THE SIGNIFICANCE OF RESTING THALLIUM-201 DELAYED SPECT FOR ASSESSING VIABILITY OF INFARCTED REGIONS

— Comparison with Exercise Thallium-201 SPECT —

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To clarify the clinical significance of resting thallium-201 (Tl) delayed SPECT for assessing the viability of infarcted regions, we studied resting Tl initial and delayed Tl SPECT one week after exercise (Ex) Tl SPECT in 38 patients (40 regions) with old myocardial infarction (OMI) and 35 patients (37 regions) with effort angina pectoris (EAP). Analysis of resting Tl and Ex Tl SPECT divided the patients with OMI into 3 groups. Twenty-three patients whose perfusion defect (PD) on resting delayed image was same as that of Ex delayed image were divided into 12 patients with Ex Tl redistribution (RD) (G1) and 11 patients without Ex Tl RD (G3). Fifteen patients showed a decrease of PD on resting delayed image compared with Ex delayed image (G2). Thirty-five patients with EAP were divided into 18 patients who had no PD on Ex delayed image (G1) and 17 patients whose PD did not disappear on Ex delayed image but disappeared on resting delayed image (G2). The increase of pulmonary artery wedge pressure on Ex was higher in G2 than in G1 of both OMI and EAP (OMI; G1 15 ± 16 mmHg vs G2 27 ± 7 mmHg; $p < 0.01$, EAP; G1 12 ± 7 mmHg vs G2 22 ± 6 mmHg; $p < 0.05$). The percent Tl uptake of the PD on Ex Tl initial images was lower in G2 than in G1 of both OMI and EAP (OMI: G1 $63 \pm 7\%$ vs G2 $55 \pm 9\%$; $p < 0.05$, EAP: G1 $72 \pm 7\%$ vs G2 $65 \pm 9\%$; $p < 0.05$). That of the PD on resting Tl delayed images was higher in G1 and G2 than in G3 of OMI (G1 $78 \pm 7\%$, G2 $74 \pm 8\%$, G3 $41 \pm 10\%$; G1 vs G3, G2 vs G3 $p < 0.001$). The prevalence of akinetic or dyskinetic wall motion on left ventriculography was higher in G2 than G1, and in G3 than G2 (G1 24.3%, G2 52.2%, G3 85.7%; $p < 0.001$). Thus, in patients with OMI the decrease of Tl PD on resting Tl delayed images compared with Ex delayed images may indicate severe ischemia induced by stress as well as in patients with EAP, and furthermore the presence of viable muscle. On the other hand, the infarcted region without decrease of Tl PD on resting delayed images may lack viable muscle.

EXERCISE thallium-201 (Tl-201) initial and delayed images are useful for distinguishing viable from nonviable myocardial segments with coronary artery stenosis and predicting the response to revasculariza-

Key words:

Resting Tl-201 delayed emission computed tomography
Infarcted region
Viability

tion!¹⁻³ However the exercise Tl-201 delayed scan may occasionally underestimate the viability of myocardium⁴ but we have no appropriate method to assess the viability of regions with perfusion defect on exercise Tl-201 delayed image.

Ritchie et al⁵ reported that the defect size was often smaller on the rest images than the exercise delayed images. Furthermore, Ber-

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||; location of region of interest(ROI)

Fig.1. Schematic representation of left ventricular segments of thallium-201 ECT and location of region of interest (ROI).

ger et al⁶ demonstrated that patients with angina pectoris might show redistribution of Tl-201 at rest. The purpose of the present study was to determine the significance of resting Tl-201 delayed images in infarcted regions. We performed both exercise Tl-201 initial and delayed scans and resting Tl-201 initial and delayed scans in patients with old myocardial infarction, and compared the significance of the resting Tl-201 delayed images in infarcted regions with that in non-infarcted regions of patients with effort angina pectoris.

SUBJECTS AND METHODS

Subjects: The subjects were 38 patients with old myocardial infarction (40 infarcted regions) who revealed electrocardiographic abnormal Q waves and 75% or more coronary artery stenosis on coronary arteriography. No patients had revascularization in both early and chronic periods. The patients who showed redistribution on the non-infarcted regions on exercise Tl-201 initial and delayed images were excluded. Thirty subjects were male and 8 were female. Their mean age was 61 ± 7 years (range 50–69).

Twenty-five had anterior infarction, 10 inferior infarction, 1 lateral infarction and 2 had both anterior and inferior infarction. Coronary arteriography showed one vessel disease in 18 cases, two vessel disease in 11 cases and three vessel disease in 9 cases. The patients with 99 percent or more stenosis in all three coronary arteries were excluded. The results were compared with those of 35 patients with effort angina pectoris (37 regions) who revealed normal electrocardiogram at rest, significant organic coronary artery stenosis, no wall motion abnormality and no perfusion defect on resting Tl-201 delayed image. Twenty-four were male and 11 were female. Their mean age was 59 ± 4 years (range 49–69). Twelve patients had anteroapical perfusion defect on exercise Tl-201 initial ECT, suggesting lesions of the left anterior descending artery, 14 were lesions of the right coronary artery and 11 were lesions of the left circumflex artery. Coronary arteriography showed one vessel disease in 10 cases, two vessel disease in 13 cases and three vessel disease in 12 cases.

Tl-201 emission computed tomography (ECT): One week after the maximal exer-

cise Tl-201 ECT, the resting Tl-201 ECT images were obtained. Patients took the symptom-limited maximal exercise which was terminated by the occurrence of chest pain or leg fatigue, or significant ST depression. The 25 watt per 3 min incremental protocol by ergometer in the supine position was used, while monitoring electrocardiogram, heart rate and blood pressure. Significant ST depression was defined as 1.0 mm or greater at 0.08 seconds after J point with a horizontal or down-sloping configuration on any leads. ST elevation on the leads showing abnormal Q in patients with old myocardial infarction on exercise did not require termination of exercise. The patients with effort angina pectoris with ST elevation on exercise were excluded. One hundred and eleven MBq of Tl-201 was injected intravenously at the maximal point, then patients were encouraged to continue exercise for an additional 1 min. Ten minutes after Tl-201 injection, a Tl-201 ECT image was taken, designated as the "exercise initial image". Three hours after injection, the second Tl-201 ECT image was taken, designated as the "exercise delayed image". One week after the exercise Tl-201 scans, 111 MBq of Tl-201 was injected at rest and then the "resting initial image" and the "resting delayed image" were taken 10 min and 3 h after the injection, respectively. A rotating gamma camera (Shimadzu LFOV) and analyzing system (Scintipac 2400) were used for ECT. Each item of imaging data was acquired by 180 degree rotation (from 60 degree left posterior oblique view to 60 degree right anterior oblique view). A total of 36 views obtained at 5 degree intervals were analyzed by the convolution method and Butter Worth filter without attenuation correction. Two 18 mm-slice left ventricular myocardial images, i.e., vertical and horizontal long axis images showing the central portion of the heart as indicated in Fig. 1, were reconstructed. The left ventricular wall was divided into 9 segments, based on the angiographic ventricular segmentation recommendations of the American Heart Association⁷ superscript. Small sized (5×5 pixels) regions of interest (ROIs) were set within these 9 segments and percentage Tl-201 uptake was calculated as the ratio of Tl-201 activity to the maximal Tl-201 activity in

each image to assess the Tl-201 perfusion defect. The mean counts per pixel in the ROIs ranged from 320 to 480 in normal segments and from 120 to 390 in perfusion defect segments. An area of scintigraphic Tl-201 perfusion defect was defined as the segments with percentage Tl-201 uptake below the normal lower limit (normal mean value - 2SD), which was obtained by normal volunteers⁸. The "redistribution" was defined when the Tl-201 uptake of defect segments was assessed to be increased clearly in the delayed image compared with the initial image visually by three experienced observers, who did not know the results of cardiac catheterization. The "decrease" of Tl-201 perfusion defect was defined as a decrease in the number of perfusion defect segments or an increase in the Tl-201 uptake of defect segments on resting delayed images compared with the exercise delayed images. The percentage Tl-201 uptake of the infarcted region or ischemic region was calculated as the mean value of the percentage Tl-201 uptake on the perfusion defect segments on the exercise Tl-201 initial image.

Measurement of hemodynamics: A Swan-Ganz catheter was placed in the pulmonary artery in 20 patients with old myocardial infarction and 12 patients with effort angina pectoris. On monitoring the pulmonary artery wedge pressure, the patients took exercise by ergometer under the same protocol as the exercise under Tl-201 ECT scan.

Evaluation of the severity of coronary artery stenosis and left ventricular wall motion abnormality: Within one week of the Tl-201 ECT scan, coronary angiography and contrast medium left ventriculography were performed on all subjects. The severity of a coronary artery stenosis was expressed as a percentage based on the classification of the American Heart Association⁷. The left ventricular wall motion was evaluated subjectively by 3 experienced observers, based on grading and segmentation recommendations of the American Heart Association⁷. The wall motion was assessed to 4 grades; normokinesis, hypokinesis, akinesis and dyskinesis.

Classification of patients: On the basis of the comparison of exercise Tl-201 and resting Tl-201 images, we classified patients with old myocardial infarction into 3 groups.

TABLE I THE PREVALENCE OF CHEST PAIN AND ST DEPRESSION DURING EXERCISE

	Patients with OMI			Patients with EAP	
	group 1	group 2	group 3	group 1	group 2
Number of patients	12	15	11	18	17
Chest pain	5 (41.7%)	8 (53.0%)	0 (0%)	13 (72.2%)	13 (76.5%)
ST-T change	8 (66.7%)	9 (60.0%)	2 (18.2%)	14 (77.8%)	11 (64.7%)

TABLE II COMPARISON OF FREQUENCY OF THALLIUM-201 REDISTRIBUTION AMONG 3 GROUP

	Number of regions	RD on Ex Tl scan	RD on resting Tl scan
Patients with OMI			
group 1	13	13 (100%)	2 (15.4%)
group 2	16	10 (62.5%)	13 (81.3%)*
group 3	11	0 (0%)	0 (0%)*
Patients with EAP			
group 1	19	19 (100%)	7 (36.8%)
group 2	18	14 (77.8%)	15 (83.3%)*

$p < 0.05$ vs group 1; Ex=exercise, RD=redistribution

TABLE III COMPARISON OF PERCENT THALLIUM-201 UPTAKE IN PATIENTS WITH OLD MYOCARDIAL INFARCTION AND EFFORT ANGINA PECTORIS

	Percent Tl uptake on Ex scan		Percent Tl uptake on Re scan	
	Initial	Delayed	Initial	Delayed
Patients with OMI				
group 1	63.0±7.4%	75.7±10.3%	75.6±9.3%	78.1±6.5%
group 2	55.3±9.3*	66.3±8.5*	63.8±8.0	74.4±8.0
group 3	36.2±11.1**	40.0±9.0**	38.9±10.5**	41.1±10.4**
Patients with EAP				
group 1	72.1±7.4	87.2±8.6	85.8±12.6	87.9±8.8
group 2	64.9±9.3*	79.1±7.5*	78.0±11.4	87.2±8.1

Tl=thallium-201; Ex=exercise; Re=resting

*: $p < 0.05$ vs group 1, **: $p < 0.001$ vs group 1 and group 2

Twenty-three patients (24 infarcted regions) whose perfusion defect on resting delayed image was the same as that of exercise delayed image were divided into 12 patients (13 infarcted regions) with exercise Tl-201 redistribution (Group 1) and 11 patients (11 infarcted regions) without exercise Tl-201 redistribution (Group 3). Group 2 consisted of 15 patients (16 infarcted regions) who had a decrease of perfusion defect on resting delayed image compared with exercise delayed

image. The viability of patients of group 2 were considered to be underestimated on exercise Tl-201 delayed image. Thirty-five patients with effort angina pectoris were divided into 2 groups. Group 1 consisted of 18 patients (19 ischemic regions) who had no perfusion defect on exercise delayed image. Group 2 consisted of 17 patients (18 ischemic regions) whose perfusion defect did not disappear on exercise delayed image but disappeared on resting delayed image. For the

TABLE IV COMPARISON OF THE LEFT VENTRICULAR FUNCTION AT REST AMONG 3 GROUPS OF PATIENTS WITH OLD MYOCARDIAL INFARCTION

	group 1	group 2	group 3
LVEF (%)	53.8±11.2	51.8±14.1	41.7±11.0*
C.I. (l/min/m ²)	3.0±0.4	2.8±0.7	2.7±0.8
PAWP (mmHg)	10.6±2.5	10.5±2.5	12.3±5.0

LVEF=left ventricular ejection fraction; C.I.=cardiac index; PAWP=pulmonary artery wedge pressure

*: $p < 0.05$ vs group 1 and group 2

Fig. 2. Comparison of the increase of pulmonary artery wedge pressure during exercise.

comparison of TI-201 findings with left ventricular wall motion, left ventricular segments of infarcted or ischemic regions were divided into 3 groups according to the same classifications.

Statistical analysis: Mean values and standard deviations were calculated for each variable. The non-paired student t test and F test were used to compare data between groups. The chi-square test was used to determine the significance of differences in rates of occurrence. A probability (p) value of less than 0.05 was considered to be significant.

RESULTS

The prevalence of chest pain and ST depression (Table I): The prevalence of chest pain on exercise in group 1 and group 2 was

lower in patients with old myocardial infarction than those with effort angina pectoris, though this was without significance. But, no group 3 patients with old myocardial infarction complained of chest pain on exercise. The prevalence of significant ST depression on exercise was not different between groups 1 and 2 in patients with both effort angina pectoris and old myocardial infarction. In group 3 patients with old myocardial infarction, ischemic ST depression on exercise seldom happened (18.2%).

Frequency of TI-201 redistribution (Table II): In group 1, the prevalence of redistribution on resting TI-201 images was low in both infarcted and ischemic regions. In group 2, the prevalence of resting TI-201 redistribution was significantly higher in both infarcted and ischemic regions than in group 1 ($p < 0.01$). In group 2 patients with old

TABLE V THE PREVALENCE OF MULTI-VESSEL DISEASE AND THE SEVERITY OF CORONARY ARTERY STENOSIS

	Patients with OMI			Patients with EAP	
	group 1	group 2	group 3	group 1	group 2
Number of patients	12	15	11	18	17
one-vessel disease	3 (25.0%)	8 (50.0%)	7 (63.6%)	4 (22.2%)	6 (33.3%)
two-vessel disease	5 (41.7%)	5 (31.3%)	3 (27.3%)	8 (44.4%)	6 (33.3%)
three-vessel disease	4 (33.3%)	2 (12.5%)	1 (9.1%)	6 (33.3%)	5 (33.3%)
Number of regions	13	16	11	19	18
99% delay or 100%	6 (46.2%)	11 (68.8%)	6 (54.4%)	9 (47.4%)	16 (88.9%)*
99%	0	2	2	5	2
90%	1	2	2	1	1
75%	3	1	0	3	0
collateral	3 (23.1%)	7 (43.8%)	2 (18.2%)	5 (26.3%)	10 (55.6%)

*: $p < 0.05$ vs group 1

TABLE VI THE PREVALENCE OF SEVERE WALL MOTION ABNORMALITIES ON LEFT VENTRICULOGRAPHY

	Number	Akinesis or dyskinesia	Percentage
group 1 segments	37	9	24.3%
group 2 segments	44	23	52.3%
group 3 segments	42	36	85.7%

 $p < 0.001$

myocardial infarction, 10 of 16 infarcted regions (62.5%) had incomplete redistribution and 6 regions (37.5%) had persistent perfusion defect on exercise delayed image. On the other hand, in group 2 patients with effort angina pectoris, 14 of 18 regions (77.8%) had incomplete redistribution on exercise delayed image and all ischemic regions had no perfusion defect on resting delayed image.

The percentage Tl-201 uptake (Table III): The percentage Tl-201 uptake shown in Table III represents the mean values of perfusion defect segments revealed on exercise initial images. In the patients with not only effort angina pectoris but also old myocardial infarction, the percentage Tl-201 uptake on resting delayed images was not different between groups 1 and 2, but that on the exercise initial image was slightly lower in group 2 than in group 1 ($p < 0.05$). In group 3 patients with old myocardial infarction, the

percentage Tl-201 uptake was lower than in group 1 and group 2 not only on resting delayed image but also on resting initial, exercise initial and delayed images ($p < 0.005$, in all). But the scatter of the values was large on exercise initial and delayed image.

The left ventricular function at rest (Table IV): In patients with old myocardial infarction, the left ventricular ejection fraction was lower in group 3 than in group 1 and group 2 ($p < 0.05$). The cardiac index and the pulmonary artery wedge pressure at rest were not different in the 3 groups.

The increase of pulmonary artery wedge pressure (PAWP) during exercise (Fig. 2): In patients with effort angina pectoris, the increase of PAWP during exercise was higher in group 2 than in group 1 (group 1 12.0 ± 6.7 mmHg vs group 2 22.0 ± 5.7 mmHg; $p < 0.05$). In the patients with old myocardial infarction, the increase of PAWP during exercise was also higher in group 2 than in group 1 (group 1 15.8 ± 5.8 mmHg vs group 2 27.0 ± 7.2 mmHg; $p < 0.01$). In group 3 patients with old myocardial infarction, the increase of PAWP during exercise was lower than in group 2 (group 3 18.2 ± 8.0 mmHg; $p < 0.05$).

Coronary artery stenosis (Table V): The frequency of multivessel disease was not different between groups 1 and 2 in patients with effort angina pectoris. In patients with old myocardial infarction, the prevalence of multivessel disease was also similar in all 3 groups. Table V shows the severity of

Fig.3. Case 1; group 2 patients with old myocardial infarction. The resting Tl-201 delayed images showed decrease of perfusion defect compared with the exercise delayed images.

Fig.4. Case 2: group 3 patient with old myocardial infarction. The perfusion defect on resting Tl-201 delayed images was same as exercise.

coronary artery stenosis associated with the infarcted or ischemic region. The frequency of stenosis with 99 percent delay or occlusion was significantly higher in group 2 than in

group 1 in patients with effort angina pectoris ($p < 0.05$). On the other hand, in patients with old myocardial infarction the frequency of stenosis with 99 percent delay or occlusion

was the same in all 3 groups. The frequency of collateral flow was similar in all 3 groups in patients with old myocardial infarction, but in patients with effort angina pectoris collateral flow was more frequent in group 2 than in group 1 ($p < 0.05$).

Left ventricular wall motion assessed by left ventriculography (Table VI): The relationship between TI-201 findings and segmental wall motion assessed by ventriculography is summarized in Table VI. The wall motion analysis of 123 infarcted segments which showed perfusion defects on exercise TI-201 initial image revealed that the prevalence of akinetic or dyskinetic wall motion was significantly higher in group 2 segments than in group 1 segments ($p < 0.001$), and in group 3 segments than in group 2 segments ($p < 0.001$). Nine (13.2%) of 68 segments with akinetic or dyskinetic wall motion were included in group 1, 23 (33.8%) were in group 2 and 36 (52.9%) were included in group 3. The decrease of perfusion defect in the infarcted region on resting TI-201 delayed images was likely to be associated with the severity of wall motion and not with the severity of coronary artery stenosis.

Typical cases: Two typical cases were as follows; Case 1: a 58 year-old man (Fig. 3). The exercise TI-201 images revealed incomplete redistribution in the anterior and septal walls, and the resting TI-201 delayed images showed decrease of perfusion defect. He had 90 percent stenosis of the left anterior descending artery. Left ventriculography revealed hypokinesis on segments 2 and 6, and akinesis on segment 3. The mean percentage TI-201 uptake of perfusion defect on resting delayed image was 71.2%. Case 2: a 66 year-old man (Fig. 4). The exercise TI-201 images revealed persistent perfusion defects in the anterior and septal walls, and the resting TI-201 delayed image showed no decrease of perfusion defects. He had total occlusion of the left anterior descending artery and akinetic or dyskinetic wall motion of segments 2, 3 and 6. The mean percentage TI-201 uptake on resting delayed image was 43.1%.

DISCUSSION

The initial myocardial uptake of TI-201 de-

pends on myocardial extraction fraction and blood flow^{9,10}. The myocardial extraction of TI-201 is about 88 percent and does not change according to the physiological condition. Therefore, the initial myocardial uptake of TI-201 is proportional to myocardial blood flow distribution!^{11,12} Nevertheless, the significance of the TI-201 delayed image is uncertain. The initial TI-201 distribution can change in the course of several hours, as determined by the equilibrium between local myocardial input and output!¹³ Beller et al reported that the intrinsic washout rate decreases on reduction of myocardial blood flow and that myocardial redistribution in the fixed coronary artery stenosis is the results of slower intrinsic cellular washout rate at reduced perfusion levels!^{14,15} The problem is that the time to complete TI-201 redistribution following stress is related to the severity of coronary artery stenosis and that 4-h delayed images may not be recordings of the equilibrium phase in some patients with severe coronary stenosis!^{16,17} On the other hand, in the resting TI-201 image, the initial TI-201 distribution is proportional to resting regional flow!^{18,19} so that an equilibrium may be reached earlier under resting conditions than following stress because of the lower regional differences in initial distribution. The TI-201 distribution is proportional to the relative myocardial blood flow level. Therefore, the assessment of myocardial perfusion by TI-201 images in patients without normal perfusion on any myocardial region is difficult. In this study, patients with 99% or more stenosis of all three coronary arteries and patients with exercise TI-201 redistribution on non-infarcted regions were excluded. Therefore, in these subjects we can assess reduced myocardial perfusion compared with normal perfusion on TI-201 images.

This study on patients with effort angina showed that group 2 (who had disappearance of perfusion defect on resting delayed image) had lower initial TI-201 uptake on exercise TI-201 image, higher increase of pulmonary artery wedge pressure on exercise and more severe coronary artery stenosis than group 1. These facts suggest that exercise-induced severe myocardial ischemia (due to severe coronary artery stenosis) did not induce the equilibrium state in the exercise TI-201 3-h

delayed image. The redistribution on resting image, frequently observed in group 2, may be associated with a low intrinsic wash out rate by underperfusion at rest, as suggested by lower initial Tl-201 uptake on resting initial image.

On the other hand, the Tl-201 kinetics in infarcted regions are associated with not only the severity of coronary artery stenosis but also the presence of scar tissue and myocytes which can take up Tl-201. The intracellular accumulation of Tl-201 is caused by a passive transport mechanism driven by the transmembrane electropotential gradient!¹³ Consequently, myocardial uptake of Tl-201 is considered to indicate the presence of viable myocardium. But, in the infarcted region, complex factors may influence myocardial Tl-201 kinetics. Firstly, the demand for blood flow in the infarcted region is decreased in association with the decrease in viable myocardium. Secondly, large infarcted regions have decreased coronary vascular reserve despite a widely patent epicardial coronary artery!²⁰ Thirdly, the surviving viable myocardium occasionally has transient ischemia under stress!^{8,21} Consequently it is considered that the decrease of viable myocardium, which possibly suffers severe ischemia under stress, influences the reaching of an equilibrium state on Tl-201 3-h delayed image after stress. That is, the resting Tl-201 image, especially the delayed image, may be suitable for the assessment of viable myocardium!¹⁸

In this study on old myocardial infarction, the percentage Tl-201 uptake on the exercise initial image was lower in group 2 than in group 1 and that on the resting delayed image was similar in the 2 groups. These facts suggest that the decrease of coronary blood flow reserve was more severe in group 2 than in group 1. On the other hand, in group 3 patients with old myocardial infarction left ventricular ejection fraction was lower and the percentage Tl-201 uptake on the resting delayed image was lower than in group 1 and group 2 patients, and almost all segments of group 3 had akinetic or dyskinetic wall motion. These results suggest an absence of viable myocardium in infarcted regions, and the presence of large scars in group 3 patients. The higher increase in pulmonary artery wedge pressure on exercise in group 2

compared with group 1 and group 3 patients, suggests that more severe ischemia was induced on exercise in group 2 than in group 1 and that more viable myocytes survived in group 2 than in group 3. But, in patients with old myocardial infarction, the decrease of perfusion defect on the resting Tl-201 delayed image compared with the exercise delayed image was not associated with the severity of coronary artery stenosis but with the severity of wall motion abnormality, which is related to the presence of viable myocardium. That is, the decrease of perfusion defect on the resting delayed image was considered to mean the presence of stress induced severe ischemia corresponding to surviving viable myocardium. But the prevalence of chest pain and ST depression during exercise was not higher in the patients with old myocardial infarction than in those with effort angina pectoris in either group 1 or group 2 in spite of the lower frequency of redistribution on the exercise Tl-201 image. These results might show that many factors offer the situation in infarcted regions, such as sensory nerve disturbance, metabolites and so on, and this needs to be clarified by other studies.

It was noteworthy that the Tl-201 uptake in infarcted regions was significantly lower in group 3 than in group 1 or group 2, not only on the resting delayed image but also the resting initial image. This suggests that the Tl-201 uptake on resting images might be useful as a marker of myocardial viability. But, it is necessary for confirming the significance of the resting Tl-201 delayed image to examine the Tl-201 uptake and wall motion abnormality after revascularization in group 2 patients.

The prevalence of redistribution on resting Tl-201 image in group 2 patients with old myocardial infarction was similar to that in patients with effort angina pectoris in spite of the lower frequency of severe coronary artery stenosis in patients with old myocardial infarction. This may be possibly explained by the fact that infarcted regions may be underperfused at rest as a result of a decrease in the quantity of viable myocardium, and that potential metabolic abnormalities in infarcted regions might influence Tl-201 uptake.

In conclusion, in patients with old myocar-

dial infarction, the decrease of the Tl-201 perfusion defect on the resting delayed image compared with the exercise delayed image may indicate severe ischemia induced by stress and the presence of viable myocardium. On the other hand, an infarcted region which does not display a decrease of Tl-201 perfusion defect on the resting delayed image and exercise Tl-201 redistribution may indicate a lack of viable myocardium.

REFERENCE

1. POHOST GM, ZIR LM, MOORE RH, MCKUSICK KA, GUINEY TE, BELLER GA: Differentiation of transiently ischemic from infarcted myocardium by serial imaging after a single dose of thallium-201. *Circulation* **55**: 294, 1977
2. ROZANSKI A, BERMAN DS, GRAY R, LEVY R, RAYMOND M, MADDAHI J, PANTALEO N, WAXMAN AD, SWAN HJC, MATLOFF J: Use of thallium-201 redistribution scintigraphy in preoperative differentiation of reversible and non-reversible myocardial asynergy. *Circulation* **64**: 936, 1981
3. OKADA RD, LIM YL, BOUCHER CA, POHOST GM, CHESTER DA, BLOCK PC: Clinical, angiographic, hemodynamic, perfusional and functional changes after one-vessel left anterior descending coronary angioplasty. *Am J Cardiol* **55**: 347, 1985
4. CLONINGER KG, DEPUERG EG, GRACIA EV, ROUBIN GS, ROBBINS WL, NODY A, DEPASQUALE EE, BERGER HJ: Incomplete redistribution in delayed thallium-201 single photon emission computed tomographic (SPECT) images: An overestimation of myocardial scarring. *J Am Coll Cardiol* **12**: 955, 1988
5. RITCHIE JL, ALBRO PC, CALDWELL JH, TROBAUGH GB, HAMILTON GW: Thallium-201 myocardial imaging: A comparison of the redistribution and rest image. *J Nucl Med* **20**: 477, 1979
6. BERGER BC, WATSON DD, BURWELL LR, CROSBY IK, WELLONS HA, TEATES CD, BELLER GA: Redistribution of thallium-201 at rest in patients with stable and unstable angina and the effect of coronary artery bypass surgery. *Circulation* **60**: 1114, 1979
7. AUSTEN WG, EDWARDS JE, FRYE RL, GESTINI GG, GOTT VL, GRIFFITH LSC, MACGOON DC, MURPHY ML, ROE BB: A reporting system on patients evaluated for coronary artery disease, Report of the Adcommittee for grading of coronary artery disease, council on cardiovascular surgery, American Heart Association. AHA Committee Report
8. MORI T, YAMABE H, SUDA K, OHNISHI M, KURIMOTO Y, KOBAYASHI K, MAEDA K, FUKUZAKI H: Significance of Tl-201 redistribution on infarcted region assessed by coronary sinus flow and lactate metabolism. *Jpn J Nucl Med* **24**: 1321, 1987
9. STRAUSS WH, HARRISON K, LANGEN JK, LEBOWITZ E, PITT B: Thallium-201 for myocardial imaging. Relation of thallium-201 to regional myocardial perfusion. *Circulation* **51**: 641, 1975
10. NIELSEN AP, MORRIS KG, MURDOCK R, BRUNO FP, COBB FR: Linear relationship between the distribution of thallium-201 and blood flow in ischemic and nonischemic myocardium during exercise. *Circulation* **61**: 797, 1980
11. WEICH HF, STRAUSS W, PITT B: The extraction of thallium-201 by the myocardium. *Circulation* **56**: 188, 1977
12. LEPPA JA, MACNEIL PB, MORING AF, APSTEIN CS: Separate effects of ischemia, hypoxia and contractility on thallium-201 kinetics in rabbit myocardium. *J Nucl Med* **27**: 66, 1986
13. POHOST GM, ALPERT NM, INGWALL JS, STRAUSS W: Thallium-201 redistribution: Mechanism and clinical utility. *Semin Nucl Med* **10**: 70, 1980
14. GRUNWALD AM, WATSON DD, HOLZGREFE HH, IRVING JF, BELLER GA: Myocardial thallium-201 kinetics in normal and ischemic myocardium. *Circulation* **64**: 610, 1981
15. BELLER GA, HOLZGREFE HH, WATSON DD: Intrinsic washout rate of thallium-201 in normal and ischemic myocardium after dipyridamole induced vasodilation. *Circulation* **71**: 378, 1985
16. GUTMAN J, BERMAN DS, FREEMAN M, ROZANSKI A, MADDAHI J, WAXMAN M, ROZANSKI A, MADDAHI J, WAXMAN A, SWAN HJC: Time to completed redistribution of thallium-201 in exercise myocardial scintigraphy: relationship to the degree of coronary artery stenosis. *Am Heart J* **106**: 989, 1983
17. KIAT H, BERMAN DS, MADDSHI J, YANG LD, TRAIN KW, ROZANSKI A, FRIEDMASN J: Late reversibility of tomographic myocardial thallium-201 defects: An accurate marker of myocardial viability. *J Am Coll Cardiol* **12**: 1456, 1988
18. GEWIRTZ H, BELLER GA, STRAUSS HW, DINSMORE RE, ZIR LM, MCKUSICK KA, POHOST GM: Transient defect of resting thallium scans in patients with coronary artery disease. *Circulation* **59**: 707, 1979
19. OKADA RD, LEPPA JA, STRAUSS HW, DAGGEST WM, BOUCHER CA, JACOBS ML, NEWELL JB, POHOST GM: mechanism for the disappearance of Tl-201 defect at rest over time. *Am J Cardiol* **45**: 479, 1980
20. KLEIN LW, AGARWAL JB, SCHNEIDER RM, HERMANN G, WEINTRUBE WS, HELFLT RH: Effect of previous myocardial infarction on measurements of reactive hyperemia and the coronary vascular reserve. *J Am Coll Cardiol* **8**: 357, 1986
21. FARIS JV: Myocardial ischemia versus scar in exerciser-induced left ventricular dysfunction. *J Am Coll Cardiol* **9**: 35, 1987