Enhanced Detection of Viable Myocardium by Technetium-99m-MIBI Imaging after Nitrate Administration in Chronic Coronary Artery Disease

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The aim of this study was to assess whether nitrate administration improves the imaging capabilities of ^{99m}Tc-MIBI tomography in detecting viable myocardium in coronary artery disease (CAD). **Methods:** Thirty-one patients with angiographically proven CAD and chronic LV dysfunction (ejection fraction 39% ± 9%) underwent two ^{99m}Tc-MIBI studies on separate days: one under rest conditions and the other after nitroglycerine (0.005 mg/kg per os) administration. Within 1 wk, all patients also underwent rest-redistribution ^{201}Tl imaging. Eight patients were also studied by echocardiography before and 5 ± 3 mo after coronary revascularization. **Results:** On resting ^{99m}Tc-MIBI images, 302 segments had normal uptake, 183 segments had moderately reduced uptake and 197 had severely reduced uptake. Of the segments with severely reduced uptake, 54 (27%) had increased uptake after nitroglycerine and were viable on ^{201}Tl images. Of the 143 (73%) segments with severely reduced ^{99m}Tc-MIBI uptake and no change after nitroglycerine, 81% were nonviable on ^{201}Tl images. In the eight patients studied before and after revascularization, 87% of segments with reversible ^{99m}Tc-MIBI defects and abnormal LV function demonstrated functional recovery after revascularization, whereas 89% of segments with irreversible ^{99m}Tc-MIBI defects did not. **Conclusion:** In patients with chronic ischemic LV dysfunction, nitrate administration improved the detection of severely hypoperfused but still viable myocardium on ^{99m}Tc-MIBI images.

Key Words: technetium-99m-MIBI; nitrate; coronary artery disease; myocardial viability; thallium-201

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In patients with chronic coronary artery disease (CAD) and severe left ventricular dysfunction, differentiation between viable and nonviable myocardium is clinically important in the selection of patients for revascularization procedures (*1,2*). Thallium-201 myocardial scintigraphy has been widely used to identify severely hypoperfused, but still viable tissue in such patients (*3–10*). Technetium-99m-methoxy isobutyl isonitrile (^{99m}Tc-MIBI) has been proposed as an alternative to ^{201}Tl in most clinical applications (*11*). Technetium-99m-MIBI and ^{201}Tl have shown comparable results in the detection of CAD (*12*), but ^{99m}Tc-MIBI's role in the differentiation between viable and nonviable myocardium in patients with chronic ischemic left ventricular dysfunction is still controversial (*13*). Several studies suggest that ^{99m}Tc-MIBI cardiac imaging may underestimate the presence of viable tissue in myocardial regions with severe reduction of coronary blood flow (*14–26*). Particularly, regions with reduced ^{99m}Tc-MIBI uptake may contain viable tissue, as demonstrated by ^{201}Tl myocardial scintigraphy (*15,18,20–24*), metabolic imaging with ^{18}F-deoxyglucose (*17,24–26*) and functional recovery after coronary revascularization (*14,16,19,23*). On the other hand, a recent study by Udelson et al. (*27*) showed that quantitative analysis of ^{99m}Tc-MIBI and ^{201}Tl uptake after rest injections may similarly differentiate viable from nonviable myocardium and predict reversibility of regional wall motion abnormalities after coronary revascularization in patients with chronic CAD. Furthermore, other studies suggest that acquisition of delayed ^{99m}Tc-MIBI images may improve ^{99m}Tc-MIBI's ability to detect viable myocardium in such patients (*24,28*).

Nitrate administration has been shown to increase regional coronary blood flow in ischemic myocardium (*29–31*). It has also been demonstrated that ^{201}Tl, ^{99m}Tc-teboroxime and ^{99m}Tc-MIBI cardiac imaging with nitrates enhances the detection of ischemic but viable myocardium (*32–34*). Therefore, we hypothesized that nitrate administration could facilitate ^{99m}Tc-MIBI uptake in regions with severely ischemic but still viable tissue. The aim of this study was to evaluate whether associated physiologic effects of nitrates with ^{99m}Tc-MIBI cardiac imaging may improve the detection of severely hypoperfused but still viable myo-

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TABLE 1
Patient Characteristics

Patient no.	Sex	Age (yr)	LVEF (%)	MI site	WMA site	Coronary artery stenosis (≥50%)
1	M	62	42	Posterolateral	Lateral	LAD, LCx, PDA
2	M	62	24	Inferior, anterior	Inferior, apical	LAD, PDA
3	M	44	49	Anteroseptal	Septal, apical	LAD, LCx
4	M	63	38	Anterior	Septal, lateral, apical	LAD, LCx, PDA
5	M	57	44	Inferior	Inferolateral	PDA
6	M	67	42	Inferior	Inferior	LAD, PDA
7	M	60	39	Inferolateral	Septal, inferoapical, lateral	LAD, LCx
8	M	49	35	Anteroseptal, inferoapical	Inferoapical	LAD
9	M	69	39	Inferolateral	Septal, posterolateral	LAD, LCx, PDA
10	M	46	34	Anterior	Anteroapical	LAD, PDA
11	M	63	48	Inferolateral	Septal, inferolateral	LAD, PDA
12	M	48	28	Anterior	Anteroseptal, apical	LCx
13	M	43	41	Anteroseptal	Septal	LAD, LCx
14	M	61	42	Inferior, anterior	Inferoapical	LAD, LCx, PDA
15	M	40	48	Anteroseptal	Septal	LAD
16	M	63	31	Anteroseptal, inferior	anteroseptal, apical	LAD, LCx, PDA
17	M	54	30	Inferolateral	Inferoapical	LAD, PDA
18	M	66	47	Anteroapical	Anterior, apical	LAD
19	M	58	49	Inferior	Inferoapical	PDA
20	M	65	48	Anterior	Anteroseptal	LAD, LCx
21	M	61	30	Anterior	Anteroapical, inferior	LAD
22	M	68	49	Anterior	Septal	LAD, LCx, PDA
23	M	50	36	Anteroseptal	Septal	LAD
24	M	57	48	Anteroseptal, apical	Apical	LAD
25	M	38	23	Anterior	Anterior, inferoapical	LAD
26	M	32	26	Anterior, inferior	Anterior, inferior, apical	LAD, LCx
27	M	42	20	Anterior	Anterior, apical	LAD
28	M	53	49	Anterior	Septal	LCx, PDA
29	M	47	44	Anterolateral	Anteroseptal	LAD
30	F	57	46	Inferior	Inferoapical, septal	LAD, LCx, PDA
31	F	65	44	Anterior	Anteroseptal, apical	LAD

LVEF = left ventricular ejection fraction; LAD = left anterior descending artery; LCx = left circumflex artery; PDA = posterior descending artery; MI = myocardial infarction; WMA = wall motion abnormality.

cardium in patients with chronic CAD and left ventricular dysfunction.

MATERIALS AND METHODS

Patients

We studied 31 patients (29 men, 2 women; mean age 55 ± 10 yr) with angiographically documented CAD and left ventricular dysfunction (Table 1). Seven patients had significant stenosis of all three major coronary vessels, 11 patients had significant stenosis of two major coronary vessels and 13 patients had significant stenosis of only one major coronary vessel. The mean left ventricular ejection fraction by resting equilibrium radionuclide angiography was 39% ± 9%. All patients had previous myocardial infarction documented clinically and electrocardiographically. No patient, however, had had an acute myocardial infarction within 6 mo of the study. The majority of patients (n = 28) were symptomatic with episodes of stable angina requiring antianginal treatment, whereas three patients were asymptomatic. In all patients, however, radionuclide studies were performed after withdrawal of all medications. Eight patients were also studied after coronary revascularization, coronary artery bypass graft in six and percutaneous transluminal coronary angioplasty in two. None of these patients had clinical evidence of perioperative or postangioplasty myocardial infarction or restenosis. Informed consent, as part of the protocol approved by the Institutional Clinical Research Subpanel on Human Studies at our university, was obtained from all patients.

Technetium-99m-MIBI Imaging

All patients had two intravenous injections of ^{99m}Tc-MIBI (740 MBq): one under resting control conditions and the other after nitrate administration. A 3-day interval separated each of the two radionuclide studies. Images were acquired 1 hr after ^{99m}Tc-MIBI injection for both studies. All patients had the same preparation for both ^{99m}Tc-MIBI studies. Patients were ambulatory and remained in the resting state for 30 min before each ^{99m}Tc-MIBI study. After an overnight fast to minimize gallbladder activity, patients were instructed to consume a light fatty meal before ^{99m}Tc-MIBI injection and imaging.

The nitrate ^{99m}Tc-MIBI study was performed after nitroglycerine administration (0.005 mg/kg per os). Technetium-99m-MIBI was injected 20 min after nitroglycerine. Heart rate and blood pressure were measured at baseline and 5 min after nitroglycerine administration for 1 hr. The time of ^{99m}Tc-MIBI injection after nitroglycerine administration was established based on previous

results demonstrating a hemodynamic peak response to nitroglycerine between 15 and 20 min after oral administration (*35*).

SPECT was performed as previously described (*36*) using a rotating large field of view gamma camera equipped with a low-energy, all-purpose, parallel-hole collimator connected to a dedicated computer system. Briefly, 32 projections (40 sec/projection) were obtained over a semicircular 180° arch, which extended from the 30° right anterior oblique to the left posterior oblique position. A 20% symmetric energy window centered on the 140-keV peak was used. All projection images were stored on a magnetic disk in a 64 × 64 word matrix. Each projection image was corrected for nonuniformity, with a 120-million count image obtained weekly from a uniform ^{57}Co flood source. The mechanical center of rotation was determined from the projection data to align the detector data with the reconstruction matrix (*37*). The raw data were initially smoothed with a nine-point weighted average algorithm. Filtered backprojection was then performed with a low-resolution Butterworth filter with a cutoff frequency of 0.5 cycles/pixel, order 5.0, to reconstruct transverse axial tomograms of 6.2-mm thickness per slice, which encompassed the entire heart. Sagittal and oblique tomograms parallel to the long-axis and short-axis of the left ventricle were then extracted from the filtered transaxial tomograms by performing coordinate transformation with the appropriate interpolation (*38*). No attenuation or scatter correction was applied.

Thallium-201 Imaging

Rest-redistribution ^{201}Tl myocardial scintigraphy was performed in all patients within 1 wk of ^{99m}Tc-MIBI studies. Patients were ambulatory and remained in a resting state for 30 min before thallium administration. After an overnight fast, ^{201}Tl (111 MBq) was intravenously injected at rest. Initial and delayed images were acquired 15 min and 4 hr after injection, respectively. During the time between the initial and delayed images, all patients were ambulatory but did not eat. SPECT acquisition was performed with the same gamma camera, matrix and computer system used for the ^{99m}Tc-MIBI studies. The photopeak was centered on 68-keV with a 20% window.

Echocardiography

In the eight patients studied before and after coronary revascularization, two sequential echocardiographic studies were performed. The first study (baseline) was performed within 1 wk of the ^{99m}Tc-MIBI and ^{201}Tl cardiac studies. The second study (follow-up) was performed an average of 5 ± 3 mo after coronary revascularization. No patient received beta-blockers or inotropic drugs at the time of the follow-up evaluation. Echocardiographic studies were performed using a phased-array sector scanner with a 2.5 MHz transducer. Two-dimensional images of the left ventricle were obtained at rest with the patients lying in the left lateral decubitus position using multiple imaging sections, including parasternal long- and short-axes and apical two- and four-chamber views. Images were recorded on videotape for analysis.

Data Analysis

In each patient, corresponding resting, nitrate ^{99m}Tc-MIBI and rest-redistribution ^{201}Tl tomographic images were evaluated for direct comparison, as previously described (*36*). For each study, tomograms were divided into 22 myocardial segments (Fig. 1). Regional ^{99m}Tc-MIBI and ^{201}Tl uptake were quantitatively analyzed. In each tomogram, the myocardial region with the maximum counts was considered as the normal reference region. Technetium-99m-MIBI and ^{201}Tl uptake in all other segments were then expressed as the percentage of the activity measured in the reference region.

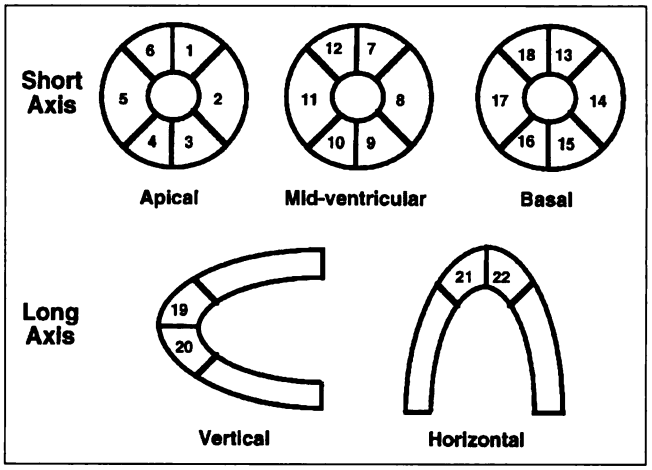

FIGURE 1. Diagram of the standard segmentation scheme used for regional quantitative analysis of ^{99m}Tc-MIBI and ^{201}Tl uptake.

To assess the normal range for quantitative data analysis, a group of 14 age-matched normal subjects (13 men, 1 woman) with no evidence of cardiovascular or pulmonary disease were also studied. For these subjects, clinical examination, echocardiogram and stress electrocardiogram were normal. A myocardial segment was considered abnormal if resting ^{99m}Tc-MIBI or initial ^{201}Tl uptake was >2 s.d. below the mean observed in the same region for normal subjects. On resting ^{99m}Tc-MIBI images, segments with abnormal uptake were subgrouped on the basis of severity of reduction in tracer activity: moderate (≥50% of peak activity) and severe (<50% of peak) defects, as previously reported (*26*). On the basis of previous reproducibility measurements in our laboratory, a segment with reduced activity on resting ^{99m}Tc-MIBI or initial ^{201}Tl images was considered reversible if the activity increased ≥10% on nitroglycerine ^{99m}Tc-MIBI or delayed ^{201}Tl images. Alternatively, a segment with reduced activity on resting ^{99m}Tc-MIBI or initial ^{201}Tl images was considered irreversible if the activity did not increase ≥10% or increased ≥10% but remained <50% on nitroglycerine ^{99m}Tc-MIBI or delayed ^{201}Tl images. Thallium-201 irreversible defects were divided on the basis of severity of reduction in tracer activity: moderate (≥50% of peak activity) and severe (<50% of peak) defects, as previously reported (*3,9*).

Echocardiographic images were interpreted by two experienced observers who were unaware of clinical, radionuclide and angiographic findings. A third investigator blindly reviewed the echocardiograms when the first two observers were not in agreement. Regional left ventricular function was assessed according to the recommendations of the American Society of Echocardiography (*39,40*). Segmental left ventricular wall motion was graded as: 1, normal; 2, hypokinetic; 3, akinetic; and 4, dyskinetic. In the eight patients studied before and after coronary revascularization, echocardiographic results were directly compared to ^{99m}Tc-MIBI images, as previously described (*41*). In these patients, a myocardial segment was considered as showing functional recovery when the regional wall motion score was abnormal at baseline and improved at least one echocardiographic grade during the follow-up study, as previously reported (*19*). Conversely, a myocardial segment was considered as showing no functional recovery when the regional

TABLE 2
Hemodynamic Parameters Recorded under Control Conditions and after Nitroglycerine Administration

	Control conditions	Nitroglycerine
Heart rate (bpm)	71 ± 15	101 ± 19*
Systolic blood pressure (mmHg)	130 ± 17	106 ± 15*
Diastolic blood pressure (mmHg)	81 ± 8	71 ± 10*

*$p < 0.001$.

wall motion score was severely impaired at baseline (grade 3 or 4) and did not change during the follow-up study (*19*).

Statistical Analysis

Data are expressed as mean ±1 s.d. Differences in the mean values were assessed by Student's t-test for unpaired data, with Bonferroni correction for multiple groups comparison or Student's t-test for paired data, as appropriate. Chi square analysis was used to assess differences between proportions. Probability values <0.05 were considered significant.

RESULTS

Technetium-99m-MIBI Imaging

Hemodynamic parameters recorded under control conditions and after nitroglycerine administration are shown in Table 2.

A total of 682 myocardial segments were analyzed. On resting ^{99m}Tc-MIBI images, 302 segments had normal tracer uptake, 183 showed moderate and 197 severe reduction of tracer uptake. Of the 197 segments with severe reduction of resting ^{99m}Tc-MIBI uptake, 54 (27%) were reversible, showing increased tracer uptake after nitroglycerine administration (from 42% ± 8% to 60% ± 8% of peak activity, $p < 0.001$). The remaining 143 (73%) segments were irreversible, showing no change in tracer uptake after nitroglycerine administration (from 33% ± 13% to 32% ± 11% of peak activity). Eleven (5%) of the 197 segments with severe reduction of resting ^{99m}Tc-MIBI uptake showed worsening tracer uptake (≥10%) after nitrate administration (Fig. 2). Furthermore, reversible defects after nitroglycerine showed significantly higher resting ^{99m}Tc-MIBI uptake compared to irreversible defects (Fig. 3).

Myocardial segments with severe reduction of resting ^{99m}Tc-MIBI uptake were observed in all 31 patients (range 1–14 segments/patient, mean 6.4 ± 3.6). Reversible ^{99m}Tc-MIBI defects after nitroglycerine administration were observed in 22 (71%) patients (range 1–6 segments/patient, mean 2.4 ± 1.5). The angiographic characteristics of the patients showing enhanced ^{99m}Tc-MIBI uptake after nitroglycerine administration and those of patients with unchanged tracer uptake after nitrates are illustrated in Table 3.

Thallium-201 Imaging

Resting ^{99m}Tc-MIBI uptake and initial and delayed thallium uptake in all myocardial segments for the entire patient population were not different (Fig. 4). None of the myocardial segments with severe reduction of resting ^{99m}Tc-MIBI uptake and reversible defects after nitroglycerine administration showed severe irreversible ^{201}Tl defects. In particular, 3 segments had normal uptake, 25 had reversible defects and 26 had moderate irreversible defects. On the other hand, the majority (81%) of myocardial segments with severe reduction of resting ^{99m}Tc-MIBI uptake and irreversible defects after nitroglycerine administration showed severe irreversible ^{201}Tl defects.

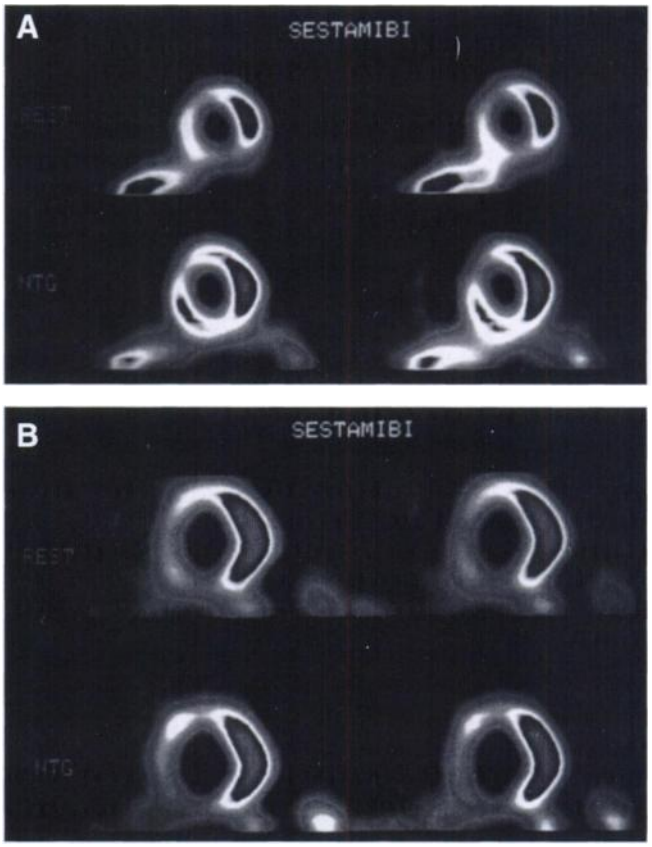

FIGURE 2. (A) Technetium-99m-MIBI cardiac tomography under rest conditions (Rest) and after nitroglycerine (NTG) administration: short-axis slices showing reversible defects involving the septal and inferior regions. (B) Technetium-99m-MIBI cardiac tomography under resting conditions (Rest) and after nitroglycerine (NTG) administration: short-axis slices show a large irreversible defect involving the anterior, septal and inferior regions.

In the 54 myocardial segments with reversible ^{99m}Tc-MIBI defects after nitroglycerine, resting ^{99m}Tc-MIBI uptake was significantly lower ($p < 0.001$) compared to both initial and delayed thallium uptake (Fig. 5). On the other hand, ^{99m}Tc-MIBI uptake after nitroglycerine in these segments was significantly higher ($p < 0.001$) compared to initial thallium uptake but was different from delayed thallium uptake (Fig. 5).

Follow-up after Coronary Revascularization

In the eight patients studied before and after revascularization, 52 (29%) myocardial segments showed severe reduction of ^{99m}Tc-MIBI uptake on resting images. Twenty-five segments were reversible and 27 were irreversible after nitroglycerine administration. The majority (87%) of seg-

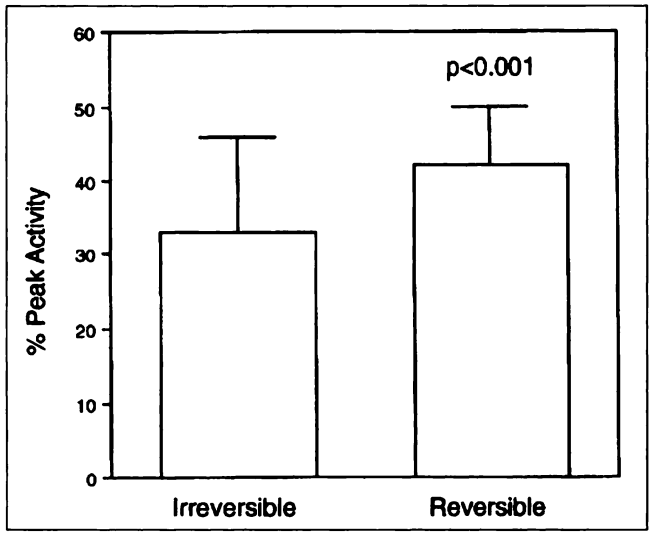

FIGURE 3. Resting ^{99m}Tc-MIBI uptake (expressed as percentage of peak activity) in myocardial segments with irreversible and reversible ^{99m}Tc-MIBI defects after nitroglycerine administration.

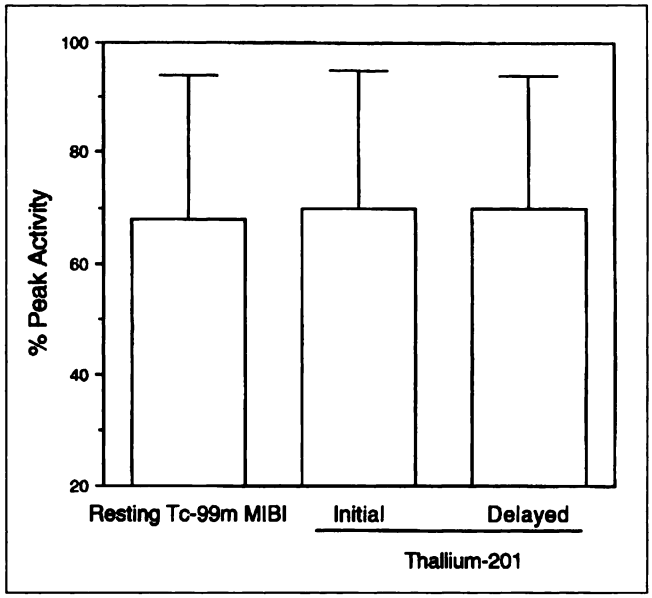

FIGURE 4. Resting ^{99m}Tc-MIBI uptake and initial and delayed ^{201}Tl uptake (expressed as percentage of peak activity) in all myocardial segments for all patients.

ments with reversible ^{99m}Tc-MIBI defects after nitroglycerine and abnormal left ventricular function showed improved wall motion after coronary revascularization (Fig. 6). Conversely, the majority (89%) of segments with irreversible ^{99m}Tc-MIBI defects after nitroglycerine and severely impaired left ventricular function did not show improved wall motion after coronary revascularization ($p < 0.001$ versus reversible defects) (Fig. 6).

DISCUSSION

In this study, we investigated whether the association of the physiologic effect of nitrate administration with ^{99m}Tc-MIBI cardiac tomography improves differentiation between ischemic but still viable myocardium from irreversibly fibrotic tissue in patients with chronic CAD and impaired left ventricular function. Our data suggest that nitroglycerine administration in such patients enhances the detection of severely hypoperfused but still viable myocardium on ^{99m}Tc-MIBI images.

Technetium-99m-MIBI as a Marker of Myocardial Viability

In patients with chronic CAD, the role of ^{99m}Tc-MIBI cardiac imaging to identify severely ischemic but viable myocardium is still controversial (*13*). Several studies demonstrated that ^{99m}Tc-MIBI uptake may underestimate the presence of viable tissue in such patients (*14–26*). Although these studies were different in terms of imaging protocols, the conclusive results were comparable, suggesting an underestimation of viable tissue by ^{99m}Tc-MIBI in myocardial regions with reduced coronary blood flow and severely depressed ventricular function. In particular, comparative studies between ^{99m}Tc-MIBI scintigraphy and metabolic imaging with ^{18}F-deoxyglucose suggested that the major

TABLE 3
Angiographic Patient Characteristics according to Nitrate Technetium-99m-MIBI Imaging

	One-Vessel disease	Two-Vessel disease	Three-Vessel disease
Group 1 (n = 22)	10 (46%)	8 (36%)	4 (18%)
Group 2 (n = 9)	3 (33%)	3 (33%)	3 (33%)

Group 1 consisted of patients with reversible ^{99m}Tc-MIBI defects after nitroglycerine administration. Group 2 consisted of patients with irreversible ^{99m}Tc-MIBI defects after nitroglycerine administration.

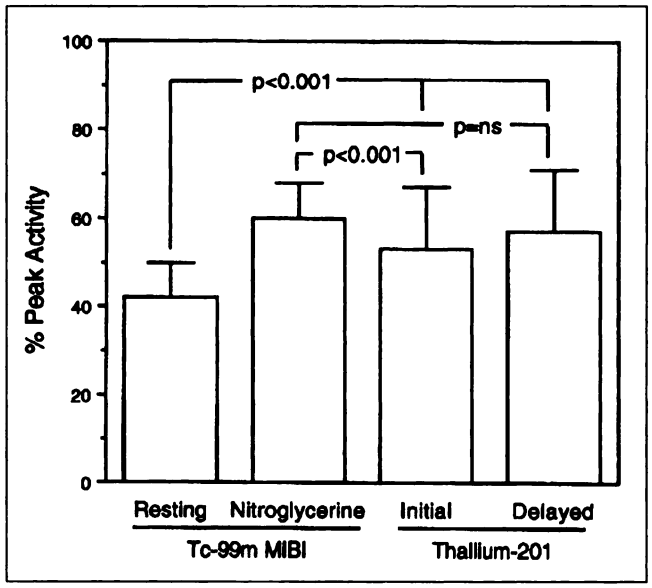

FIGURE 5. Technetium-99m-MIBI and ^{201}Tl uptake (expressed as percentage of peak activity) in myocardial segments with reversible ^{99m}Tc-MIBI after nitroglycerine administration. ns = nonsignificant.

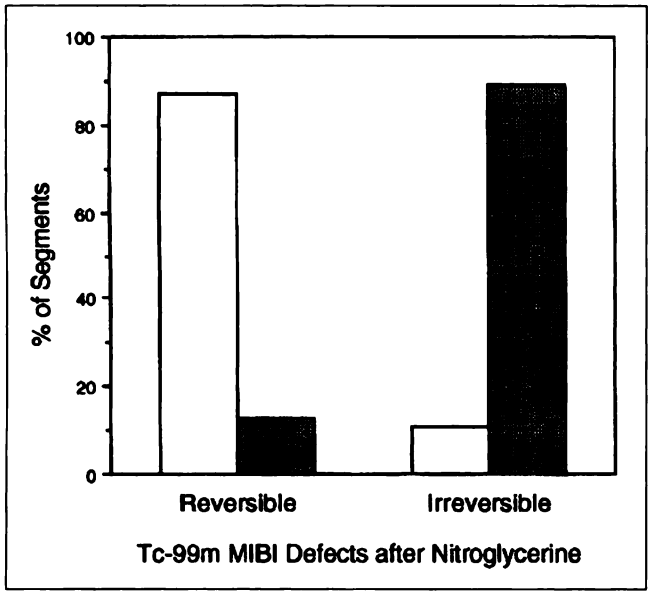

FIGURE 6. Percentage of myocardial segments with reversible and irreversible ^{99m}Tc-MIBI defects after nitroglycerine administration show functional (open bars) and no functional recovery (closed bars) after coronary revascularization.

determinant of ^{99m}Tc-MIBI myocardial uptake is regional coronary blood flow rather than tissue viability (*17,25,26*). Udelson et al. (*27*) recently demonstrated, however, that quantitative analysis of ^{99m}Tc-MIBI and ^{201}Tl uptake in resting conditions may similarly differentiate viable from nonviable myocardium and predict reversibility of regional wall motion abnormalities after coronary revascularization. Furthermore, delayed acquisition of ^{99m}Tc-MIBI images may enhance the identification of viable myocardium, as recently suggested by preliminary clinical and experimental studies (*24,28*).

Nitrate Technetium-99m-MIBI Imaging

Since nitrate administration has been shown to increase regional blood flow in ischemic myocardium (*29–31*), we hypothesized that this pharmacologic effect could favor ^{99m}Tc-MIBI uptake, particularly in regions with severely hypoperfused but still viable tissue. It has been demonstrated that ^{201}Tl, ^{99m}Tc-teboroxime and ^{99m}Tc-MIBI cardiac imaging with nitrate administration enhances the detection of ischemic but viable myocardium (*32–34*). In this study, we focused our analysis on myocardial segments with severe reduction of resting ^{99m}Tc-MIBI uptake, in which the presence of viable myocardium was in question. Twenty-seven percent of these segments showed significantly enhanced ^{99m}Tc-MIBI uptake after nitroglycerine administration and were considered to be reversible defects. Conversely, the remaining segments (73%) did not show significant change after nitroglycerine and were considered to be irreversible defects. Only 5% of segments with severe reduction of ^{99m}Tc-MIBI uptake on resting images showed worsening tracer uptake after nitroglycerine administration. Our results are concordant with those reported by Bisi et al. (*34*), who demonstrated a comparable percentage of myocardial segments showing a decrease in the defect extent of ^{99m}Tc-MIBI uptake after nitrate administration. An interesting finding in the present study was that reversible ^{99m}Tc-MIBI defects showed significantly higher tracer uptake on the rest images compared to irreversible ^{99m}Tc-MIBI defects (Fig. 2). On the basis of these results, myocardial segments with reversible ^{99m}Tc-MIBI defects could be differentiated from those with irreversible defects after nitroglycerine due to the amount of ^{99m}Tc-MIBI on resting images. Furthermore, these findings suggest that quantitative ^{99m}Tc-MIBI criteria currently used to assess myocardial viability should be redefined. These observations agree with the results of other studies comparing metabolic imaging with ^{18}F-deoxyglucose and resting ^{99m}Tc-MIBI uptake (*17,25,26*), in which several myocardial segments with severely reduced resting ^{99m}Tc-MIBI uptake showed evidence of viable myocardium on ^{18}F-deoxyglucose PET images.

In this study, the occurrence of ^{99m}Tc-MIBI reversibility after nitroglycerine administration was observed in 71% of the patients. This finding may be clinically relevant because it demonstrates that nitrate ^{99m}Tc-MIBI imaging may identify viable myocardium more accurately than resting ^{99m}Tc-MIBI imaging in patients with chronic ischemic left ventricular dysfunction. The angiographic results suggest that patients with multivessel CAD demonstrate increased ^{99m}Tc-MIBI uptake after nitroglycerine administration less frequently compared to those with single-vessel disease. The majority (77%) of patients with single-vessel disease showed increased ^{99m}Tc-MIBI uptake after nitroglycerine. Sixty-seven percent of patients with multivessel disease also had increased MIBI uptake.

Comparison with Thallium-201 Imaging

Resting ^{99m}Tc-MIBI uptake, initial and delayed thallium uptake were not different when all myocardial segments for the entire patient population were considered (Fig. 4). Rest-redistribution ^{201}Tl cardiac imaging in myocardial segments with reversible ^{99m}Tc-MIBI defects after nitroglycerine administration confirmed the presence of viable myocardium in these regions. In particular, no segment with reversible ^{99m}Tc-MIBI defects after nitroglycerine administration showed severe irreversible thallium defects. Another interesting finding is that resting ^{99m}Tc-MIBI uptake was significantly lower in these latter segments compared to both initial and delayed thallium uptake (Fig. 5). These results confirm previous observations (*18–22*). Udelson et al. (*27*), however, recently reported that quantitative analysis of ^{99m}Tc-MIBI and ^{201}Tl uptake after rest injections may similarly differentiate viable from nonviable myocardium in patients with chronic CAD. A possible explanation for the differences between these findings and the results of the present study could be that we included in the analysis only segments with severely reduced rest ^{99m}Tc-MIBI uptake and the majority of these segments did not show severe reduction of initial thallium uptake. On the other hand, ^{99m}Tc-MIBI uptake after nitroglycerine was significantly higher compared to initial thallium uptake but was not

different from delayed thallium uptake (Fig. 5). Therefore, similar information on the presence of viable myocardium in patients with chronic ischemic left ventricular dysfunction may be obtained by thallium redistribution and ^{99m}Tc-MIBI nitrates cardiac tomography.

Follow-up after Coronary Revascularization

Although thallium uptake may be considered an accurate marker of myocardial viability(*3–10*), the definite gold standard is functional recovery after coronary revascularization(*1,2*). In this study, we evaluated the clinical significance of ^{99m}Tc-MIBI uptake after nitrate administration in terms of myocardial viability by using the presence or the absence of wall motion improvement following revascularization in a subgroup of 8 patients (36% of the 22 patients had reversible ^{99m}Tc-MIBI defects after nitroglycerine). The results of the follow-up study after coronary revascularization also support the hypothesis that segments with reversible ^{99m}Tc-MIBI defects after nitroglycerine administration reflect the presence of viable myocardium. In fact, 87% of these segments showed improved wall motion after coronary revascularization (Fig. 6).

Conversely, 89% of myocardial segments with irreversible ^{99m}Tc-MIBI defects after nitroglycerine administration and severely impaired left ventricular function did not show functional recovery after coronary revascularization, suggesting the presence of irreversibly fibrotic tissue (Fig. 6). These findings are concordant with results reported by Bisi et al. (*34*), who demonstrated that 91% of asynergic myocardial segments with enhanced ^{99m}Tc-MIBI uptake after nitrate administration showed functional recovery following coronary revascularization. On the other hand, 88% of asynergic segments with no change in ^{99m}Tc-MIBI uptake after nitrate administration did not improve after revascularization (*34*). Thus, these results demonstrate that rest ^{99m}Tc-MIBI cardiac imaging with nitroglycerine administration may identify severely hypoperfused but still viable myocardium and predict reversibility of severe regional wall motion abnormalities after coronary revascularization in patients with chronic ischemic left ventricular dysfunction.

Study Limitations

There are some limitations in this study that should be considered. First, our patient population only included two women and follow-up data after coronary revascularization were obtained in a limited number of patients. Although our data need to be confirmed in larger series, including patients of both sexes, the follow-up results confirmed enhanced detection of viable myocardium by ^{99m}Tc-MIBI imaging after nitroglycerine administration. Second, since there are no established criteria in the literature to assess the severity of ^{99m}Tc-MIBI defects, we arbitrarily chose a threshold value for reduced ^{99m}Tc-MIBI uptake. The same threshold, however, has been used in previous studies (*24,26*).

CONCLUSION

In patients with chronic CAD and impaired left ventricular function, ^{99m}Tc-MIBI imaging with nitroglycerine administration improved the differentiation between severely hypoperfused, but still viable myocardium, and irreversibly fibrotic tissue compared to rest ^{99m}Tc-MIBI imaging. Therefore, when myocardial viability is in question, nitrate ^{99m}Tc-MIBI scintigraphy is recommended to select those patients with chronic ischemic left ventricular dysfunction for revascularization procedures.

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