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Is quantitative analysis superior to visual analysis of planar thallium 201 myocardial exercise scintigraphy in the evaluation of coronary artery disease?

Analysis of a prospective clinical study

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Abstract. Quantitative analysis of myocardial exercise scintigraphy has been previously reported to be superior to visual image interpretation for detection of the presence and extent of coronary artery disease. Computer analysis of perfusion defects and washout rate of thallium 201 was performed on scintigrams from a group of 131 consecutive patients (prospective group), using criteria defined from a previous group of 72 patients (initial group), and compared with visual interpretation of scintigrams for detection and evaluation of coronary artery disease. The sensitivity of the quantitative technique with regard to overall detection of coronary artery disease was not significantly different from the visual method (69% and 74%, respectively), whereas the specificity was higher (86% and 68%). Quantitative analysis did not increase the sensitivity of thallium imaging over the visual method in the left anterior descending artery (46% vs 65%) and the right coronary artery (51% vs 72%) but did increase sensitivity in the left circumflex artery (75% vs 47%). Whereas in the initial group quantitative analysis resulted in a better identification of multivessel disease (sensitivity 81% vs 57%), in the prospective group sensitivity decreased (54% vs 67%) without significant loss of specificity. The initial group had a 40% incidence of three-vessel disease and the prospective group, 22% ($P<0.05$). One-vessel disease was higher in the prospective group (32% vs 11%, $P<0.05$). Thus, assessing the quantitative technique in a larger prospective patient population, there was no improvement of detection of the presence and extent of coronary artery disease when compared with visual interpretation.

Key words: Thallium 201 myocardial scintigraphy – Thallium 201 washout – Exercise test – Coronary artery disease

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Introduction

Thallium 201 myocardial exercise scintigraphy has been increasingly used in the diagnosis of coronary artery disease (Beller and Gibson 1987). Conventionally, thallium images have been analyzed visually for the presence of reduced segmental uptake in the initial images and partial or complete "filling-in" of the initial defects in delayed images (redistribution) (Bailey et al. 1977; Ritchie et al. 1977; Okada et al. 1980a). Several studies have reported on the value and limitations of a quantitative approach of thallium 201 exercise imaging, and the diagnostic accuracy of this technique can be high if the results of initial uptake and washout of thallium 201 are combined (Berger et al. 1981; Massie et al. 1983; Wackers et al. 1985; Ascoop et al. 1986). Quantitative analysis has been reported to be more accurate than visual interpretation of planar thallium images, and due to significant inter- and intraobserver variability, the sensitivity and specificity of visual analysis may not be

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optimal for the detection of coronary artery disease (Trobaugh et al. 1978; Okada et al. 1980b).

In an initial study quantitative analysis of uptake scintigrams and washout curves was compared with a semiquantitative visual analytic method in 72 patients with a 40% incidence of three-vessel disease (Ascoop et al. 1986). It was found that quantitative analysis of uptake in combination with a washout rate study of thallium 201 was not better than visual interpretation in the overall detection of significant coronary stenoses. The sensitivity of the quantitative analysis was 85% for the entire population and 90% for the three-vessel disease patients (specificity 90%). Quantitative analysis was more useful than visual interpretation in identifying multivessel coronary artery disease.

This study was undertaken to compare the results of quantitative analysis of uptake and washout of thallium 201 scintigrams with a semiquantitative visual analysis in patients referred for evaluation of chest pain, and to test the diagnostic value of quantitative criteria as established in an initial group ($n=72$) in a larger patient population ($n=131$) for detection of the presence, localization, and extent of coronary artery disease.

Methods

Patient population. The study population consisted of 203 patients who were referred to our cardionuclear department for assessment of suspected coronary artery disease between February 1983 and November 1986. All patients underwent exercise electrocardiography in conjunction with stress and redistribution thallium 201 scintigraphy and coronary arteriography. The interval between thallium myocardial scintigraphy and cardiac catheterization was less than 6 months in all cases. The study consisted of two parts: the initial study (group I), comparison with criteria as defined by others and development of own interpretive criteria; and the prospective study (group II), for application of the derived criteria.

Group I consisted of 72 patients referred between February 1983 and April 1984. This patient group has been previously described (Ascoop et al. 1986) and included 57 males and 15 females ranging in age from 24 to 69 years (mean 55 ± 9). Patients in group I were used to establish visual and quantitative scintigraphic criteria for detection of the presence and localization of coronary artery disease. These criteria were applied prospectively to analyze the scintigraphic results of the subsequent patient group (group II). Group II consisted of 131 patients referred between May 1984 and November 1986. The patients in group II comprised a small subgroup of a much larger population of patients who underwent thallium 201 testing during the 2.5-year study period and were selected for analysis because clinically indicated coronary angiography was performed within a 6-month period. This group included 111 males and 20 females ranging in age from 35 to 75 years (mean 55 ± 8). We tested prospectively the results of criteria established in group I with patients of group II. The characteristics of the patients of both groups are presented in Table 1.

The following patients were excluded: (1) those who underwent exercise testing after coronary bypass surgery or percutaneous transluminal coronary angioplasty; (2) those who failed to perform adequate exercise, that is if the patient achieved less than 85% of the age-predicted maximal heart rate in the absence of angina or ischemic ST depression; (3) those with valvular, congenital, or cardiomyopathic heart disease; (4) those with technically inadequate angiographic or scintigraphic registrations.

Table 1. Characteristics of hemodynamic results, chest pain, incidence and localization of myocardial infarction, and number of diseased vessels

	Group I	Group II	*P* value
Total	72	131	
Age (year)	55 ± 9	55 ± 8	NS
Sex (M/F)	57/15	111/20	NS
Max HR	134 ± 23	145 ± 17	0.001
Max BP	170 ± 16	180 ± 22	0.001
DP	22.8 ± 5.0	26.1 ± 4.9	0.001
Chest pain			NS
Atypical	22 (31%)	39 (30%)	
AP NYHA II	25 (35%)	59 (45%)	
AP NYHA III	25 (35%)	33 (25%)	
Myocardial infarction (Q waves)	20 (28%)	47 (36%)	0.05
septal	0	3 (2%)	
anterior	7 (10%)	13 (10%)	
lateral	1 (1%)	4 (31%)	
inferior	12 (17%)	19 (15%)	
combination	0	8 (6%)	
Number of vessels			0.001
1 vessel	8 (11%)	42 (32%)	
2 vessels	15 (21%)	38 (29%)	
3 vessels	29 (40%)	29 (22%)	
No significant CAD	20 (28%)	22 (17%)	

Max HR, maximal heart rate; *Max BP*, maximal blood pressure; *DP*, double product/1000; *AP*, angina pectoris; *NYHA*, New York Heart Association; *HR*, heart rate; *CAD*, coronary artery disease

Exercise electrocardiography. Exercise electrocardiography was carried out in the upright position on a calibrated bicycle ergometer using an exercise protocol with stepwise increased work load (Lode) (Rijneke et al. 1980). The initial external workload was 60 W during 3 min. Thereafter the load was increased every 3 min by 30 W until one of the stop criteria was fulfilled.

In all patients drugs such as beta-blocking agents and calcium antagonists were discontinued 24 h before the test, and digitalis derivates were withheld 2 weeks before the test. Thallium scintigraphy was performed in conjunction with the exercise test.

Thallium 201 imaging. A dose of 74 MBq (2 mCi) of thallium 201 was injected through an indwelling intravenous cannula at maximal exercise, which was continued for 1 min after injection. After termination of exercise, multiple view myocardial scintigrams were obtained at approximately 5 min and 4 h after injection of thallium. At each interval imaging was performed in the anterior, 30°, and 70° left anterior oblique (LAO) views for 10 min per view. The patient's physical activities and food consumption were restricted between the two recordings. For imaging a General Electric small field-of-view camera (26 cm) was used equipped with 37 photomultiplier tubes, $^{1}/_{4}$-inch (0.5-cm)-thick sodium iodide crystal,

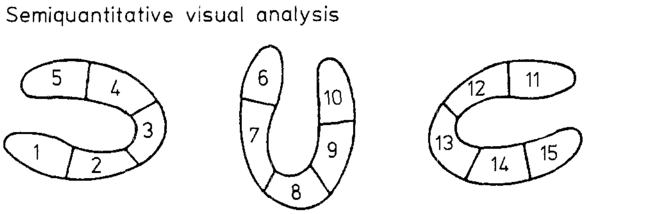

Fig. 1. Division of the myocardium into five segments per view as used in visual analysis (see text for flow regions of the major coronary arteries)

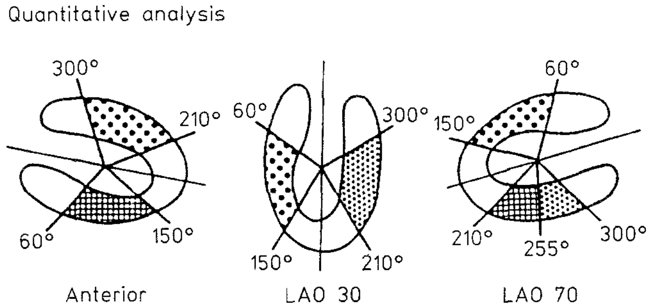

Fig. 2. Flow regions of the major coronary arteries as used in quantitative analysis. ▧ Left anterior descending coronary artery segments; ▦ Right coronary artery segments; ▩ Left circumflex artery segments; □ Apex outflow tract segments

and a general purpose, low energy, hexagonal parallel hole collimator was used. A 20% energy window centered on the 80-keV photopeak was used. There was a minimum of 300000 counts per image obtained. All images were stored by the computer on magnetic disc in a 128 × 128 × 8-bit matrix (MDS-A[2]).

Visual analysis. Visual analysis was performed by means of a 'semiquantitative' analysis of 15 segments (Rigo et al. 1980) (Fig. 1). The rough images of the myocardial activity (without background adjustment or smoothing) of the initial uptake and the delayed interval were visualized on a screen arranged per view. Matching views from initial uptake and delayed images were displayed side by side for comparison. Thallium 201 activity in each segment was visually graded from 1 to 3 (grade 1 = no defect, grade 2 = possible defect, grade 3 = definite perfusion defect). Summarizing the three views, the global score lies between 15 and 45 (Fig. 1). The visual differences between the postexercise and delayed images were classified in the same manner (1 = no reversible defect, 2 = possible reversible defect, grade 3 = definite reversible defect). The overall scintigram was considered abnormal when the total score was proven to be higher than 18 in the postexercise phase and higher than 17 in the redistribution phase.

The images were interpreted by two independent experienced investigators in a retrospective blinded reading session. The scores of the observers were averaged, yielding a 'multiobserver score' for each segment.

Flow regions were defined as follows: anterior flow region, segments 4, 5, 6, 7, 11, 12 (score 6 to 18); inferior flow region, segments 1, 2, 14 (score 3 to 9); lateral flow region, segments 9, 10, 15 (score 3 to 9). The apical segment was not assigned to one of these particular flow regions. In each flow region a criterion was constructed as follows: anterior, inferior, and lateral flow regions a score of 7, 4, and 4, respectively (Ascoop et al. 1986). Multivessel coronary artery disease was considered to be present if the initial uptake scintigram showed thallium defects in two or more specific vascular areas.

Computer processing and analysis. The computer method of quantifying thallium images has been described previously (Maddahi et al. 1981; Ascoop et al. 1986). The maximum count profile (maximum counts per pixel traversing the myocardium) was constructed by the computer from the result of 120 radii spaced at 3° intervals from the center of the ellipse. The three profiles were then aligned so that the 180° point in each view corresponded to the visually located apex (Fig. 2). In addition to the initial profile, washout circumferential profiles (after 4 h) were generated by calculating percentage washout for each point from the time of stress to the delayed imaging [(counts initial-counts delayed/counts initial) × 100].

Definition of normal limits. The uptake and washout rate circumferential profiles were compared with the lower limits of the profiles of a normal population available from a study from Maddahi and colleagues (Maddahi et al. 1981; Ascoop et al. 1986). In addition to the calculations for the entire myocardium according to the three views, flow regions were calculated for the left anterior descending artery (anterior), right coronary artery (inferior), and the left circumflex artery (lateral-posterior) as shown in Fig. 2.

Criteria for abnormality and multivessel/single vessel disease. Initial uptake and washout rate circumferential profiles were interpreted by a computer program which compared each curve to the normal limits described above. In a previous study optimal results were obtained from the 72 patients of group I and used to evaluate the 131 patients of group II prospectively. The following criteria were used: the overall scintigram was considered abnormal when an arc composed of at least 28 consecutive sample points (the angle between two sample points is 3° in our study) fell below the normal limit, considering the combination of the uptake scintigram and washout curve. Separate criteria were constructed for the three vascular areas, as previously described by our group (Ascoop et al. 1986). Multivessel coronary artery disease was considered to be present if the combination of uptake and/or the washout curves were abnormal in two or more specific vascular areas.

Coronary arteriography. The selective coronary angiogram was performed according to the Sones or Judkins technique (Sones and Shirey 1972; Judkins 1967). The angiograms were interpreted independently by two cardiologists; disagreement was resolved by an independent third cardiologist. Patients were considered to have significant coronary artery disease if they had 50% or more reduction of luminal diameter. Table 1 shows the distribution of the stenosed vessels in both groups.

Statistical analysis. The relation between scintigraphic variables and the angiographic findings is given in terms of sensitivity, specificity, positive predictive value, negative predictive value, and accuracy (Armitage 1977). Significance of difference was calculated using Student's t-test for continuous variables and the χ^2 test for discrete variables. Significance of the difference between sensitivity and specificity of the different methods was assessed by McNemar's test. A P value of less than 0.05 was considered to indicate significance.

Results

The characteristics of hemodynamic results, chest pain, incidence and localization of myocardial infarction, and

Table 2. Visual analysis of the initial uptake and redistribution of thallium 201 scintigrams in the prediction of significant coronary artery disease

	Group I ($n=72$)		Group II ($n=131$)	
Method	Uptake	Redistribution	Uptake	Redistribution
Criterion score[a]	18	17	18	17
Sens	0.86	0.73	0.74	0.52
Spec	0.90	0.95	0.68	0.68
PVpos	0.96	0.97	0.92	0.89
PVneg	0.72	0.57	0.35	0.22
χ^2	37.3	26.9	15.0	3.1

[a] A test is considered negative if the score is equal to or less than the criterion

Sens, sensitivity; *Spec*, specificity; *PVpos*, predictive value positive test; *PVneg*, predictive value negative test

Table 3. Quantitative analysis of the initial uptake scintigram and the combination uptake scintigram and washout curve of thallium 201 scintigrams in the prediction of coronary artery disease

	Group I ($n=72$)			Group II ($n=131$)		
Method	Initial uptake	Combination		Initial uptake	Combination	
Criterion score[a]	20	12	28	20	12	28
Sens	0.65	0.90	0.85	0.61	0.82	0.69
Spec	0.90	0.65	0.90	0.82	0.64	0.86
PVpos	0.94	0.87	0.96	0.94	0.92	0.96
PVneg	0.50	0.72	0.69	0.30	0.41	0.36
χ^2	17.7	23.6	34.8	13.8	19.5	23.1

[a] A test is considered negative if the number of sample points under lower limit is equal to or less than the criterion

Sens, sensitivity; *Spec*, specificity; *PVpos*, predictive value positive test; *PVneg*, predictive value negative test

number of vessels involved are listed in Table 1. In the 131 patients of group II, 42 had one-vessel disease, 38 had two-vessel disease, 29 had three-vessel disease, and 22 patients had no significant coronary artery disease. Comparing groups I and II, the difference of distribution of coronary artery disease was statistically significant ($P=0.001$).

Detection of presence of coronary artery disease

In Table 2 the results of groups I and II were compared. The diagnostic results of the classification of reversible defects are also presented.

In the analysis of the initial uptake alone, circumferential profiles of the initial radionuclide uptake generated from each of three left ventricular images were compared with lower limits. Using a criterion of an arc of 20 sample points below the lower limits for the global myocardium of three views, group I showed a sensitivity of 65% and a specificity of 90%, and group II showed a sensitivity of 61% and a specificity of 82% (Table 3).

Using the combination of the results of the quantitative analysis of the initial uptake scintigram and of the washout, the sample points under the lower limits of the uptake and washout profiles are summed: in fact six arcs of 240° are analyzed. In the initial study optimal results were obtained using a criterion of an arc of 28 sample points under the lower limits: the sensitivity was 85% and the specificity was 90%. Using this criterion in group II we found a sensitivity of 69% and a specificity of 86%. The results of both groups were also compared with the study of Maddahi, who used a criterion of an arc of 12 sample points (Table 3).

Table 4. Results of scintigraphic prediction of coronary artery disease in individual arteries by visual and quantitative analysis

		Sens	Spec	PVpos	PVneg	χ^2
Group I ($n=72$)						
LAD	VA	0.52	0.85	0.86	0.50	9.5
	QA	0.61	0.85	0.88	0.55	13.9
RCA	VA	0.61	0.82	0.84	0.58	13.1
	QA	0.71	0.89	0.91	0.66	24.5
LCX	VA	0.39	0.87	0.80	0.52	6.0
	QA	0.83	0.71	0.79	0.76	21.3
Group II ($n=131$)						
LAD	VA	0.65	0.69	0.75	0.58	14.2
	QA	0.46	0.85	0.81	0.52	13.5
RCA	VA	0.72	0.73	0.76	0.69	26.6
	QA	0.51	0.88	0.84	0.60	22.5
LCX	VA	0.47	0.81	0.66	0.67	12.1
	QA	0.75	0.66	0.63	0.78	22.4

Sens, sensitivity; *Spec*, specificity; *PVpos*, predictive value positive test; *PVneg*, predictive value negative test; *LAD*, left anterior descending artery; *RCA*, right coronary artery; *LCX*, left circumflex artery; *VA*, visual analysis; *QA*, quantitative analysis (combination of uptake and washout analysis)

Detection of coronary artery disease in individual coronary arteries

The results of detection of coronary artery disease in the major coronary arteries, left anterior descending artery, right coronary artery, and left circumflex artery are presented in Table 4. The sensitivity of the visual method for detection of disease in each of the coronary arteries in group I was 52% (24/46), 61% (27/44), and 39% (16/41) for the left anterior descending artery, right coronary artery, and left circumflex artery, respectively.

Table 5. Prediction of multivessel disease by the number of related flow regions as detected by visual and quantitative analysis of uptake and washout of thallium 201

	Group I ($n=72$)		Group II ($n=131$)	
	VA	QA	VA	QA
Sens	0.57	0.81	0.67	0.54
Spec	0.79	0.82	0.75	0.78
PVpos	0.81	0.88	0.74	0.72
PVneg	0.54	0.72	0.69	0.62
χ^2	9.8	22.5	23.4	14.1

VA, visual analysis; *QA*, quantitative analysis; *Sens*, sensitivity; *Spec*, specificity; *PVpos*, predictive value positive test; *PVneg*, predictive value negative test

Table 6. Assessment of extent of coronary disease by thallium 201 scintigraphy

Method	No. of obstructed vessels	Patients (n)	No. of abnormal ^{201}Tl flow regions			
			0	1	2	3
Visual analysis group I	0	20	18	1	1	0
	1	8	3	0	4	1
	2	15	2	5	8	0
	3	29	2	10	13	4
Quantitative analysis group I	0	20	18	0	1	1
	1	8	4	1	1	2
	2	15	0	2	8	5
	3	29	3	4	8	14
Total		72				
Visual analysis group II	0	22	14	4	4	0
	1	42	14	16	6	6
	2	38	6	6	18	8
	3	29	3	7	13	6
Quantitative analysis group II	0	22	18	2	1	1
	1	42	15	15	11	1
	2	38	12	9	11	6
	3	29	3	7	6	13
Total		131				

Thus, of the 131 diseased vessels, only 67 were detected by the visual method (51% sensitivity). The quantitative technique showed quite similar results for detection of disease in the left anterior descending artery (61%: 28/46) and the right coronary artery (71%: 31/44) but significantly higher sensitivity for detection of disease in the left circumflex artery (83%: 34/41). Considering all diseased vessels, the sensitivity was 71% (93/131).

In group II the results of the visual method for assessment of disease were 65% (50/77), 72% (51/71), and 47% (27/57) for the left anterior descending artery, right coronary artery, and left circumflex artery, respectively, and the results of the quantitative technique were 46% (35/77), 51% (36/71), and 75% (43/57), respectively. Considering all diseased vessels in group II, the sensitivity of the visual method was 62% (128/205) and of the quantitative method, 56% (114/205).

Prediction of extent of coronary artery disease

Sensitivity, specificity, and predictive values of test variables for two- or three-vessel disease by visual analysis and the quantitative method for groups I and II are presented in Table 5. In group I quantitative analysis appeared to be superior to visual analysis for the detection of multivessel disease, whereas in group II quantitative analysis appeared not to be superior. The results of assessment of extent of coronary artery disease by visual and quantitative analysis are presented in Table 6.

Discussion

Computerized quantitative evaluation of thallium 201 exercise scintigraphy is reported to have better sensitivity and specificity than visual interpretation and eliminates the subjective components of intra- and interobserver variability (Meade et al. 1978; Maddahi et al. 1981; Wackers et al. 1985). Visual inspection of thallium 201 scans does not provide information about myocardial kinetics, and therefore, important diagnostic information can be missed (Wackers et al. 1985). Several groups have shown that quantitative scintigraphy enhances disease detection in individual coronary arteries and results in improved recognition of multivessel disease (Berger et al. 1981; Maddahi et al. 1981; Abdulla et al. 1985). By using washout analysis it has been shown that 30% more patients with three-vessel disease could be detected (Gewirtz et al. 1983). Regional washout abnormalities of thallium 201 have been described without uptake defects (Abdulla et al. 1985; Beller and Gibson 1987). In a study of Abdulla et al. (1985) 14% of areas had isolated slow washout without initial defect.

The present study was performed to compare the results of quantitative analysis of thallium 201 exercise scintigraphy in a prospective group of 131 patients with a previously described group of 72 patients (initial group). In the initial group we demonstrated that quantitative analysis of the combination of uptake and washout of thallium 201 was not superior to the visual analysis for the overall detection of coronary artery disease, but that is was superior to visual analysis for the detection of multivessel disease. In the prospective group we found no additional value of quantitative analysis for the detection of both the presence and extent of coronary artery disease. According to the literature, by using washout criteria, quantitative analysis improves the detection of coronary artery disease in the individual major coronary arteries (Wackers et al. 1985; Abdulla et al. 1985). Our quantitative analysis in group I showed a slight improvement of sensitivity in the left anterior descending artery and the right coronary artery and a marked improvement of the sensitivity in the left circumflex artery. In group II though, quantitative analysis revealed lower sensitivities for the left anterior descending artery and the right coronary artery but higher sensitivity for the left circumflex artery.

Combining the results of the quantitative analysis of uptake and washout, a criterion of an arc of 28 sample points (84°) was obtained in the initial group. Quantitative analysis was less accurate using 12 sample points (36°) as defined by Maddahi et al. (1981). In the prospective group the sensitivity of quantitative analysis for the detection of coronary artery disease was lower than in the initial group (69% vs 82%). In retrospect, optimal results should have been obtained using an arc of 24 sample points. The reason why the sensitivity of both visual assessment and quantitative analysis was lower in group II may be explained by the lesser extent of coronary artery disease than in group I. In a study of Osbakken et al. (1984), the sensitivity of thallium 201 imaging by visual assessment decreased significantly the fewer the number of diseased vessels. However, in a study of Wackers et al. (1985) using quantitative analysis, the detection rate of patients with single-vessel disease was 55% by visual and 84% by quantitative analysis. In group II, however, more patients had sustained a previous myocardial infarction, which should result in a higher sensitivity.

It must be stressed that the initial study may differ from the spectrum of patients in whom the test is typically used (Philbrick et al. 1980). Performance may change as the test becomes clinically accepted. When a test is newly introduced, as in the initial study, the patients with negative test results are used to measure specificity (Rozanski et al. 1983). Following test validation, as in the prospective group, when the noninvasive test becomes used clinically, posttest referral bias is unavoidable. It is common to select patients for cardiac catheterization on the basis of the test result, especially if the test appears to be relatively accurate. This type of referral pattern will result in a decline in specificity of the test, as was seen considering visual analysis in our study. This was confirmed by Rozanski and Berman (1987), who found a decline of specificity of the exercise radionuclide ventriculography over a 5-year period in their laboratory from 100% to 58%.

The quantitative analysis in group II appears to be less accurate than visual analysis for the detection of multivessel coronary artery disease. This was in contradiction to the results of group I and the results described by Maddahi et al. (1981) and Wackers et al. (1985). Besides technical considerations of quantitative processing, this could be explained by the significantly lower incidence of three-vessel disease in the prospective group, resulting in less patients with global ischemia (Gewirtz et al. 1983). It has to be stressed that the accuracy of visual analysis is observer dependent, and less favorable results may be found if the observers are less experienced. Whether quantitative analysis improves the diagnostic value in patients with multivessel coronary artery disease remains unclear. In a previous study of our group both visual and quantitative analysis showed limited value for the detection of multivessel disease in 67 patients with a prior myocardial infarction (sensitivity 69% and 67%, specificity 56% and 50%, respectively) (Niemeyer et al. 1989). In some patients the test is discontinued because of a severely narrowed coronary artery, without significant impairment of coronary flow in other, less severely narrowed vessels. However, it is found that in patients with submaximal testing, washout is significantly lower than in the maximally tested patients (Massie et al. 1982; McCarthy and Makler 1985).

Potential limitations of quantitative analysis in the present study could be:

1. Background subtraction. This is used to create a real myocardial image to correct for noncardiac counts. According to the experiments of Narahara et al. (1977) there is a tendency toward overestimation of the background activity. After background subtraction this may lead to artificial perfusion defects on the initial scintigram or a false positive interpretation of slow regional washout of thallium 201. This problem exists in particular when there is considerable background activity in organs surrounding the heart. Although we found a high specificity in both groups I and II, this problem may still be a potential cause for false positive test results.

2. Patient and camera position. Makler et al. (1983) reported on repositioning of the patient for the delayed imaging as a source of variability in quantitative analysis. We do not consider this repositioning variability as an important factor because of the use of standard views, the supine position of the patient, and careful attention to patient positioning in our laboratory.

3. Mean or maximal segment counts. We used circumferential profiles based on maximal count per segment. Wackers et al. (1985) found a quite similar sensitivity but a slightly better specificity using mean segment counts when compared with maximal counts. In our laboratory we did not compare these two techniques for exercise thallium imaging, but in a study of 81 patients undergoing thallium imaging after dipyridamol infusion, these techniques were compared. The sensitivity was quite similar (71% for maximal counts and 73% for mean segment counts); the specificity was slightly better (76%) using mean counts than using maximal counts (68%).

4. Exercise level. In quantitative analysis uptake and washout is compared with "normal limits." "Normal" subjects may be different to patients with coronary artery disease. Patients with coronary artery disease cannot perform exercise at the same level as normal subjects, and the coronary blood flow, myocardial oxygen consumption, and thallium kinetics may be different, not as a consequence of ischemia but of the different level of exercise (McCarthy and Makler 1985). Massie et al. found that the washout rate was significantly greater on the maximal exercise test than the submaximal test. Consequently, in some patients who had to discontinue because of nonischemic reasons, they found a slow washout in areas with "normal" coronary arteries, leading to false positive test results (Massie et al. 1983).

5. Timing of initial and delayed imaging. Initial imaging was started at approximately 5 min after thallium 201 injection. The phenomenon of rapid washout (early redistribution) must be considered during the first 20 min. This may lead to false positive interpretation of slow washout after 4 h (Gutman et al. 1983). On the other hand, a perfusion defect at delayed scintigraphy does not necessarily indicate myocardial infarction since improvement following surgical intervention has often been found to suggest that severe ischemia may be the cause of this problem (Okada et al. 1985; Shelbert 1988). Some late defects show late redistribution 18–24 h after exercise, and when the uptake and washout of thallium are taken as two separate phases, misjudgement can take place in the assessment of viability of the myocardium.

Conclusion

Although the initial study showed similar results for the detection of coronary artery disease but better results for quantitative analysis in the detection of multivessel disease, we could not show equal results in the prospective group for these purposes. The quantitative approach to analysis of regional stress myocardial redistribution and washout of thallium 201 can offer additional information over visual scan interpretation, although several factors influencing the test result must be taken into account.

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