# Inadequate Exercise Leads to Suboptimal Imaging. Thallium-201 Myocardial Perfusion Imaging After Dipyridamole Combined with Low-Level Exercise Unmasks Ischemia in Symptomatic Patients with Non-Diagnostic Thallium-201 Scans Who Exercise Submaximally

J. Fred Verzijlbergen, Paul HMJ Vermeersch, Gert-Jan Laarman, and Carl APL Ascoop

*Departments of Nuclear Medicine and Cardiology, St. Antonius Hospital, Nieuwegein, The Netherlands; and Department of Cardiology, Onse Lieve Veouwe Gasthuis, Amsterdam, The Netherlands*

This study was undertaken to establish the additional value of $^{201}$Tl imaging after dipyridamole in combination with low-level exercise in 15 symptomatic patients with non-diagnostic $^{201}$Tl scans, who exercised submaximally. Most patients had angina, ST-segment depression and even exertional hypotension and were referred for stress $^{201}$Tl testing for determining the functional significance of known coronary artery disease. Six patients with a normal exercise $^{201}$Tl test and one patient with an apical defect only were found to have 37 segments (of 105 segments) with reversible perfusion defects after dipyridamole infusion. One patient showing two reversible defects after exercise had five reversible segments after dipyridamole. Seven patients with fixed defects in 28 segments after exercise and two with small areas of border zone ischemia in seven additional (sub)segments, demonstrated fixed in defects in only nine segments but reversible defects in 40 segments after dipyridamole. Quantitative analysis resulted in 24.8 ± 28.5 (mean value) sample points below −2 s.d. of the mean normal uptake after exercise, which increased to 72 ± 26.5 after dipyridamole infusion ($p < 0.005$). The washout analysis resulted in a mean value of 5.5 ± 8.1 sample points below −2 s.d. after exercise, increasing to 33.3 ± 22.1 after dipyridamole ($p < 0.005$). Thallium-201 myocardial perfusion imaging after dipyridamole combined with low-level upright bicycle exercise may unmask scintigraphic evidence for ischemia in symptomatic patients who would otherwise have non-diagnostic imaging studies during submaximal exercise.

**J Nucl Med 1991; 32:2071–2078**

Myocardial perfusion scintigraphy with $^{201}$Tl can determine the presence, localization and extent of ischemic regions. One of the major causes of false-negative test results is an inadequate exercise level in the absence of symptoms (*1*). In exercise ECG studies 39%–50% of abnormalities occur at heart rates in excess of 85% of the maximally predicted heart rate and the highest level accounts for a quarter of detected ST-segment abnormalities (*2,3*). Sensitivity of the $^{201}$Tl test in detecting coronary artery disease (CAD) is lower when exercise tolerance is decreased due either to beta-blockade or physical impairment (*4–6*).

Myocardial oxygen demand is mainly determined by the heart rate. An increase of the oxygen demand with the level of exercise enhances coronary blood flow disparity in the presence of significant CAD. More distinct, regional differences in coronary flow will lead to a better spatial contrast using $^{201}$Tl scintigraphy (*7*).

Exercise testing may be interrupted at a lower heart rate because the patient reaches diagnostic criteria, such as severe angina, tachyarrhythmias or ischemic ST-segment depression. In most cases, reversible perfusion defects will be visible. Despite the fact that $^{201}$Tl is injected when a definite exercise endpoint is reached, it may be that in some cases the images are not diagnostic. This may be due to a false-positive exercise criterium or small branches CAD but also to the fact that $^{201}$Tl is injected at a submaximal exercise level.

While it is known that dipyridamole increases the sensitivity of $^{201}$Tl exercise in detecting ischemia in asymptomatic patients (*8*), little has been reported regarding the contribution of dipyridamole in detecting ischemia in symptomatic patients with known CAD who exercise submaximally. In this report, the hypothesis was tested that in those selected cases $^{201}$Tl scintigraphy after dipyridamole with low-level exercise could offer additional diagnostic power to the test. A greater degree of coronary vasodilatation may be produced and subsequently disparity in

Received Jan. 23, 1991; revision accepted Jun. 26, 1991.
For reprints contact: J. Fred Verzijlbergen, MD, Dept. of Nuclear Medicine, St. Antonius Hospital, P.O. Box 2500, 3430 EM Nieuwegein, The Netherlands

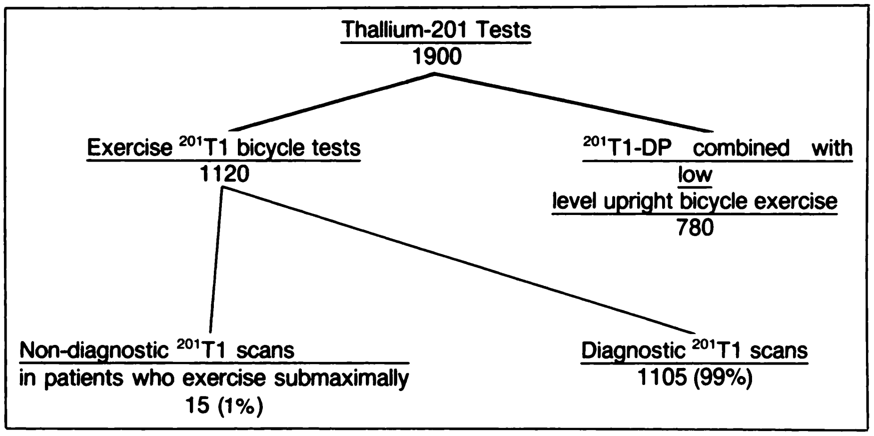



**FIGURE 1.** Patient population studied between February 1987 and October 1989.

coronary flow with less restriction due to ischemic symptoms at the moment of $^{201}$Tl injection.

## PATIENTS AND METHODS

Between February 1987 and October 1989, 1900 patients were referred to the department of nuclear medicine for exercise $^{201}$Tl testing for the detection or evaluation of CAD. In the same period, 780 patients underwent $^{201}$Tl myocardial perfusion imaging after dipyridamole combined with low-level exercise (*9*). A $^{201}$Tl bicycle exercise test was used unless it was known or suspected that the patient would not be able to reach a sufficient exercise level due to peripheral artery disease, orthopedic problems, emphysema, etc. If the patient was unable to reach at least 85% of the age-predicted heart rate without achieving one or more of the criteria to terminate, injection of $^{201}$Tl was deferred and the test was extended with dipyridamole (*9*).

The study group was composed of 15 patients who had a nondiagnostic $^{201}$Tl scan after a submaximal exercise test which was interrupted because of accepted criteria (Fig. 1). Dipyridamole-$^{201}$Tl imaging was performed 7–10 days after exercise $^{201}$Tl. Patient characteristics are given in Table 1.

### Exercise Electrocardiography

A calibrated bicycle ergometer in the upright position was used in a symptom-limited exercise test. The initial external load was 60 W for 3 min. Thereafter the load was increased every 3 min by 30 W until one of the following termination criteria was fulfilled: severe angina pectoris, an ischemic ST-segment depression of at least 0.2 mV (leads CM5 and CC5), dyspnea, sustained ventricular tachyarrhythmias or exertional hypotension (Table 2). In all patients, drugs such as beta-blocking agents and calcium antagonists were discontinued 24 hr before the test and digitalis derivatives were withheld for 2 wk. Anti-anginal medication was replaced with short-acting nitrates. Patients were requested to inform our department in case of progressive angina.

### Thallium-201 Imaging Protocol

At the highest achievable level of exercise, 2.5 mCi (92 MBq) $^{201}$Tl were injected intravenously and exercise was continued for another minute. Imaging was performed in the anterior, 30° and 70° left anterior oblique (LAO) view for 10 min/projection, beginning within 5 min after cessation of exercise. Redistribution scintigrams were obtained after 4 hr. The patients' physical activities were restricted between the two recordings and the patients were allowed to drink one cup of coffee but were to refrain from eating (*10*). All studies were performed on a Toshiba GCA 50, a small field of view gamma camera, with a low-energy, all-purpose parallel-hole collimator. A 20% symmetrical energy window centered on the 80 keV photopeak was used. There was a minimum of 400,000 counts per image obtained. The camera was interfaced to a Medical Data Systems (MDS-A2) computer with dedicated nuclear medicine software.

### Dipyridamole Infusion with Low-Level Exercise

In all patients beta-blocking agents, calcium antagonists and aminophylline derivatives were discontinued at least 24 hr before the test. Patients were asked to refrain from drinking caffeinated beverages after midnight of the day before the study.

After intravenous administration of 0.14 mg dipyridamole per kilogram body weight per minute for 4 min and flushing the line during the fifth minute, the patient was exercised for 4 min at a

**TABLE 1**
Characteristics of Clinical and Hemodynamic Results in 15 Symptomatic Patients with Non-diagnostic $^{201}$Tl Tests

| Patient no. | Age (yr) | Gender | HR (%) | Exercise level (W/m) |
|---|---|---|---|---|
| 1 | 58 | M | 64 | 90 W/3 |
| 2 | 69 | F | 84 | 60 W/3 |
| 3 | 48 | M | 78 | 120 W/3 |
| 4 | 49 | F | 70 | 90 W/2 |
| 5 | 57 | M | 60 | 90 W/2 |
| 6 | 51 | M | 84 | 120 W/2 |
| 7 | 51 | M | 74 | 120 W/2 |
| 8 | 50 | M | 85 | 180 W/1 |
| 9 | 52 | M | 74 | 120 W/1 |
| 10 | 50 | M | 78 | 120 W/3 |
| 11 | 60 | M | 79 | 120 W/3 |
| 12 | 55 | M | 63 | 120 W/1 |
| 13 | 47 | M | 82 | 120 W/1 |
| 14 | 75 | M | 82 | 90 W/2 |
| 15 | 58 | M | 82 | 90 W/3 |
| | mean 55 ± 7.9 | | mean 76 ± 8.2 | |

HR (%) = percentage of age-related peak heart rate achieved with $^{201}$Tl injection.

W/m = exercise level in Watts during a given time period in minutes.

**TABLE 2**
Criteria To Terminate During Exercise $^{201}Tl$ Tests: Symptoms and ST-changes After Dipyridamole Infusion

| Patient | Stop criteria during exercise | | Dipyridamole infusion | |
|---|---|---|---|---|
| | Symptoms | ST changes | Symptoms | ST changes |
| 1 | Angina | 3 mm DS | none | 2 mm H |
| 2 | Angina | 1.5 mm H | none | none |
| 3 | Angina | none | none | none |
| 4 | None | 3 mm DS | angina | 2 mm DS |
| 5 | Angina | 1.5 mm H | angina | none |
| 6 | Angina | 2 mm H | angina | 2 mm DS |
| 7 | Angina | 1 mm EL | angina | none |
| 8 | Dyspnea | 1 mm DS | none | none |
| 9 | Angina | none | angina | 1 mm DS |
| 10 | Angina | none | angina | none |
| 11 | Angina | none | angina | 1 mm DS |
| 12 | Angina | none | angina | none |
| 13 | Angina + Hypotension | 2 mm DS | none | 2 mm DS |
| 14 | Angina | 1.5 mm H | angina | none |
| 15 | Angina | none | angina | none |

DS = Downsloping ST-segment depression; EL = Elevating ST-segment; and H = Horizontal ST-segment depression.

low level (30–60 W/60 cycles/min) while sitting on a bicycle table. Four minutes after completing dipyridamole infusion, 2.5 mCi (92 MBq) were injected and exercise was continued for 1 min. Two minutes after $^{201}Tl$ injection the patient was brought to a supine position and imaging was started 2 min thereafter according to the same protocol used for the exercise $^{201}Tl$ scintigraphy. During the first 30 min ECG, blood pressure and heart rate were recorded every minute. In case of occurrence of severe angina pectoris and/or symptomatic hemodynamic changes, 125–150 mg aminophylline (a dipyridamole antagonist) were administered intravenously.

### Analysis

All studies were stored on magnetic disk in a 128 × 128 8-bit matrix. Visual interpretation was performed on unprocessed $^{201}Tl$ images by three experienced observers with a computer gray scale display, which yielded a multi-observer score (*11*). Initial uptake and delayed redistribution images were presented side by side for comparison. Interpretation of the images was performed blinded with an interval of at least 1 mo between the exercise and dipyridamole studies. Due to relatively greater radionuclide concentration in the liver in some of the initial uptake dipyridamole studies as compared to immediate postexercise studies, it is not possible to blind readers entirely. However, the addition of low-level exercise generally decreases splanchnic uptake to the level of an exercise study. Each view was divided in five segments. The activity in each segment was visually graded from 1 to 3 (grade 1 = no defect; grade 2 = possible defect; grade 3 = definite perfusion defect).

The visual difference between the initial uptake and delayed images were graded for ischemia. Reversibility of the stress-induced perfusion defect indicated ischemia (1 = no reversibility; 2 = possible reversibility; 3 = definite reversibility). The overall scintigram was considered abnormal when the total score proved to be higher than 18 in the postexercise phase and higher than 17 in the redistribution phase (*12*).

Visual assessment of $^{201}Tl$ images was performed in conjunction with the uptake and washout rate circumferential profiles compared to lower limits of the stress and dipyridamole-specific profile of a normal population obtained in our laboratory (*12*, *13*). In both the exercise and dipyridamole/low-level exercise quantitative analysis, a −2 s.d. of the normal files was used as the lower limit of normal (*13*). Flow regions of the left anterior descending (LAD), right coronary artery (RCA) and left circumflex artery (LCX) were defined according to previous studies (*14*).

### Coronary Angiography

The interval between myocardial scintigraphy and cardiac catheterization was less than 3 mo. Coronary angiography was performed in multiple LAO and RAO projections and with craniocaudal angulations, according to the Sones or Judkins technique. The angiograms were visually interpreted independently by two cardiologists; disagreement was resolved by an independent third cardiologist. The cardiologists were blinded to the results of the exercise and dipyridamole-$^{201}Tl$ scans. Patients were considered to have significant CAD if they had 50% or more reduction in luminal diameter. Table 3 shows the distribution of the stenosed vessels in the patients.

### Statistical Analysis

The relation between the scintigraphic findings in both sets of images, both visually and quantitatively analysed, are given in terms of hypoperfused and ischemic segments. Significance of difference between quantitative parameters was calculated using a Wilcoxon signed ranks test for matched pairs. Values are presented as the mean ± s.d.

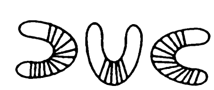
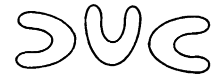
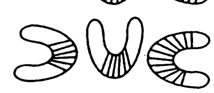
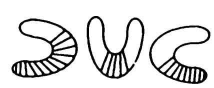
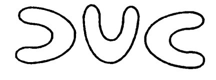
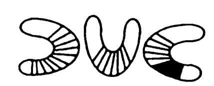
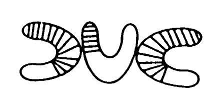
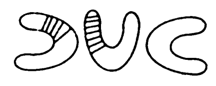
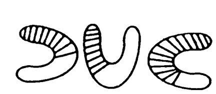
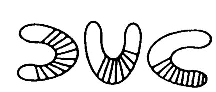
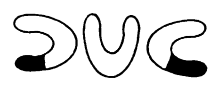
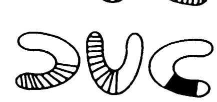
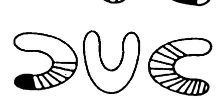
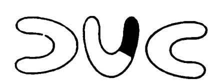
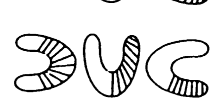
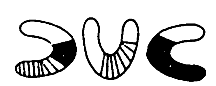
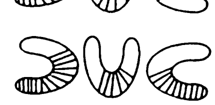
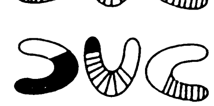
## RESULTS

The characteristics of clinical and hemodynamic results of the $^{201}Tl$ exercise tests are given in Table 1. Thirteen male patients and two female patients were studied with a mean age of 55 ± 7.9 yr. Mean percentage of the age-related peak heart rate achieved during exercise was 76% ± 8.2%, absolute values 117 ± 13 bpm.

Criteria for terminating the test (Table 2) demonstrate that 13 patients suffered from severe angina, one patient had severe angina in combination with exertional hypotension and only one patient had no angina but stopped exercising because of a rapidly progressive downsloping ST-segment. The mean double product increased from 11.160 ± 3.4 bpm × mmHg at rest to 21.740 ± 4.3 bpm × mmHg during exercise. After dipyridamole infusion, 10 patients suffered from angina pectoris and 6 patients demonstrated ST-segment changes indicative of myocardial ischemia. The mean double product increased from 12.166 ± 3.3 bpm × mmHg at rest to 18.760 ± 3.86 bpm × mmHg after dipyridamole infusion.

Assessment of $^{201}Tl$ myocardial perfusion images after exercise and after dipyridamole is given in Table 3 and the results are combined with the coronary angiographic findings. Six patients (Patients 1–6) with a normal exercise $^{201}Tl$ test and Patient 7 with only a small apical defect

**TABLE 3**
Thallium-201 Myocardial Perfusion Imaging After Exercise and Dipyridamole Infusion in Combination with Low-Level Exercise and Angiographic Findings

| Patient No. | EXC MPI | DP/EXC MPI | Coronary angiography |
|---|---|---|---|
| 1 |  |  | LCX 100%, LAD distal 85% |
| 2 |  |  | LAD 70% |
| 3 |  |  | RCA 100%, LAD 80%<br>LCX distal 95% |
| 4 |  |  | LAD 75% |
| 5 |  |  | RCA 100%, LCX prox. 50% and distal 100%, apical hypokinesia |
| 6 |  |  | RCA 75% |
| 7 |  |  | LAD 65%, LCX distal 100% |
| 8 |  |  | LAD 100%, RCA distal 90% |
| 9 |  |  | RCA 100%, LCX 80% |
| 10 |  |  | RCA 90%, inferior wall hypokinesia |
| 11 |  |  | RCA 90%, LCX 80% |
| 12 |  |  | LCX 90%, LAD 70% |
| 13 |  |  | RCA 80%, LCX prox. 70%, distal 100%, apical hypokinesia |
| 14 |  |  | RCA 95% |
| 15 |  |  | RCA 100%, LCX 90% inferior wall hypokinesia |

Note: a striped area depicts a reversible defect and a closed area depicts a fixed defect.
DP/EXC MPI = Dipyridamole in combination with low-level exercise myocardial perfusion imaging; EXC MPI = myocardial perfusion imaging after exercise; LAD = left anterior descending; LCX = left circumflex artery; and RCA = right coronary artery.

showed reversible perfusion defects in 37 out of 105 segments after dipyridamole. The localization and extent of the lesions after dipyridamole was in close correlation with the angiographic findings (Fig. 2).

One patient (Patient 8) demonstrated only limited ischemia in the LAD flow-region that could hardly explain increased lung uptake and severe dyspnea during exercise. After dipyridamole infusion the ischemic area extended over five instead of two segments within the LAD flow region, which was found to be occluded in combination with jeopardized collaterals from the RCA.

Seven patients (Patients 9–15) had one or more fixed

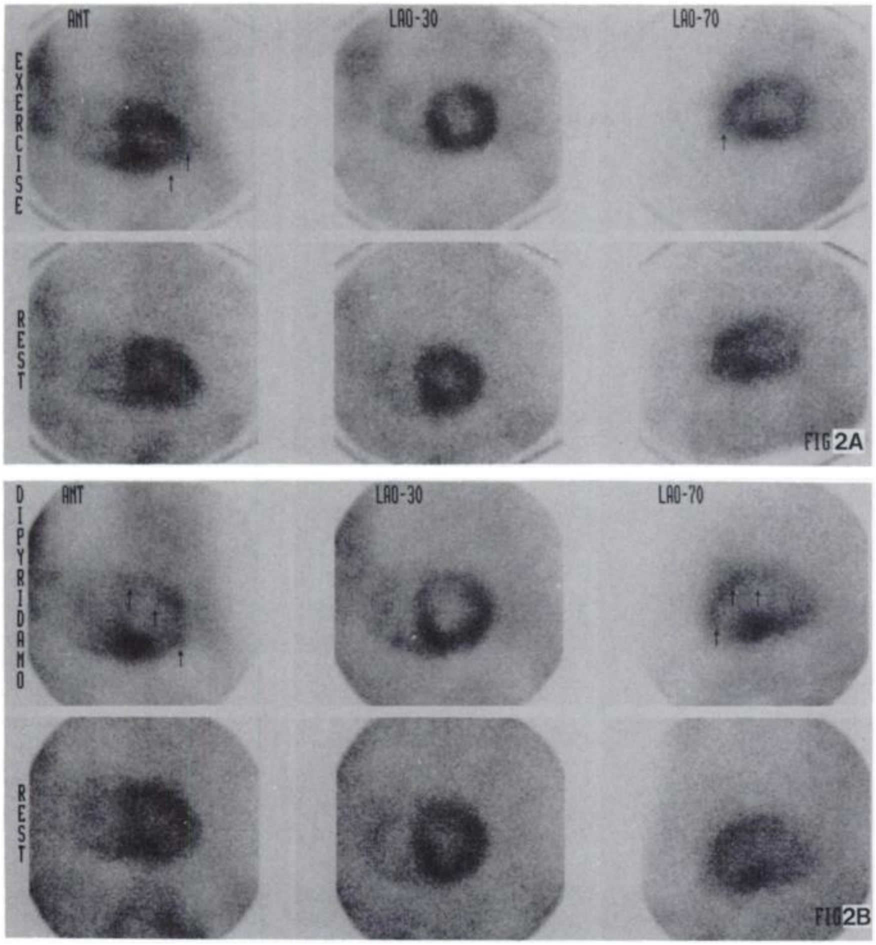



**FIGURE 2.** (A) Thallium-201 myocardial perfusion images of a 51-yr-old male in whom a successful PTCA procedure was performed on the left circumflex and left descending anterior artery 6 mo before imaging (patient no. 7). Thallium-201 exercise was performed because of progressive angina pectoris. Thallium-201 was injected at a heart rate of 74% of the predicted value in combination with 1 mm ST-segment elevation. Despite high lung-uptake only a small fixed apical defect is found (anterior) and a small reversible apical defect (LAO-70). (B) After dipyridamole infusion, an extensive reversible perfusion defect is found in the anterolateral and anteroseptal wall (arrows). Again extensive lung-uptake is noted. Coronary bypass surgery was performed on the anterolateral and diagonal branch and LAD.

defects, and two patients had fixed defects combined with small concomitant areas of ischemia (Patients 13 and 14). After dipyridamole infusion, the 28 fixed defects found after exercise decreased to 9 fixed defects, but the 7 reversible perfusion defects increased to 40 segments. Most fixed defects correlated well with hypokinetic and akinetic segments demonstrated with left ventricular angiography.

Quantitative analysis resulted in decreased uptake of $^{201}$Tl in 372 sample points (mean 24.8 ± 28.5) after exercise and in 1080 sample points (mean 72 ± 26.5) after dipyridamole (Table 4). Decreased washout was noted in 82 sample points (5.5 ± 8.1) after exercise and in 500 sample points (33.3 ± 22.1) after dipyridamole. The differences between both sets of results were of statistical significance ($p < 0.005$).

## DISCUSSION

### Test Results

From a large series of patients referred for stress $^{201}$Tl imaging, we studied 15 patients who failed to demonstrate reversible perfusion defects despite angina pectoris and/or ischemic ST-segment changes at a submaximal exercise level. After dipyridamole infusion, 7–10 days later, the amount of ischemic segments increased from 9 to 82. Six patients lacking any perfusion defects after exercise and one patient with only a small apical defect exhibited 37 reversible hypoperfused segments after dipyridamole, whereas the eighth patient revealed a much larger reversible perfusion defect in the LAD region (from two to five segments).

In seven patients fixed defects were found, which were not expected on the basis of any proof of sustained myocardial infarctions. Two of these patients had seven concomitant reversible perfusion defects as well. After dipyridamole infusion only 9 of the presumably found 28 fixed defects remained fixed and the other 19 segments turned out to be reversible. These fixed defects after dipyridamole infusion correlated well with akinetic and hypokinetic segments found with left ventricular angiography. Additionally, fourteen segments, which were assessed normal after exercise, showed reversible defects after dipyridamole.

Most patients were referred for stress $^{201}$Tl testing for determining the localization and extent of known CAD. All patients, but one, were symptomatic during exercise. Based on angiographic and/or clinical findings implicating a high pre-test likelihood, it was reasonable to expect reversible perfusion defects on the $^{201}$Tl images. The obvious lack of ischemic areas warranted additional dipyridamole studies since in all patients $^{201}$Tl was injected at a submaximal exercise level.

**TABLE 4**
Quantitative Analysis of $^{201}$Tl Exercise and Dipyridamole Initial Uptake and Washout Rate Expressed as the Amount of Sample Points Below 2 s.d. of the Mean Normal Uptake and Washout Rate Circumferential Profiles

| Patient no. | Initial uptake | | Washout | |
|---|---|---|---|---|
| | Exercise | Dipyridamole | Exercise | Dipyridamole |
| 1 | 0 | 80 | 0 | 48 |
| 2 | 0 | 35 | 0 | 20 |
| 3 | 0 | 30 | 0 | 30 |
| 4 | 21 | 48 | 6 | 20 |
| 5 | 0 | 64 | 0 | 33 |
| 6 | 0 | 100 | 0 | 25 |
| 7 | 29 | 110 | 24 | 61 |
| 8 | 0 | 81 | 0 | 57 |
| 9 | 34 | 118 | 6 | 83 |
| 10 | 29 | 66 | 12 | 14 |
| 11 | 10 | 63 | 0 | 0 |
| 12 | 37 | 99 | 15 | 49 |
| 13 | 60 | 50 | 0 | 15 |
| 14 | 95 | 58 | 19 | 30 |
| 15 | 57 | 78 | 0 | 15 |
| | mean 24.8 ± 28.5 | 72 ± 26.5 | 5.5 ± 8.1 | 33.3 ± 22.1 |
| | $p < 0.005$ | | $p < 0.005$ | |

### Degree of Effort During Exercise

In most patients referred for stress testing, exercise is performed to provoke ischemia and to demonstrate its localization and extent. This requires sufficient work so that myocardial demand exceeds coronary blood supply. Hemodynamic parameters such as heart rate, blood pressure, and exercise duration have provided the clinician with practical criteria in judging the adequacy of the exercise test (*15,16*). During exercise electrocardiography studies, 39%–50% of these abnormalities occur at heart rates in excess of 85% of those age-predicted maximums (*2,3*).

To test whether different degrees of effort affect the prevalence of $^{201}$Tl initial defects in any one patient requires exercising the same patient to various degrees of effort and acquiring $^{201}$Tl images at these stages. Results in a small number of patients suggest an increasing sensitivity of initial defects at higher degrees of effort (*17*). Recently Iskandrian et al. (*18*) demonstrated that the results of exercise SPECT-$^{201}$Tl are significantly better in patients with adequate exercise endpoints than in patients with submaximal exercise. Their results were confirmed regardless of the extent of CAD.

In a recent study by Young et al. (*9*) 48% of 385 *asymptomatic* patients referred for stress $^{201}$Tl imaging exercised submaximally and 19% had no clinical evidence of ischemia. Dipyridamole-$^{201}$Tl imaging unmasked ischemia in nearly 30% of the normal submaximal studies. The results of this study indicate that even in *symptomatic* patients with known CAD who exercise submaximally dipyridamole may unmask (larger) areas of ischemia.

### Dipyridamole-$^{201}$Tl Imaging

Gould and Albro have shown that the quality of $^{201}$Tl myocardial perfusion images after dipyridamole-induced coronary vasodilatation are equal to, or better than that of images during maximal exercise (*19–21*). Dipyridamole images, with increased myocardial to background count ratios, may reflect higher coronary flows than with exercise and may therefore be theoretically a better stress. Dipyridamole is reported to increase mean coronary flow by up to 3.4 to 5 times baseline values in man (*22–24*). Exercise stress has been reported to increase coronary flow one to three times in man (*25,26*).

Higher flow differentials between normal and stenotic coronary arteries may occur utilizing the most potent stimulus for coronary blood flow resulting in a higher spatial contrast between the normally perfused myocardium and the post-stenotic area and probably better lesion detectability (*27*).

Several investigators have compared the results of dipyridamole and exercise $^{201}$Tl imaging. A summary of five reports comprising of 215 patients demonstrated a sensitivity of 79% for both tests and a specificity of 95% and 92% for dipyridamole and exercise, respectively (*28*). These results suggest that dipyridamole $^{201}$Tl myocardial perfusion imaging yields the equivalent diagnostic information of exercise $^{201}$Tl scintigraphy. However, the results may not be applicable to subsets of patients, for instance those with documented CAD especially with multi-vessel disease in whom the "culprit lesion" leads to interruption of the exercise test at a submaximal level or less resulting in smaller perfusion defects than to be expected on the basis of the angiographic findings (*18*).

### Fixed Defects

Recent studies suggest that up to 30% of patients with fixed abnormalities on 4-hr postexercise $^{201}$Tl scans have viable myocardium, not scar (*29–33*). The cause for this lack of redistribution is unclear, but may be related to the ingestion of glucose between initial and delayed imaging (*10,34*), low peak exercise heart rate (*35*) and jeopardized myocardium at rest. Despite inducing much larger perfusion defects than after vigorous exercise, dipyridamole demonstrated accelerated redistribution resulting in delayed images assessing an accurate reflection of viable myocardial tissue compared to left ventricular angiographic findings. These findings are in sharp contrast with the 19 false-positive fixed defects suggesting scar tissue, but actually were proven to contain large areas of ischemia. The protocol in both studies was exactly the same, permitting the patient to take only one cup of coffee between initial and delayed images. Ingestion of glucose cannot account for the different findings.

Mean percentage myocardial $^{201}$Tl washout after dipyridamole is only slightly lower than after exercise (*12*) in normally perfused myocardium. Slower than normal regional myocardial washout occurs in the absence of CAD if the patient is injected at a submaximal heart rate; the difference with $^{201}$Tl washout after dipyridamole will increase in relation to the lower level of heart rate. Not only will the submaximal exercise level lead to a lower sensitivity in the detection of CAD, slow washout may hamper the filling-in of hypoperfused segments. Whether a thallium defect after the administration of dipyridamole represents relative hypoperfusion with limited ischemia compared to exercise-induced ischemia remains a tempting question. It may be that ischemia is the main cause of slow filling-in. It is obvious that further basic research is necessary to better evaluate this observation. The observation that a fixed defect after 3–4 hr does not necessarily demonstrate scar tissue necessitates delayed redistribution or better reinjection of 1 mCi of $^{201}$Tl at rest (*32,33,36*).

## CONCLUSION

It has been proven that dipyridamole-$^{201}$Tl myocardial imaging unmasks ischemia in nearly 30% of *asymptomatic* submaximal tests. The present study indicates that dipyridamole with low-level exercise unmasks ischemia or a larger area of ischemia in *symptomatic* patients with nondiagnostic $^{201}$Tl scans who exercised submaximally as well. Fixed defects after exercise, not expected on the basis of sustained myocardial infarction, turned out to be reversible perfusion defects after dipyridamole infusion in most cases. Dipyridamole-$^{201}$Tl myocardial perfusion imaging with low-level exercise more accurately reflected the severity and extent of CAD and, most importantly, provoked redistribution in viable myocardium with fixed defects after exercise $^{201}$Tl imaging in this subset of patients.

## ACKNOWLEDGMENT

We express our gratitude for the patient and skillful assistance of Mrs. J. Starink.

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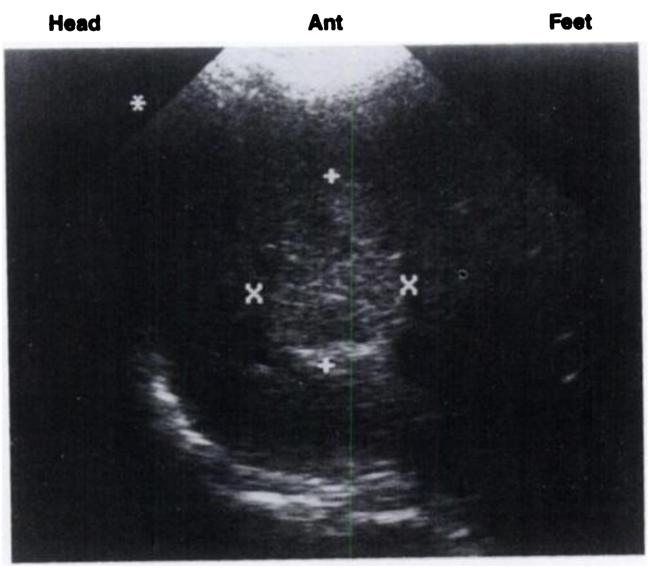
*(continued from p. 2063)*

# SELF-STUDY TEST

A 43-yr-old woman with irritable bowel syndrome developed an episode of acute abdominal pain, which was not characteristic of her prior symptoms. You are shown both a hepatic sonogram (Fig. 3) and a hepatic blood-pool scintigram obtained with $^{99m}$Tc-labeled red blood cells (Fig. 4).

Based on the *sonographic findings (in Fig. 3) alone*, which of the following diagnoses should be considered?

**6.** hepatic adenoma
**7.** cavernous hemangioma
**8.** simple hepatic cyst
**9.** metastasis
**10.** hepatocellular carcinoma




**Longitudinal Scan**

**Figure 3**

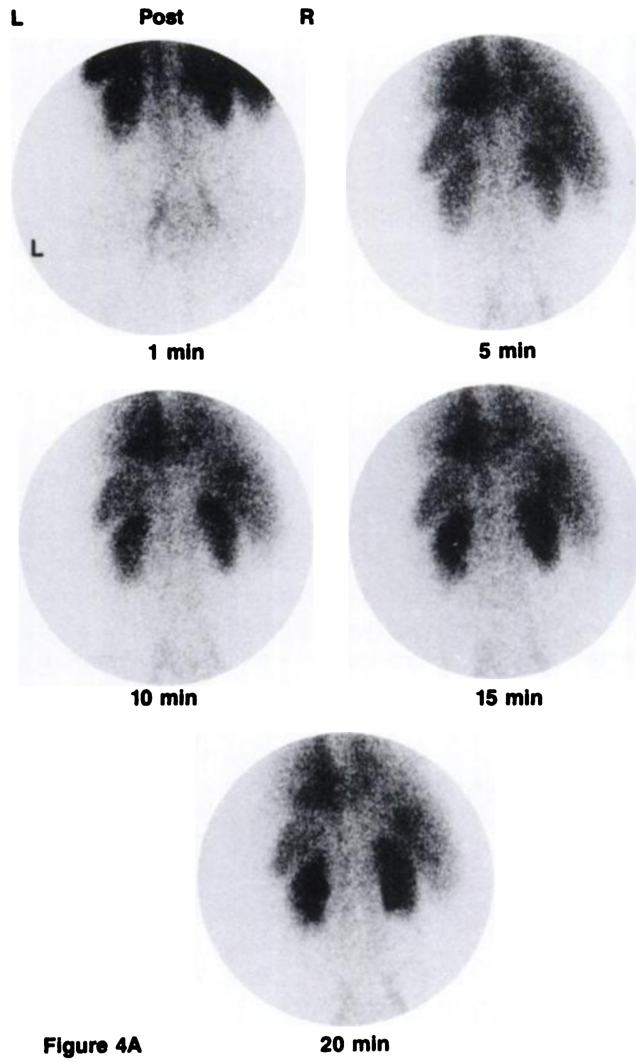



**Figure 4A**

True statements concerning the findings in this patient's labeled red blood cell study (Fig. 4) include which of the following?

**11.** Cavernous hemangioma is the most likely diagnosis.
**12.** SPECT is necessary for definitive diagnosis.
**13.** The likelihood of hepatocellular carcinoma is approximately 20%.
**14.** The likelihood of metastasis is approximately 20%.


**Figure 4B**

*(continued on p. 2125)*