera; alternatively, BMIPP imaging is simple and can be performed on a routine basis because fatty acid uptake is closely related to oxidative, mitochondrial metabolism.

We designed the present study to investigate the changes of regional and global function after revascularization with respect to the different nuclear image combination. It is noteworthy that metabolic mismatch (glucose/fatty acid mismatch) was superior to metabolic/perfusion mismatch (FDG/MIBI or BMIPP/MIBI) for accurate prediction of the regional and global functional recovery after revascularization.

In ischemic myocardium, suppressed fatty acid metabolism is associated with enhanced glucose utilization, resulting in an increase of metabolic mismatch, which is recognized as the mismatch of uptake score between FDG and BMIPP SPECT. A higher increase of metabolic mismatch will be observed in the myocardium under more serious ischemic circumstances, and the function of such myocardial regions will be more suppressed. Therefore, revascularization of the myocardium with higher metabolic mismatch will be expected to have a more beneficial effect.

Regional wall motion scores of high metabolic mismatch (FDG/BMIPP) segments were most suppressed at baseline and improved to the same level as the other groups at follow-up, resulting in the highest improvement of regional wall motion score. This line of evidence possibly caused the significant and strong correlation between the difference of EF and the difference of the total uptake score of FDG and BMIPP.

![Figure 5](http://journal.publications.chestnet.org/pdfaccess.ashx?url=/data/journals/chest/21938/)
BMIPP. These findings showed that the combined SPECT imaging of FDG in combination with BMIPP is useful in identification of myocardial viability and promises more accurate prediction of the effect of coronary revascularization, leading to identification of patients who benefit most from revascularization.

Study Limitations

Some limitations of our study should be acknowledged. First, complete improvement of left ventricular function after revascularization may occur up to 1 year, so the period for assessment of functional recovery used in this study may be rather short to assess left ventricular function after revascularization. Further studies are needed to answer this question. Second, because crossover of peak energy of $^{99m}$Tc and $^{123}$I has to be avoided, the perfusion studies were conducted 3 days apart. This raises the possibility that intervening events could have influenced the outcome in individual cases. However, this possibility is unlikely because all patients were in stable condition, without the occurrence of cardiac events during the study period. Finally, although viability testing is predominantly important in patients with severely depressed left ventricular function, mean left ventricular EF among the 30 patients in this study was $46 \pm 8\%$. Further studies on the subset of patients with severe left ventricular function are required.

CONCLUSION

Significant discrepancy of glucose/fatty acid metabolic SPECT imaging was observed in severely impaired ischemic myocardium. Combined metabolic SPECT imaging of FDG in combination with BMIPP has the potential to identify severely impaired ischemic myocardium with prognostic implications for functional outcome predicting the effect of revascularization as well as for identification of patients who may benefit most from revascularization.

ACKNOWLEDGMENT: We thank Tadashi Suzuki, MD, Department of Laboratory Sciences, Gunma University School of Medicine and Norio Kanazawa, MD, Department of Internal Medicine, National Takasaki Hospital for their collaborations and Katsumi Tomiyoshi and Kunio Matsubara, the Division of Cyclotron Laboratory in Gunma University School of Medicine for their technical assistance.

REFERENCES

5 Opie LH. Metabolism of the heart in health and disease: part I. Ann Heart J 1988; 76:685–698


26 Welty FK, Mittleman MA, Lewis SM, et al. Significance of location (anterior versus inferior) and type (Q-wave versus non-Q-wave) of acute myocardial infarction in patients undergoing percutaneous transluminal coronary angioplasty for postinfarction ischemia. Am J Cardiol 1995; 76:431–435


