DIAGNOSTIC METHODS
NUCLEAR CARDIOLOGY

Slow regional clearance of myocardial thallium-201 in the absence of perfusion defect: contribution to detection of individual coronary artery stenoses and mechanism for occurrence

ALNOOR ABDULLA, M.D., JAMSHID MADDAHI, M.D., ERNEST GARCIA, PH.D., ALAN ROZANSKI, M.D., H. J. C. SWAN, M.D., PH.D., AND DANIEL S. BERMAN, M.D.

ABSTRACT As a result of the ‘‘spatially relative’’ nature of perfusion defect analysis of stress-redistribution thallium-201 (201T1) scintigrams, hyperperfused myocardial segments may not appear as perfusion defects but they may demonstrate a slow washout rate of 201T1 that can be analyzed in a ‘‘spatially nonrelative’’ manner. Quantitative analysis of perfusion defects and slow washout rate of 201T1 was performed on scintigrams from 116 consecutive patients with adequate exercise tests, defined as achievement of 85% or more of age-predicted maximum heart rate or development of angina or ST segment depression. A total of 232 diseased and 116 nondiseased vessels were found in the patients. Additional analysis of slow washout rate significantly (p < .05) improved sensitivity for detection of disease in the left anterior descending (from 74% to 82%), left circumflex (from 40% to 61%), and right coronary arteries (from 78% to 90%) without significant loss of specificity. This improvement resulted from the additional detection of 32 of 232 (14%) diseased vascular distributions when the isolated slow washout rate of 201T1 was also determined. In nine of these 32, isolated slow washout rate was associated with another region with isolated slow washout rate in the contralateral myocardial segment. Coronary arteriography revealed similar degrees of stenosis in the vessels supplying these segment pairs. In 13 of 32 cases, a perfusion defect and a slow washout rate were found in the contralateral segment. Coronary angiography revealed that 10 of these 13 segments with perfusion defects were supplied by vessels in which there was a greater degree of stenosis than that in the vessel supplying the segment with isolated slow washout rate. For the remaining 10 of 32, the contralateral myocardial segment was normal. The initial 201T1 distribution in all 10 myocardial segments in which isolated slow washout rates were noted showed slightly decreased regional 201T1 activity that was just within the normal range. The coronary artery supplying the myocardial segment with an isolated slow washout rate had stenosis of a greater degree than that supplying the contralateral myocardial segment in nine of 10 cases. The finding of isolated slow washout rates in these patients with adequate exercise tests was highly specific (95%) for segmental disease. We conclude that in patients with adequate exercise tests the occurrence of slow regional myocardial washout of 201T1 in the absence of perfusion defect significantly improves the detection of segmental myocardial hyperperfusion. This improvement appears to be due to the spatially nonrelative nature of 201T1 washout rate analysis, which complements the spatially relative perfusion defect analysis for the assessment of diseased myocardial segments.


From the Division of Cardiology, Department of Medicine, and the Department of Nuclear Medicine, Cedars-Sinai Medical Center, and the Departments of Medicine and Radiology, UCLA School of Medicine, Los Angeles.
Supported in part by NIH grant Nos. 17651 and 732 G2-2 from the American Heart Association, Greater Los Angeles Affiliate, and a grant to Dr. Abdulla from the Aga Khan Foundation, Geneva, Switzerland.
Address for correspondence: Jamshid Maddahi, M.D., Cardiology Division, Cedars-Sinai Medical Center, 8700 Beverly Blvd., Los Angeles, CA 90048.
Received July 19, 1982; revision accepted Oct. 4, 1984.
Presented in part at the 54th Annual Scientific Session of the American Heart Association, Dallas, 1981.

STRESS-REDISTRIBUTION thallium-201 (201T1) myocardial scintigraphy with conventional perfusion defect analysis has high sensitivity for overall detection of coronary artery disease.1–4 Perfusion defect analysis, however, fails to detect all myocardial regions subtended by diseased coronary arteries and therefore frequently results in underestimation of the extent of disease in patients with multivessel coronary involvement.5–9 This has been attributed in part to the fact that stress perfusion defect analysis (performed
either visually or quantitatively) is a "spatially relative" method: in a given view, myocardial regions are assessed relative to one another and thus, a region with decreased absolute $^{201}$TI concentration may appear normal relative to another region in which there is equally low or lower initial uptake of $^{201}$TI. A "spatially nonrelative" indicator of regional myocardial hypoperfusion might, however, demonstrate abnormality in a hypoperfused myocardial region that is missed by perfusion defect analysis.

Experimental studies of myocardial thallium kinetics have demonstrated that there is a slower than normal washout rate of $^{201}$TI in ischemic regions. Since it is difficult to evaluate the regional myocardial washout rate of thallium visually, objective computerized techniques for this measurement have been recently developed. In the technique developed by our group, regional myocardial washout rate is expressed as percent change in regional $^{201}$TI activity from stress to redistribution time. This technique also uses a spatially nonrelative approach to the definition of the abnormal regional myocardial percent $^{201}$TI washout: each patient's observed regional percent washout values are compared with a previously determined normal limit rather than with findings from other regions in the same patient. While the diagnostic accuracy of this technique for overall detection of disease was comparable to that of conventional visual analysis, it demonstrated a significantly higher sensitivity for detection of individual coronary artery stenoses when compared with visual analysis, and thus led to improved evaluation of the extent of coronary artery disease. Of particular interest was the finding that the majority of hypoperfused regions that were missed by visual analysis but were detected by the quantitative method were in patients with multivessel coronary disease, and that they demonstrated a slow $^{201}$TI washout rate without any apparent stress perfusion defects.

This study was undertaken (1) to evaluate further the contribution of regional myocardial $^{201}$TI washout analysis to the detection of disease in individual coronary arteries and (2) to investigate the mechanism by which certain hypoperfused myocardial regions demonstrate slow clearance rate of $^{201}$TI in the absence of an initial perfusion defect.

Methods

Patient population. The study population consisted of 116 patients who were referred to our cardiac stress laboratory for diagnosis and/or evaluation of coronary artery disease between June 1979 and October 1980 and who underwent both $^{201}$TI stress-redistribution scintigraphy and coronary angiography. The following patients were not included in this group: (1) patients whose stress testing-to-angiography interval was more than 6 months, (2) patients who were referred for stress testing after coronary artery bypass surgery, and (3) patients with inadequate stress tests (nine patients). An exercise test was considered to be inadequate when it was terminated before the patient had reached 85% of his or her age-predicted maximum heart rate without development of angina or ST segment depression. Patients on $\beta$-blockers were routinely asked to discontinue the drug 48 hr before the test. The mean age of these patients was 55 years (range 31 to 78). There were 94 males and 22 females. Of these patients, 39% had typical angina, 28% had atypical angina, 15% had nonanginal chest pain, and 18% were asymptomatic. Forty-five patients had prior myocardial infarction documented by history and/or diagnostic changes on the resting electrocardiogram.

Coronary arteriography. Coronary arteriography in multiple projections was performed by the Judkin’s or Sones’ technique within 26 ± 8 days (mean ± SD) of the thallium stress study. Coronary cineangiograms were reviewed by two independent, experienced observers who were unaware of the results of thallium scintigraphy. Coronary artery stenosis was graded according to the maximal diameter narrowing of the lumen. For purposes of analysis, coronary artery diameter narrowing of 50% or more was considered anatomically significant. The severity of coronary involvement was classified according to the following categories, depending on the degree of stenosis: (1) 50% or more to less than 75% stenosis, (2) 75% or more to less than 99%, (3) 99% stenosis (subtotal occlusion), and (4) 100% occlusion. In arteries with multiple stenoses, the severity of coronary disease was judged based on the most severe lesion.

Exercise thallium scintigraphy. Patients exercised while in the postabsorptive state on a continuous multistage treadmill according to the Bruce protocol until chest pain, serious arrhythmia, exertional hypotension, or fatigue occurred. Blood pressure and the 12-lead electrocardiogram were monitored before, during, and after exercise. At peak exercise 1.5 to 2.0 mL of $^{201}$TI was injected through a previously inserted intravenous cannula. All patients continued to exercise for another 60 to 90 sec after injection. Thallium imaging was begun approximately 6 min from the time of injection of intravenous tracer with a standard field of view Anger camera with 37 photomultiplier tubes, a 1/2 inch thick sodium iodide crystal, and a high-resolution, parallel-hole collimator. Multiple images were obtained in the anterior, 45 degree, and 70 degree left anterior oblique views, each for a preset period of 10 min. The total count rate on each initial image was approximately 500,000, which decreased to approximately 300,000 counts per view on the redistribution study. Redistribution images were obtained 3 to 5 hr after exercise in the three identical views. All images were stored on a magnetic disk in a 128 × 128 × 8-bit matrix. Images were also recorded directly on Polaroid film for visual interpretation.

Quantitative thallium scintigraphic analysis. The technique for quantitative analysis of thallium stress-redistribution scintigrams has been previously described in detail and clinically applied. Briefly, the principal steps of computer processing included: (1) modified bilinear interpolative background subtraction and standard nine-point smoothing, (2) generation of maximum count circumferential profiles for both the stress and redistribution images, and (3) alignment of the apex to 90 degrees on the circumferential profiles. The percent of myocardial $^{201}$TI washout between the times stress and delayed imaging time was calculated for each of 60 points along the profile in each view with the formula:

$$\frac{A-B}{A} \times 100$$
where A = stress myocardial activity and B = myocardial activity at the same location at the time of delayed imaging. From this calculation the computer generated a washout rate circumferential profile.

The stress and washout rate circumferential profiles were then automatically compared with previously established lower limits of normal for each view (mean minus 2 SD of normal population sample of 33 patients). A stress perfusion defect was defined by points along the stress circumferential profile lying below the normal limits. Similarly, slow washout was defined by points along the washout rate profile lying below the normal limit.

For a segment to be designated abnormal, at least one area of 18 degrees (three continuous radii) or more in either of the profiles had to extend below the normal limit. For a study result to be considered abnormal at least two abnormal segments had to be present in the entire study.

Assignment of myocardial segments to coronary arteries.
The myocardium was divided into three segments in each view. In figure 1 the angular degrees of circumferential profiles correspond to the different myocardial segments are shown. The segment of the ventricle from 210 to 330 degrees in each view was not analyzed since it was considered to represent the outflow tract. Moreover, the apical and inferoapical regions (segment of the ventricle from 60 to 120 degrees in each view) were not assigned to a specific coronary artery because of variable overlap of different coronary arteries in these regions.\(^4\),\(^9\),\(^11\) The remaining segments in each view were assigned to a specific branch of the coronary system in the following manner:\(^4\),\(^9\),\(^11\) In the anterior view, the anterolateral segment to the diagonal branch of the left anterior descending artery, and the inferior segment to the right coronary artery; in 45 degree left anterior oblique view, the septal segment to the left anterior descending coronary artery or its septal branches and the posterolateral region to the left circumflex artery; in 70 degree left anterior oblique view, the anteroseptal segment to the left anterior descending coronary artery or its septal branches and the inferior wall to the right coronary artery.

The territory of the left anterior descending coronary artery therefore consisted of the anterolateral, septal, and anteroseptal segments, that of the right coronary artery comprised the inferior wall in the anterior and 70 degree left anterior oblique views, and that of the left circumflex artery was represented by the posterolateral wall. For detection of disease in each of the three major coronary arteries, abnormality of any segment in a vascular territory was considered indicative of disease in the corresponding coronary artery.

Statistical analysis. McNemar's test\(^17\) was used to assess the significance of the differences in the sensitivity and specificity of perfusion defect and/or slow washout rate vs perfusion defect alone with regard to overall detection of coronary artery disease and detection of disease in individual coronary arteries. A p value of less than .05 was considered to indicate significance.

Results
Table 1 depicts the distribution of coronary artery disease in the study population. Of 116 patients, 60 had triple-vessel, 18 had double-vessel, and 16 had single-vessel disease and 22 were found to have no significant coronary stenosis.

Detection of disease in each of the three major coronary arteries. The sensitivity for detection of individual coronary stenosis by the various quantitative criteria is shown in figure 2. Of 85 diseased left anterior descending arteries, perfusion defects were present in the distribution of 63 (74%) and either perfusion defects or slow washout was present in 70 (82%). The sensitivity for detection of stenosis of the left anterior descending coronary artery with the combined analysis of perfusion defect and slow washout was significantly higher (p < .05) than that of the criterion of perfusion defect alone. The sensitivity for detection of stenosis of the left circumflex coronary artery was 61% (46 of 75 vessels) with use of the combination of perfusion defect and/or slow washout criteria. This sensitivity was significantly higher (p < .05) than that of perfusion defect analysis alone (30/75 = 40%). Similarly, a higher (p < .05) percentage of lesions of the right coronary artery (65/72 = 90%) were detected by use of the combination of criteria compared with perfusion defect criterion alone (56/72 = 78%).

There was no significant difference between the specificities for identification of individual coronary lesions with use of the criterion of perfusion defect alone or the combination criteria; 22 of 31 (71%) left anterior descending vessels that were not diseased were appropriately designated normal by quantitative perfusion defect analysis and 21 of 31 (68%) were

![FIGURE 1. Myocardial regions assessed quantitatively in each of the three views. The arc from 210 to 330 degrees in each view was considered to represent the outflow tract and was not evaluated. See text for assignment of the different myocardial regions to specific coronary arteries. ANT-LAT = anterolateral; INF = inferior; SEPT = septal; INF-AP = inferoapical; POST-LAT = posterolateral; ANT-SEPT = anteroseptal region.](image)

<table>
<thead>
<tr>
<th>Disease vessels</th>
<th>Normal vessels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient group</td>
<td>No. of patients</td>
</tr>
<tr>
<td>TVD 60</td>
<td>60</td>
</tr>
<tr>
<td>DVD 18</td>
<td>16</td>
</tr>
<tr>
<td>SVD 16</td>
<td>9</td>
</tr>
<tr>
<td>NCA 22</td>
<td>0</td>
</tr>
<tr>
<td>Total 116</td>
<td>85</td>
</tr>
</tbody>
</table>

LAD = left anterior descending; LCX = left circumflex; RCA = right coronary artery; TVD = triple-vessel disease; DVD = double-vessel disease; SVD = single-vessel disease; NCA = normal coronary arteries.
identified by the combined analysis. For the left circumflex artery, the specificities were 98% (40/41) and 93% (38/41) for perfusion defect and the combined analyses, respectively, and for the right coronary artery the specificities were 70% (31/44) and 64% (28/44) for perfusion defect and the combined analyses, respectively. Overall, the specificity of perfusion defect criteria alone was 80% (93/116), which was not significantly different from the overall specificity of 75% (87/116) when the combined criteria were used.

Presence of isolated slow washout. Isolated slow washout was considered present only when it was the only abnormality in the entire vascular territory on all three views, i.e., only when there was no perfusion defect in any segment of the vascular territory in question.

Of a total of 348 vascular territories (three vascular territories for each of 116 patients) isolated slow washout, i.e., slow washout in the absence of an associated perfusion defect, was observed in 38. In each case the abnormality was restricted to one myocardial segment. Thirty-two of the 38 were supplied by vessels with significant stenosis and six were subtended by a normal coronary artery. Isolated slow washout of ²⁰¹Tl therefore occurred in 32 of 232 (14%) diseased and six of 116 (5%) nondiseased vascular territories. There was no electrocardiographic evidence of prior myocardial infarction in any of 32 myocardial segments associated with diseased coronary arteries. The presence of slow washout in these segments was responsible for the increased sensitivity of the combined criteria approach over that of the perfusion defect criterion alone for detection of individual coronary stenoses; the abnormal washout pattern in these segments allowed detection of an additional seven stenosed left anterior descending arteries, 16 stenosed left circumflex arteries, and nine abnormal right coronary arteries.

In each case the segment in which there was an isolated washout abnormality (the ipsilateral segment) was compared with the contralateral segment in that view (figure 3). Quantitative analysis of the latter segments demonstrated isolated slow washout in nine (group I), both a perfusion defect and a slow washout abnormality in 13 (group II), and normal findings in the remaining 10 (group III) (table 2). It should be noted that although the nine contralateral segments in group I had isolated slow washout abnormalities, these did not contribute to the detection of additional diseased vascular territories since in each case a perfusion defect was present in another view in the distribution of the contralateral vascular territory. There were therefore only 32 diseased vascular territories in which the only scintigraphic abnormality in any view was slow washout of ²⁰¹Tl.

In each of the three groups the segment pairs were compared with respect to relative regional concentration of thallium as well as the degree of stenosis in the vessels supplying the two segments. The relative regional concentration of thallium was judged by examination of the circumferential profiles of the initial ²⁰¹Tl distribution.

All the segment pairs in group I had essentially equal thallium concentrations; the variation in counts between the two segments was no different from that noted in a previously studied group of normal subjects. Moreover, the angiographic classifications of stenosis in vessels supplying these nine segment pairs were the same (table 2). This implied balanced reduction of blood flow to both ipsilateral and contralateral myocardial segments.

Figure 4 illustrates data from a characteristic patient with group I segments. The circumferential profile of the stress thallium distribution (figure 4, A) showed a similar degree of ²⁰¹Tl activity in the anterolateral and inferior myocardial segments in the anterior view. The

![FIGURE 2. Comparative sensitivities of perfusion defect analysis vs perfusion defect and/or slow washout analysis for detection of disease in individual coronary arteries.](image)

![FIGURE 3. Subgrouping of the 32 myocardial scintigrams according to the quantitative findings in the segments contralateral to those demonstrating isolated slow washout.](image)
normalized activity curve of the patient was well above the lower limit of normal and thus no perfusion defect was present. Washout analysis (figure 4, B) revealed that the patient’s washout profile fell below the lower limits of normal in both the anterolateral and inferior segments, demonstrating isolated slow washout of $^{201}$Tl from these myocardial segments. With respect to the blood supply of the anterior wall, coronary angiographic examination of this patient revealed 90% stenosis of the proximal left anterior descending and 90% stenosis of the first diagonal branch. Similarly, the blood supply of the inferior wall was by the right coronary artery, in which 90% proximal stenosis and 90% stenosis of the posterior descending branch was found.

In group II segments, by definition, the contralateral segment demonstrated both a perfusion defect and slow washout while the ipsilateral segment had isolated slow washout. Thus, there was a lower initial thallium concentration in all 13 contralateral segments than in the ipsilateral segments. In 10 of these 13, coronary angiograms revealed that the artery supplying the contralateral myocardial segment had a greater degree of stenosis than the artery supplying the ipsilateral segment in which slow washout alone was found.
This implied bilateral but imbalanced reduction of blood flow to myocardial segmental pairs.

Figure 5 illustrates results of quantitative analysis of the 45 degree left anterior oblique view from a patient with group II segments. The stress circumferential profile (figure 5, A) showed that the $^{201}$Tl activity of the posterolateral segment was within the normal range in this patient, but perfusion defects were demonstrable in the inferoapical and septal segments. The washout circumferential profile, however (figure 5, B), showed that in addition to the septal and inferoapical segments, the posterolateral segment was abnormal. Coronary angiograms from this patient showed 99% stenosis of the left anterior descending artery proximal to the first septal perforator. The left circumflex artery, supplying the posterolateral wall, had a 60% proximal lesion.

**Figure 5.** Initial $^{201}$Tl stress distribution (A) and regional percent washout (B) profiles in 45 degree left anterior oblique view from a representative patient with group II segments. The patient’s stress circumferential profiles (PT) for the septal and inferoapical regions lie below the normal limit (NL), indicating presence of perfusion defects in these areas. The posterolateral segment is normal. The patient’s washout circumferential profiles for the posterolateral and the septal and the inferoapical regions also lie below the normal limit, indicating presence of slow washout in these areas.

In group III by definition the contralateral myocardial segment demonstrated no perfusion or washout abnormality. Although the thallium concentration was relatively lower in the ipsilateral segments, in all 10 segments it remained within the lower limit of normal. In nine of 10 cases coronary angiography revealed a higher class of stenosis in the vessel supplying the segment with isolated slow washout than in the vessel supplying the contralateral segment with no abnormality on quantitative analysis. In the remaining one of 10 cases the degree of stenosis was similar bilaterally.

**Figure 6.** Initial stress $^{201}$Tl distribution (A) and regional percent washout (B) profiles in 70 degree left anterior oblique view from a representative patient with group III segments. The patient’s initial distribution profile (PT) lies entirely above the normal limit (NL); however, $^{201}$Tl uptake in the inferior myocardial segment is less than that in the anteroseptal segment. The patient’s washout profile falls below normal limits for the apical and inferior myocardial segments, demonstrating presence of isolated slow washout in these myocardial regions.
ment compared with the anteroseptal segment, the degree of decrease was not large enough to cause a fall below the lower limit of normal. The washout profile (figure 6, B) for the inferior segment, however, was abnormal. Coronary angiography in this patient showed complete occlusion of the right coronary artery, which supplied the inferior wall. The left anterior descending vessel, which supplied the anteroseptal segment, had 50% proximal stenosis.

Discussion

In this study, addition of 201Tl washout analysis to stress perfusion defect analysis significantly enhanced the ability to detect abnormality in myocardial segments subtended by diseased coronary arteries and thus there was improved detection of individual coronary stenoses. This contribution was the result of the fact that 32 ischemic vascular territories in which no perfusion defects were found demonstrated slow 201Tl myocardial washout rates.

To determine the mechanisms of slow regional washout rate of thallium in the absence of a perfusion defect, the scintigraphic findings and regional coronary blood supplies in the 32 myocardial segments with isolated slow washout were compared with those in the contralateral myocardial segments in the same view.

The findings in group I segments suggest that because of balanced reduction of flow to both myocardial segments, the spatially relative approach for defect analysis fails to demonstrate any perfusion defect; however, results obtained with the spatially nonrelative approach of regional washout analysis demonstrate presence of slow regional washout of 201Tl as an index of myocardial hypoperfusion. The suggestion that blood flow in group I segments was reduced to a similar degree bilaterally is supported by the finding of similar degrees of stenosis in the vessels supplying the ipsilateral and the contralateral segments and the finding of associated similar initial 201Tl activity in both segments in each case. Segmental myocardial 201Tl uptake has been shown to be directly and linearly related to the amount of regional blood flow in patients at rest and during exercise.18-21 Our findings in group I segment pairs are in agreement with those of Nichols et al.,22 who demonstrated in man that over a range of global left ventricular blood flows of 35 to 114 ml/100 g/min, 201Tl images show no perfusion defects if myocardial blood flow is homogeneously reduced.

Our findings in group II segments suggested imbalanced reduction of blood flow to myocardial segment pairs resulting in no apparent perfusion defect in the region supplied by the vessel with a relatively lesser degree of coronary stenosis. Spatially nonrelative analysis of 201Tl washout, however, uncovered the abnormality in these apparently normal but actually hypoperfused segments. These first two mechanisms may in part explain the reason for low sensitivity of perfusion defect analysis for detection of individual coronary stenoses in patients with multivessel coronary disease and the complementary role of regional washout rate analysis of 201Tl in improving the detection rate.

The ipsilateral segments of group III that were supplied by diseased coronary arteries and showed isolated slow washout of 201Tl represent segments in which both perfusion defect and slow washout might be expected to occur together. Although a quantitative perfusion defect was not present in these segments, all 10 did show a relative decrease in initial uptake of 201Tl compared with the contralateral segments, although the extent of decrease remained within the range of normal limits. This problem is inherent in a method that uses a statistically determined range of normal limits.12 Although our method assumes a Gaussian distribution of normal segmental 201Tl counts around the mean and uses mean – 2 SDs as the lower limit of normal, in a separate study we found no difference in the results obtained with use of an observed range in which the 97th percentile was used to define the normal limits.23

Occurrence of isolated slow regional washout of myocardial 201Tl was highly specific for presence of segmental disease, as evidenced by the fact that it was observed in only six of 116 nondiseased coronary arteries. It is possible that termination of exercise test at a very low heart rate in the absence of clinical and electrocardiographic evidence of ischemia may result in a higher incidence of false-positive results of regional slow washout analysis.24 However, this mechanism was probably not operative in our patients since none of them were on propranolol and all had an adequate exercise test (i.e., either achieved heart rate of ≥ 85% predicted maximum for age and sex or attained a lower than 85% predicted heart rate but developed angina and/or ST segment depression). We are currently investigating the effect of achieved exercise heart rate on regional myocardial 201Tl washout rate in a larger group of patients.25

In addition to inadequate exercise tests, the following other conditions may cause slow regional washout rate of 201Tl in the absence of coronary artery disease: (1) subcutaneous infiltration of 201Tl at the site of injection, (2) inappropriate data acquisition (e.g., inad-
equate counting statistics or use of preset count rather than preset time for acquisition), (3) inappropriate imaging times, e.g., delayed start of stress imaging (>15 min after exercise) and early start of redistribution imaging (<3 hr after stress), and (4) processing error such as malpositioning of the background subtraction box and center and apex of the left ventricle, the latter of which results in misalignment of the stress and/or redistribution profiles. Thus, before a slow washout abnormality (ether segmental or diffuse) can be considered indicative of coronary disease, these aspects of quality control of the exercise test, acquisition of scintigraphic data, and procedure for image processing are necessary.

In summary, the present study confirms our previous findings that the additional quantitative analysis of regional $^{201}$TI washout rate improves the ability to detect individual coronary stenoses compared with that by defect analysis alone. This improvement appears to be due to spatially nonrelative nature of washout rate analysis, which complements the spatially relative perfusion defect analysis in the assessment of diseased myocardial segments. Such improved detection of diseased myocardial segments by regional myocardial $^{201}$TI washout analysis may result in enhanced identification of patients with triple-vessel and/or left main disease. The results are particularly important in the occasional triple-vessel disease patient with balanced reduction of coronary blood flow that may go entirely undetected by perfusion defect analysis alone.

**References**


20. Weihe MF, Strauss HW, Pitt B: The extraction of thallium-201 by the myocardium. Circulation 56: 188, 1977


Slow regional clearance of myocardial thallium-201 in the absence of perfusion defect: contribution to detection of individual coronary artery stenoses and mechanism for occurrence.

A Abdulla, J Maddahi, E Garcia, A Rozanski, H J Swan and D S Berman

Circulation. 1985;71:72-79
doi: 10.1161/01.CIR.71.1.72

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://circ.ahajournals.org/content/71/1/72