ASSESSMENT OF VIABLE MYOCARDIUM WITHIN INFARCT ZONE
BY EXERCISE THALLIUM-201 SCINTIGRAPHY

Makoto Kondo, M.D., Schunichi Miyazaki, M.D.
Mamoru Takahashi, M.D., and Yukio Shimono, M.D.

The viability of the myocardial regions corresponding to pathologic Q waves was evaluated. Thirty-four patients with prior myocardial infarction underwent serial thallium-201 scintigraphy during treadmill exercise testing. On the delayed images, 8 of the initial 85 segmental defects (8 patients, 9%) showed total redistribution (RD) and 11 (6 patients, 13%) showed partial RD. In contrast, 66 segments showed persistent defect. The segments with total RD were more likely to be associated with normal or hypokinetic wall motion than the segments with persistent defect (p < 0.05). Six of the 38 segments (13%) with collateral vessels showed total RD and 10 (21%) showed partial RD. However, 35 of 38 segments (92%) without collateral vessels showed persistent defect. There was a significant difference (p = 0.02) in myocardial thallium uptake patterns when the segments with and without collateral vessels were compared.

It is concluded that (1) exercise-induced thallium RD may occur in patients with prior myocardial infarction, and myocardial infarct regions with total RD are highly associated with good contractility; these suggest the presence of viable but jeopardized myocardium within the infarct zone, and (2) collateral vessels may play a role in limiting infarct size.

It has generally been understood that pathologic Q waves represent transmural myocardial necrosis or fibrosis and irreversible myocardial damage. On the other hand, Parodi et al! reported reversible reduction of myocardial thallium-201 uptake in regions with electrocardiographically proved prior myocardial infarction during episodes of spontaneous angina pectoris. For selecting treatment and establishing the prognosis in patients with prior myocardial infarction, it is important to evaluate the presence of transient ischemia in the regions represented by pathologic Q waves, that is, to evaluate the myocardial viability of such regions.

In the present investigation, we used exercise thallium-201 scintigraphy to evaluate the presence or absence of thallium redistribution in the infarcted myocardium and correlated the thallium uptake patterns with wall motion abnormalities and coronary collateral vessels.

MATERIALS AND METHODS

Patients
We studied 34 patients with prior myocardial infarction, 30 males and 4 females aged 43 to 73 years (average 56 years). All of these patients satisfied the criteria proposed by AHA2: localized abnormal depolarization of ECG with abnormal Q waves and/or diagnostic changes in

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Key Words:
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Transient ischemia

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Division of Cardiology, Shimada City Hospital
Mailing address: Makoto Kondo, M.D., Division of Cardiology, Shimada City Hospital, 1205 Noda Shimada, Shizuoka 427, Japan

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Fig. 1. Schema of thallium-201 images and left ventriculograms.
Abbreviations: ANT = anterior; LAO = left anterior oblique; LL = left lateral; RAO = right anterior oblique.

<table>
<thead>
<tr>
<th>TABLE I  EXERCISE THALLIUM-201 REDISTRIBUTION</th>
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<tbody>
<tr>
<td><strong>Location of MI</strong></td>
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<tr>
<td>-------------------------------</td>
</tr>
<tr>
<td><strong>Anterior</strong></td>
</tr>
<tr>
<td><strong>Inferior</strong></td>
</tr>
<tr>
<td><strong>Lateral</strong></td>
</tr>
<tr>
<td><strong>Total</strong></td>
</tr>
</tbody>
</table>

Abbreviation: MI = myocardial infarction.

serum myocardial enzyme levels. A total of 35 anatomic sites of infarction were detected in resting ECGs (21 anteroseptal infarcts, 13 inferior infarcts and 1 anterolateral infarct). The interval between the onset of the acute myocardial infarction and the present study was less than 1 month for 8 infarcts, 1 to 2 months for 21 infarcts, 2 months to 1 year for 1 infarct and over 1 year for 5 infarcts.

Exercise Testing
All patients underwent symptom-limited treadmill exercise testing according to Bruce’s protocol. The exercise was continued until 85 percent of the age-predicted maximal heart rate was attained or until the patient complained of chest pain, dyspnea, fatigue or leg discomfort. At this peak exercise, thallium-201 (2 mCi) was injected intravenously and flushed with 10 cc of saline solution. Exercise was continued for an additional one minute.

**Thallium-201 Imaging**
Imaging was started 5 minutes after injection of thallium-201 with a Hitachi RC-1C-1635 LD Scintillation camera equipped with a low energy, high resolution parallel hole collimator operated with a 25 percent window centered on the 80 keV X-ray peak. Images were obtained in at the anterior, 45° left anterior oblique (LAO) and left lateral projections, with 60° LAO projection added at times. Delayed imaging in the same

projections were performed 3 to 5 hours after the injection. Camera settings were adjusted for accumulation of 2,000 counts/cm² in the myocardial region where thallium-201 uptake at the anterior projection was highest. Imagings at the other projections were performed for the same duration required for the imaging of the anterior projection. Thallium-201 scintigrams were evaluated as previously described. That is, the initial imaging was classified visually, by 3 observers who had no knowledge of the angiographic results, into 3 grades according to the criteria of Smitherman et al. Any defects in the initial and delayed images were compared and graded (total redistribution = complete filling in of the initial defect; partial redistribution = incomplete filling in of the initial defect; none = no change as compared with the initial image) as described by Pohost et al. In these evaluations, the anterior and LAO images were divided into 3 segments each and the left lateral image was divided into 4 segments for analysis (Fig. 1 a).

Cardiac Catheterization

Coronary arteriography and left ventriculography were performed percutaneously within 2 weeks after thallium-201 imaging. Left ventriculography was done in 30° RAO and 45° LAO projections, and contractility was determined according to the criteria of AHA. Ventriculograms were divided into 3 segments each for analysis (Fig. 1 b). For correlation of wall motion abnormalities and thallium-201 uptake patterns, the anterior scintigrams were compared with 30° RAO ventriculograms, and the 45° LAO scintigrams and ventriculograms were compared (Fig. 1). Coronary stenoses were considered significant if the luminal diameter was reduced by 50 percent or more. Of the 34 patients, 18 had single-vessel disease, 13 had double-vessel disease and 3 had triple-vessel disease. In addition to examining for the presence or absence of collateral vessels, we estimated the quality of these vessels according to the method of Hecht et al. This method grades collateral flow as good, intermediate or poor according to the size and number of the collateral channels, the density of filling of the native circulation and the washout times in the distal arterial segment.

The chi-square test was used to determine the significance of differences in rates of occurrence.
TABLE II  CORRELATION BETWEEN EXERCISE THALLIUM-201 REDISTRIBUTION AND WALL MOTION BY LEFT VENTRICULORTAGRAMS

<table>
<thead>
<tr>
<th>Thallium uptake patterns</th>
<th>Number of segments</th>
<th>Wall Motion</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Normal or</td>
<td>Akinetic or</td>
</tr>
<tr>
<td></td>
<td></td>
<td>hypokinetic</td>
<td>dykinetic</td>
</tr>
<tr>
<td>Total redistribution</td>
<td>8</td>
<td>6 (75%)</td>
<td>2 (25%)</td>
</tr>
<tr>
<td>Partial redistribution</td>
<td>5</td>
<td>1 (20%)</td>
<td>4 (80%)</td>
</tr>
<tr>
<td>Persistent defect</td>
<td>40</td>
<td>9 (22.5%)</td>
<td>31 (77.5%)</td>
</tr>
</tbody>
</table>

TABLE III  CORRELATION BETWEEN EXERCISE THALLIUM-201 REDISTRIBUTION AND PRESENCE OR ABSENCE OF COLLATERAL VESSELS

<table>
<thead>
<tr>
<th>Collateral vessels</th>
<th>Number of segments</th>
<th>Redistribution</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Total</td>
<td>Partial</td>
<td>None</td>
<td>p</td>
</tr>
<tr>
<td>Present</td>
<td>47</td>
<td>6 (13%)</td>
<td>10 (21%)</td>
<td>31 (66%)</td>
<td>0.02</td>
</tr>
<tr>
<td>Absent</td>
<td>38</td>
<td>2 (5%)</td>
<td>1 (3%)</td>
<td>35 (92%)</td>
<td></td>
</tr>
</tbody>
</table>

RESULTS

Manifestation of Redistribution

Table I summarizes the exercise thallium-201 uptake patterns in 340 segments in 34 patients. All the 34 patients had at least one postexercise perfusion defect identified by pathologic Q waves. In the initial images, 85 of these segments showed decreased or absent activity. In the delayed images, 8 segments of these initial defects (8 patients, 9%) showed total redistribution and 11 segments (6 patients, 13%) showed partial redistribution (Fig. 2). In contrast, 66 segments showed persistently decreased activity.

Presence of Absence of Redistribution versus Wall Motion

Table II summarizes the correlation between thallium-201 uptake patterns and wall motion abnormalities demonstrated by left ventriculography. One patient who had an indeterminate ventriculogram and one who had initial defects in the left lateral scintigram alone were excluded, and 53 segments in 32 patients were analyzed. Six of 8 segments (75%) with total redistribution showed normal or hypokinetic motion. However, only 1 of 5 segments with partial redistribution and 9 of 40 segments with persistent defect (20% and 22.5%, respectively) showed normal or hypokinetic wall motion. It was evident from the above results that the segments with total redistribution were more likely to be associated with normal or hypokinetic wall motion than the segments with persistent defect ($p < 0.05$).

Effect of Collateral Vessels on Thallium Redistribution

Table III summarizes the correlation between thallium-201 uptake patterns and presence or absence of coronary collateral vessels. Eighty-five initial segmental defects corresponding to pathologic Q waves were evaluated. Six of 47 segments (13%) with collateral vessels showed total redistribution and 10 (21%) showed partial redistribution. However, only 3 of 38 segments (8%) without collateral vessels showed redistribution and 35 (92%) showed persistent defect. There was a significant difference ($p = 0.02$) in myocardial thallium uptake patterns when segments with and without collateral vessels were compared.

The effect of collateral vessels on myocardial thallium uptake patterns was further analyzed according to the quality of collateral filling. Thirteen segments were supplied by intermediate collateral filling and 34 segments were supplied by poor collateral filling, however, no segments were supplied by good collateral filling. There was no significant difference in myocardial thallium uptake patterns.

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DISCUSSION

It has been understood that pathologic Q waves indicate transmural myocardial necrosis or fibrosis and irreversible myocardial damage. On the other hand, the clinical status in the presence or absence of thallium-201 redistribution in the region with pathologic Q waves is still controversial.\(^6\)\(^{9-13}\) The presence of redistribution is usually considered to indicate the viability of that myocardial region.\(^4\)\(^-\)\(^7\),\(^14\) In the present study using exercise thallium-201 scintigraphy, total redistribution on the delayed images was observed in 9% of the initial segmental defects with pathologic Q waves and partial redistribution was observed in 13%. This finding suggests that viable myocardium is present within the infarct zone. Also, normal or hypokinetic regional wall motion was present in 75% of the myocardial segments with total redistribution, and left ventricular contractility of the segments with total redistribution was better than that of the segments without redistribution (p < 0.05). Helfant et al.\(^15\) showed that normal or hypokinetic wall motion correlated well with predominantly viable myocardium when such areas were biopsied at surgery. These findings support the viability of the myocardial infarct zone with total redistribution. On the other hand, 2 segments with total redistribution showed akinetic or dyskinetic wall motion. This wall motion abnormality does not negate the possibility that a certain amount of viable myocardium might remain in that myocardial region.\(^7\) Revascularization may improve the abnormal contractility.

Transient ischemia (post-infarction angina) may occur in such viable region within the infarct zone. Recently, it has been reported that ischemia in the infarct zone in addition to the transient ischemia at distant areas occurs in post-infarction angina pectoris. For example, Schuster et al.\(^16\) demonstrated this type of pathology in 27 of 70 patients with early post-infarction angina, and stated that such patients were more likely to have had “incomplete infarct”, that is, the wall motion in that area was hypokinetic, with good left ventricular function. Although they observed pathologic Q waves less frequently in these patients than in those with “ischemia at a distance”, the incidence was still very high, 55%. This means that transient ischemia can occur spontaneously even in the region corresponding to pathologic Q waves; that is, some viable myocardium is still present as an area of jeopardy in this region. Our results demonstrated the presence of stress-induced ischemia within the infarct zone by serial imaging after a single dose of thallium-201.

The function of collateral vessels in limiting infarct size is controversial. In the present study, there was a significant difference (p = 0.02) in myocardial thallium uptake patterns when segments with and without collateral vessels were compared. This indicates the possibility that collateral vessels play a role in limiting infarct size. However, the presence of collateral vessels does not necessarily have the same significance in the chronic stage as in the acute stage. In addition, 66% of the segments with collateral vessels showed persistent defect. Yet, to conclude the role of the collateral vessels in the reduction of infarct size, we consider that further studies of collateral vessels in the acute stage in many patients with acute myocardial infarction are needed.

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REFERENCES


6. 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-

8. HECHT HS, AROESTY JM, MORKIN F, LaRAIA PJ, PAULIN S: Role of the coronary collateral circulation in the preservation of left ventricular function. Radiology 114: 305, 1975


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