One-Year Effect of Myocardial Revascularization on Resting Left Ventricular Function and Regional Thallium Uptake in Chronic CAD

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It is still unclear whether in patients with chronic coronary artery disease (CAD) the improvements in myocardial perfusion and left ventricular (LV) function induced by revascularization persist in the long run. This study was planned to evaluate the 1-yr effects of successful revascularization on myocardial perfusion and LV function in patients with CAD and to assess the accuracy of thallium imaging in the prediction of functional recovery 1 yr after revascularization. **Methods:** Thirty-eight patients with chronic CAD who were revascularized (experimental group) underwent, while off drugs, ^{201}Tl tomography, two-dimensional echocardiography and radionuclide angiography before and after a 1-yr follow-up. Twenty-nine patients with similar characteristics who were not revascularized (control group) and completed the 1-yr follow-up were also studied. Regional thallium activity was quantitatively measured in 13 segments per patient. Systolic function was assessed by echocardiography in corresponding segments. **Results:** In the experimental group, at baseline, on the basis of regional LV function and thallium uptake, 276 segments were normal, 169 dysfunctional–viable and 49 nonviable. After revascularization, the majority (75%) of the dysfunctional–viable segments at baseline showed functional recovery at follow-up, whereas the majority (81%) of the nonviable segments at baseline did not. Simultaneously, LV ejection fraction increased 4 wk after revascularization (from 39% ± 9% to 42% ± 10%, $p < 0.01$) and remained unchanged after 1-yr (43% ± 8%, $p < 0.01$ versus baseline study). LV wall-motion score index after 1 yr was reduced (from 1.68 ± 0.4 to 1.42 ± 0.3, $p < 0.001$) as compared with baseline. On the contrary, in the control group, no change in myocardial perfusion and LV function was detected after the 1-yr follow-up. **Conclusion:** In patients with chronic CAD, successful coronary revascularization induces a stable improvement in myocardial perfusion and LV function, which is still detectable after a 1-yr follow-up. Furthermore, preserved thallium uptake in dysfunctional regions is predictive of functional recovery after revascularization.

Key Words: ischemic left ventricular dysfunction; myocardial perfusion; cardiac function

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Revascularization procedures, such as coronary artery bypass grafting (CABG) and percutaneous transluminal coronary angioplasty (PTCA) may improve regional myocardial perfusion and left ventricular (LV) function in patients with chronic coronary artery disease (CAD) (*1–3*). However, all the studies evaluating myocardial perfusion and LV function after revascularization in patients with chronic ischemic LV dysfunction have included only a short-term follow-up period, such as 3–8 wk (*4–9*). Therefore, it is still unclear whether the revascularization-induced improvement in regional perfusion and LV function may persist after a longer follow-up period. On the other hand, this information seems to be particularly relevant, because in the case that the functional improvement induced by CABG or PTCA was stable in the long term, this effect on LV function may represent a main goal of myocardial revascularization. Furthermore, the recent observation that the recovery of perfusion and wall motion may continue well after the subacute phase of myocardial infarction, up to 7 mo, has raised further doubts on the evidence so far available on the effects of revascularization on LV function (*10*). In fact, the majority of the studies evaluating the functional outcome after revascularization were performed in patient populations that included patients at the subacute phase of myocardial infarction (*2–9*). Therefore, this study was planned to prospectively evaluate the 1-yr effects of successful coronary revascularization on myocardial perfusion and LV function in patients with angiographically documented chronic CAD and evidence of dysfunctional, but still viable, myocardium at thallium imaging. Furthermore, this study provides an opportunity to assess the diagnostic accuracy of rest-redistribution thallium tomography in the prediction of recovery of function in the long run after revascularization. A separate group of patients with comparable characteristics who did not undergo coronary revascularization were also studied and constituted the control group.

MATERIALS AND METHODS

Patient Population and Selection

Between January 1991 and March 1994, 96 patients with previous myocardial infarction and impaired global and/or regional LV function underwent thallium perfusion imaging and coronary angiography within 3 wk of each other to characterize LV dysfunction. In no case was the decision to perform coronary angiography based on the results of thallium imaging.

Twelve (13%) of the patients had echocardiograms inadequate to assess wall motion in every myocardial segment of the LV and, therefore, were excluded from the study. Forty-six patients underwent coronary revascularization (CABG in 25 and PTCA in 21) within 3 wk of baseline imaging studies. During the follow-up, six patients (five with previous PTCA) presented with recurrent angina. In these patients, repeated angiograms demonstrated inadequate revascularization and, therefore, these patients were excluded from the study. Two other patients (one with previous PTCA) were lost at follow-up. The remaining 38 patients completed the follow-up and constituted the experimental group. Coronary angiography was not repeated in these patients because exercise stress tests failed to show ischemic electrocardiographic changes after revascularization (in 22 patients) or it was not clinically indicated (in 16 patients). None of the patients of the experimental group had associated surgical procedures such as valve replacement or aneurysmectomy.

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Thirty-eight patients did not undergo coronary revascularization within 3 wk of baseline imaging studies because of the presence of anatomically unfavorable lesions for PTCA and/or the refusal of the patient to consider surgery. Six of these patients died during the follow-up and three others underwent late revascularization procedures (>3 wk after baseline imaging studies) and were not considered for this study. The remaining 29 patients who were not revascularized and completed the follow-up constituted the control group.

Exclusion criteria were normal regional and/or global LV function (ejection fraction ≥50%), coronary revascularization before enrollment, unstable angina or acute myocardial infarction within the previous 8 mo. The protocol was approved by the institutional ethical committee, and informed consent to participate in the study was obtained from all patients.

Study Protocol

In patients from the experimental group, two thallium, radionuclide angiographic and echocardiographic studies were performed before and 13 ± 2 mo after revascularization. To compare the short-term and the 1-yr effects of revascularization on LV function in these patients, radionuclide angiography was also performed 4 ± 2 wk after revascularization. In patients from the control group, two thallium, radionuclide angiographic and echocardiographic studies were performed before and after a follow-up of 14 ± 4 mo.

Thallium Imaging. Thallium myocardial scintigraphy was performed in all patients as described previously (*11*). Briefly, after an overnight fast, thallium (111 MBq) was intravenously injected at rest. Initial (rest) and delayed (redistribution) images were acquired 15 min and 4 hr after tracer injection, respectively. SPECT was performed using a rotating large field-of-view gamma camera (Elscint SP4HR, Haifa, Israel) equipped with a low-energy, all-purpose, parallel-hole collimator. Thirty-two projections (40 sec per projection) were obtained over a semicircular 180° arch. Filtered backprojection was then performed with a low-resolution Butterworth filter with a cutoff frequency of 0.5 cycle/pixel, order 5.0. No attenuation or scatter correction was applied.

Radionuclide Angiography. At the end of thallium imaging, in vivo labeling of red blood cells was performed with 555 MBq of ^{99m}Tc. Equilibrium radionuclide angiography was performed at rest in the 45° left anterior projection at a 15° craniocaudal tilt with the patient in supine position. A small field-of-view gamma camera equipped with a low-energy all-purpose collimator, was used. Data were recorded at a rate of 30 frames per cardiac cycle on a dedicated computer system. At least 200,000 counts per frame were acquired.

Echocardiography. Echocardiographic studies were performed on the same day of radionuclide imaging using a wide-angle two-dimensional phased-array sector scanner equipped with a 2.5-MHz transducer. Two-dimensional images of LV were obtained at rest with the patients lying in the left lateral position using multiple imaging sections, including parasternal long and short axes and apical 2- and 4-chamber views. All studies were videotaped on a 3/4-in videocassette recorder super video high scope. The video frame rate of the system was 60 frames per sec.

Data Analysis

Thallium Imaging. In each patient, scintigraphic studies were analyzed using the same modalities by observers who were unaware of angiographic and echocardiographic findings and of the time of the study (pre- or postrevascularization in the experimental group and baseline or follow-up in the control group). Regional thallium activity was quantitatively measured on two short-axis tomograms using a semiautomatic circumferential profile method, as reported previously (*12*). Each short-axis tomogram was divided into six sectors of equal arc, representing the anterolateral, lateral, inferior, posteroseptal, septal and anterior myocardium. Apical activity was measured in a single region from vertical and horizontal long-axis tomograms. Therefore, in each patient, 13 anatomic segments were evaluated (Fig. 1). In each tomogram, the myocardial sector with the maximum counts was used as the normal reference region. Tracer uptake in all other myocardial sectors was then expressed as a percentage of the activity measured in the reference region. Each myocardial segment was assigned to one of the major vascular territories, as described previously (*13*). Briefly, the anterior descending artery territory included the anterior wall, septum and apical wall, the right coronary artery was assigned the inferior wall and the left circumflex artery was assigned the lateral wall.

A myocardial segment was considered abnormal if thallium uptake was >2 s.d. below the mean observed in the same region for normal volunteers (*11*). On the basis of previous reproducibility measurements in our laboratory, a segment with reduced activity on initial images was considered reversible if the activity increased at least 10% on delayed images. Alternatively, a segment with reduced activity on initial images was considered irreversible if the activity did not change on delayed images or remained <50% of peak activity. Irreversible defects were divided on the basis of the severity of the reduction in tracer activity: moderate (≥50% of peak) and severe (<50%) defects, as previously reported in our laboratory and by others (*4,11,14*).

Radionuclide Angiography. Radionuclide angiographic studies were analyzed using a standard commercial software. Reproducibility of ejection fraction measurements in our laboratory has been reported previously (*15*). In particular, assessment of the ejection fraction within the same patients under steady-state conditions on different days of observation showed a significant correlation ($r = 0.97$, $p < 0.01$), and the s.d. of the reproducibility of the measurement was 1.5%. In the experimental group, an improvement in LV ejection fraction ≥3% (i.e., ≥2 s.d. of the reproducibility) from the baseline study to the 1-yr follow-up was considered significant.

Echocardiography. All studies were performed by the same investigator and were analyzed independently by two experts unaware of the radionuclide and angiographic findings and of the time of the study (pre- or postrevascularization in the experimental group and baseline or follow-up in the control group). A third

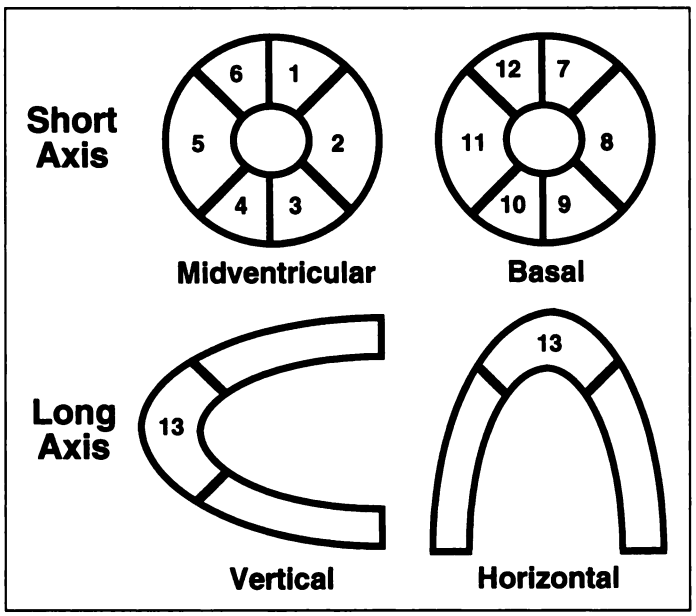

FIGURE 1. Segmentation scheme used for regional analysis of ^{201}Tl activity and echocardiographic left ventricular function.

investigator blindly reviewed the echocardiograms when the first two observers were not in agreement. The LV was divided into 13 segments corresponding to the scintigraphic regions. Six segments, in addition to a single apical segment (Fig. 1), were evaluated at both basal and midventricular level. Regional LV function was assessed according to the recommendations of the American Society of Echocardiography (*16*). Segmental LV wall motion and thickening were graded semiquantitatively using a scoring system where 1 indicated normal, 2 hypokinesia (severely reduced wall thickening and inward motion) and 3 akinesia (absence of wall motion and of systolic thickening) or dyskinesia. The global LV wall-motion score index was calculated as the sum of segment scores divided by the number of scored segments (*17,18*). For quantitative analysis, interobserver agreement was within 95% ($r = 0.96$, $p < 0.001$), and the agreement for the same observer on two different occasions in analyzing the same segment was within 98% ($r = 0.97$, $p < 0.001$). To assess LV wall-motion score index reproducibility, 20 patients were studied under steady-state conditions on different days of observation. A significant correlation ($r = 0.95$, $p < 0.001$) between the two measurements was found, and the s.d. of the reproducibility of the measurement was 0.09. Therefore, in the experimental group, a reduction in LV wall-motion score index ≥ 0.18 (i.e., ≥ 2 s.d. of the reproducibility) from baseline to 1-yr follow-up was considered significant.

Functional Outcome after Revascularization. In the experimental group, regional LV wall-motion analysis by echocardiography was used to define functional outcome after revascularization (*11,18*). A dysfunctional segment was considered as showing functional recovery when the regional wall-motion score was abnormal at baseline (Grade 2–3), but had improved at least one grade at follow-up. Conversely, a segment was considered as showing no functional recovery when the regional wall-motion score was impaired at baseline (Grade 2–3) and did not change at follow-up.

Statistical Analysis

Data are expressed as mean ± 1 s.d. Differences between mean values were assessed by Student's t-test for unpaired or paired data, as appropriate. Chi-square analysis was used to assess differences between proportions. Linear regression analysis was used to assess intraobserver and interobserver agreement. Multivariate regression analysis was performed to evaluate which variable independently influenced the revascularization-induced LV ejection fraction change in the experimental group. A p value <0.05 was considered significant.

RESULTS

Clinical Characteristics of the Patients

Individual characteristics of experimental group patients are reported in Table 1. No difference was detected in clinical characteristics between experimental and control groups (Table 2). All patients of both groups had experienced a myocardial infarction and were in stable hemodynamic condition at the time of the study. In all patients, for both baseline and follow-up imaging studies, calcium antagonists and nitrates had been withdrawn for at least 48 hr, and beta-blockers and angiotensin-converting enzyme inhibitors for at least 72 hr before the protocol studies.

Baseline Results

Experimental and control groups did not differ with respect to LV ejection fraction, wall-motion score index and occurrence of normal, viable and nonviable segments (Table 2). In the experimental group, a total of 494 myocardial segments (13 per patient) were evaluated. Before revascularization, 276 segments (56%) had normal echocardiographic function and normal thallium uptake (normal segments). Another 169 segments (34%) showed hypokinesia or akinesia associated with thallium uptake $\geq 50\%$ of peak activity and were considered viable. The remaining 49 segments (10%) showed akinesia or dyskinesia associated with thallium uptake $<50\%$ and were considered nonviable. In the control group, at baseline, 201 segments (53%) had normal function and normal thallium uptake; another 131 segments (35%) were viable and the remaining 45 segments (12%) were nonviable.

In the experimental group, LV ejection fraction was $\leq 40\%$ (mean, 30% ± 8%) in 15 patients (Group A) and between 41% and 49% (mean, 46% ± 3%) in the remaining 23 patients (Group B). Clinical characteristics of patients of Groups A and B are reported in Table 3. No difference was detected in medical management between these two groups.

Coronary Revascularization

Coronary revascularization procedures were performed in all patients of the experimental group within 3 wk of the baseline imaging studies (Table 4). Twenty-three patients underwent CABG, and the remaining 15 underwent PTCA. Successful dilatation was obtained in all the latter cases, as defined by a diameter of the residual stenosis of the target vessel not exceeding 30% of luminal diameter. No patient had major complications associated with the revascularization procedure.

At baseline there were a total of 218 dysfunctional segments at echocardiography (169 viable and 49 nonviable at thallium imaging). Of these segments, 197 (90%) were revascularized and the remaining 21 (10%) were not. Of the revascularized segments, 154 (97 hypokinetic and 57 akinetic or dyskinetic) were viable at thallium imaging and 43 (all akinetic or dyskinetic) were nonviable.

Follow-Up Results

In the experimental group, 1 yr after revascularization, LV ejection fraction increased from 39% ± 9% to 43% ± 8% ($p < 0.01$) and wall-motion score index decreased from 1.68 ± 0.4 to 1.42 ± 0.3 ($p < 0.001$) (Fig. 2). When the 1-yr LV ejection fraction was compared with that observed at the short-term follow-up (42% ± 10%), no significant change was detected. In the control group, at 1-yr follow-up, LV ejection fraction and wall-motion score index did not change as compared with baseline (Fig. 2). In the experimental group, LV ejection fraction improved $\geq 3\%$ in 23 patients (61%) and wall-motion score index decreased ≥ 0.18 in 22 patients (56%) (Table 4). At multivariate regression analysis, group assignment (*1* for group A, *0* for group B), but not baseline LV ejection fraction, predicted ejection fraction changes after revascularization (constant 6.5; partial regression coefficient of group assignment 4.9, 95% confidence interval 1.7–8.0; $p < 0.005$). In particular, in Group A, ejection fraction increased from 30% ± 8% to 36% ± 9% ($p < 0.001$), whereas no significant change was observed in the patients of Group B; simultaneously, the wall-motion score index was significantly reduced in both Group A and Group B (Fig. 3).

In the experimental group, after revascularization, 400 segments (81%) were normal ($p < 0.01$ versus baseline), 40 (8%) viable ($p < 0.01$) and the remaining 54 (11%) nonviable ($p =$ ns) (Fig. 4 upper). On the contrary, in the control group no differences in the occurrence of normal, viable and nonviable segments between baseline and follow-up were observed (Fig. 4 lower). Thallium uptake at baseline and after 1-yr follow-up in segments that were normal, viable and nonviable at basal imaging studies is shown in Figure 5. In the experimental group, thallium uptake significantly increased after revascular-

TABLE 1
Demographic Data and Individual Clinical Characteristics of Experimental Group Patients

Patient	Sex	Age (yr)	Site of myocardial infarction	Site of wall-motion abnormalities	Coronary artery stenosis (≥50%)
1	M	48	Anterior	Anteroseptal, apical	LAD, LCx, PDA
2	M	54	Inferior	Septal, inferior, apical	LAD, LCx*, PDA
3	M	43	Anterior	Anteroseptal, apical, inferior, lateral	LAD, LCx, PDA
4	M	68	Inferior	Anteroseptal, apical, inferior, lateral	LAD, LCx, PDA
5	M	53	Anterior	Anterolateral, apical	LAD, PDA
6	M	58	Inferior	Septal, apical, inferior	LAD, PDA
7	M	66	Anterior	Anteroseptal, apical, inferior, lateral	LAD, LCx, PDA
8	M	54	Anterior	Anteroseptal, apical, inferior, lateral	LAD, LCx, PDA
9	M	62	Inferior	Inferior, lateral	LAD, LDx*, PDA
10	M	61	Anterior	Anteroseptal, apical	LAD
11	M	59	Inferior	Inferior, apical, lateral, septal	LAD, LCx, PDA
12	M	46	Anterior	Anteroseptal, apical	LAD, PDA
13	F	60	Anterior	Anterior, inferior, lateral	LAD, LCx
14	M	67	Anterior	Anteroseptal, apical	LAD, PDA
15	M	38	Anterior	Anteroseptal, apical	LAD, PDA*
16	M	59	Inferior	Anterior, apical, inferior	LAD, PDA*
17	M	53	Inferior	Inferior	LAD*, LCx
18	M	63	Anterior, inferior	Septal, apical	LAD, PDA*
19	F	61	Anterior (non-Q)	Apical	LAD, PDA*
20	M	59	Inferior	Apical, inferior	LAD, LCx, PDA
21	M	53	Inferior	Apical, inferior, lateral	LAD*, LCx, PDA
22	M	35	Inferior	Inferior, apical	PDA
23	M	57	Inferior	Inferior, lateral	LCx, PDA
24	M	48	Anterior	Anteroseptal, apical, lateral	LAD, LCx, PDA
25	M	48	Anterior, inferior	Septal, apical, inferior, lateral	LAD, PDA
26	M	45	Anterior	Anteroseptal, apical	LAD, LCx
27	M	64	Inferior	Inferior, lateral	LCx, PDA*
28	F	69	Inferior (non-Q)	Inferior, lateral	LAD, LCx
29	M	44	Anterior	Anterior, apical	LAD, LCx
30	M	68	Anterior (non-Q)	Anterolateral, apical, inferior, lateral	LAD, LCx, PDA
31	M	71	Anterior	Anteroseptal, apical, inferior, lateral	LAD, LCx*, PDA*
32	M	68	Anterior	Anterior	LAD, LCx
33	M	51	Inferior	Inferior	LAD, LCx
34	M	58	Anterior	Anteroseptal, apical	LAD
35	M	48	Inferior (non-Q)	Anterolateral	LAD, LCx
36	M	71	Inferior	Inferior, apical, lateral	LCx, PDA
37	M	51	Anterior	Septal	LAD, LCx, PDA*
38	M	47	Anterolateral	Anteroseptal, apical	LAD, LDx
Mean ± s.d.		56 ± 9			

LAD = left anterior descending artery; LCx = left circumflex artery; PDA = posterior descending artery; non-Q = non-Q wave myocardial infarction.
*Denotes lack of subsequent revascularization.

ization in segments viable at baseline. On the other hand, no significant difference was detected in the control group.

At 1-yr follow-up, 116 (75%) of the 154 viable segments involved in revascularization showed functional recovery, while 38 (25%) did not (Fig. 6). Of these latter segments, 19 were hypokinetic and 19 were akinetic or dyskinetic at baseline. On the other hand, 35 (81%) of the 43 nonviable segments did not show functional improvement after revascularization. When all dysfunctional segments were considered, sensitivity, specificity and diagnostic accuracy of thallium uptake in the prediction of regional functional recovery were 93%, 48% and 75%, respectively. When only akinetic and dyskinetic segments were considered, these values were 83% (p = ns versus all dysfunctional segments), 65% ($p < 0.001$) and 73% (p = ns), respectively. A separate analysis was performed in the 41 segments with severe dysfunction (akinesia or dyskinesia) at baseline and regional thallium activity between 40% and 60%. Functional recovery after revascularization was observed in 13 of these segments, and 12 (92%) of them showed baseline thallium uptake ≥50%. On the other hand, 28 of these 41 segments did not show functional recovery, and 18 (64%) of them had thallium uptake <50% at baseline. Sensitivity, spec-

TABLE 2
Clinical and Imaging Characteristics of Patients in Experimental and Control Groups

	Experimental group (n = 38)	Control group (n = 29)
Age (yr)	56 ± 9	52 ± 10
LV ejection fraction (%)	39 ± 9	37 ± 9
LV wall-motion score index	1.68 ± 0.4	1.70 ± 0.3
Normal segments (n)	276 (56%)	201 (53%)
Viable segments (n)	169 (34%)	131 (35%)
Nonviable segments (n)	49 (10%)	45 (12%)

LV = left ventricular.

ificity and diagnostic accuracy of thallium imaging in predicting functional recovery in these segments were 92%, 64% and 73%, respectively.

A representative example of thallium imaging in a patient of the experimental group studied before and after revascularization is shown in Figure 7.

DISCUSSION

The results of this study demonstrate that in patients with chronic CAD and evidence of dysfunctional, but viable, myocardium shown in thallium imaging, successful coronary revascularization induced stable beneficial effects on myocardial perfusion and LV function that are still detectable after 1-yr follow-up. Our data also show that preserved thallium uptake in dysfunctional segments is predictive of regional functional recovery in the long run after revascularization. Furthermore, the results obtained in patients of the control group who completed the 1-yr follow-up rule out the possibility that a spontaneous delayed improvement in LV function had a role in the results of experimental group.

Thallium Imaging in the Identification of Myocardial Viability

Thallium imaging has been widely used to assess myocardial perfusion and tissue viability in patients with CAD (*2–4,19–25*). Initial myocardial thallium uptake depends on coronary blood flow and cellular extraction capability, whereas thallium redistribution is the result of both myocardial washout and successive wash-in rates (*26,27*). The evaluation of thallium redistribution images may be more appropriate to assess tracer uptake, particularly in patients with chronic CAD, in which severely decreased coronary blood flow and partially necrotic myocardium are present. In this setting, the real thallium amount in the myocardium might be dependent more on redistribution phenomenon rather than initial delivery (*28–30*). Mori et al. (*22*) and Ragosta et al. (*4*) demonstrated that some segments without rest-injected thallium redistribution, but with preserved thallium uptake, exhibited improved regional function at short-term follow-up after revascularization. Therefore, the presence of thallium activity in some segments without redistribution, but with improved wall motion after revascularization, may indicate that their blood supply is not low enough to determine myocardial necrosis (*22*). Thus, these segments may represent hibernating myocardium rather than fibrotic tissue. This hypothesis also is supported by the results of this

TABLE 3
Clinical and Imaging Characteristics of Experimental Group Patients with Baseline Ejection Fraction ≤40% (Group A) and between 41% and 49% (Group B)

	Group A (n = 15)	Group B (n = 23)	p value
Age (yr)	58 ± 9	55 ± 9	ns
Single-vessel coronary artery disease (n)	1 (8%)	2 (8%)	ns
Multivessel coronary artery disease (n)	12 (92%)	23 (92%)	ns
Normal segments (%)	35	69	<0.001
Viable segments (%)	56	20	<0.001
Nonviable segments (%)	9	11	ns

ns = not significant.

TABLE 4
Revascularization Procedures, Ejection Fraction and Wall-Motion Score Index at Baseline and after Revascularization in Experimental Group Patients

		Baseline		Follow-up	
Patient	Revascularization procedure	LVEF (%)	WM score index	LVEF (%)	WM score index
1	CABG	43	1.8	49*	1.5*
2	CABG	34	2.1	45*	1.4*
3	CABG	27	2.5	35*	1.4*
4	CABG	34	2.6	39	2.5
5	CABG	49	1.3	56*	1.2
6	CABG	34	1.6	46*	1.2*
7	CABG	15	2.1	25*	1.1*
8	CABG	27	2.4	40*	1.4*
9	CABG	47	1.6	50*	1.6
10	PTCA	48	1.9	42	1.5*
11	CABG	43	2.2	42	1.6*
12	PTCA	34	1.6	32	1.5
13	PTCA	48	1.5	52*	1.5
14	CABG	33	1.9	34	1.6*
15	PTCA	43	1.5	47*	1.5
16	PTCA	48	1.7	52*	1.5*
17	PTCA	49	1.5	48	1.5
18	PTCA	41	1.2	45*	1.0*
19	PTCA	48	1.2	52*	1.0*
20	CABG	30	1.3	42*	1.1*
21	PTCA	49	1.6	54*	1.5
22	PTCA	47	1.5	49	1.4
23	CABG	48	1.6	52*	1.5
24	CABG	32	2.1	40*	1.8*
25	CABG	38	1.9	44*	1.5*
26	CABG	42	1.2	46*	1.0*
27	PTCA	47	1.6	45	1.5
28	CABG	40	1.4	47*	1.1*
29	CABG	47	1.4	46	1.1*
30	CABG	25	2.2	37*	1.7*
31	PTCA	10	2.5	10	2.5
32	CABG	49	1.2	42	1.1
33	CABG	46	1.2	41	1.2
34	PTCA	34	1.5	38*	1.3*
35	PTCA	43	1.1	45	1.0
36	PTCA	45	2.0	53*	1.8*
37	CABG	48	1.1	48	1.1
38	CABG	44	1.6	44	1.1*
Mean ± s.d.		39 ± 9	1.68 ± 0.4	43 ± 8†	1.42 ± 0.3†

LVEF = radionuclide-assessed left ventricular ejection fraction; WM = wall motion; CABG = coronary artery bypass grafts; PTCA = percutaneous transluminal coronary angioplasty.

*Indicates improvement ≥2 s.d. of the reproducibility of the measurements vs. baseline.

†$p < 0.01$ vs. baseline.

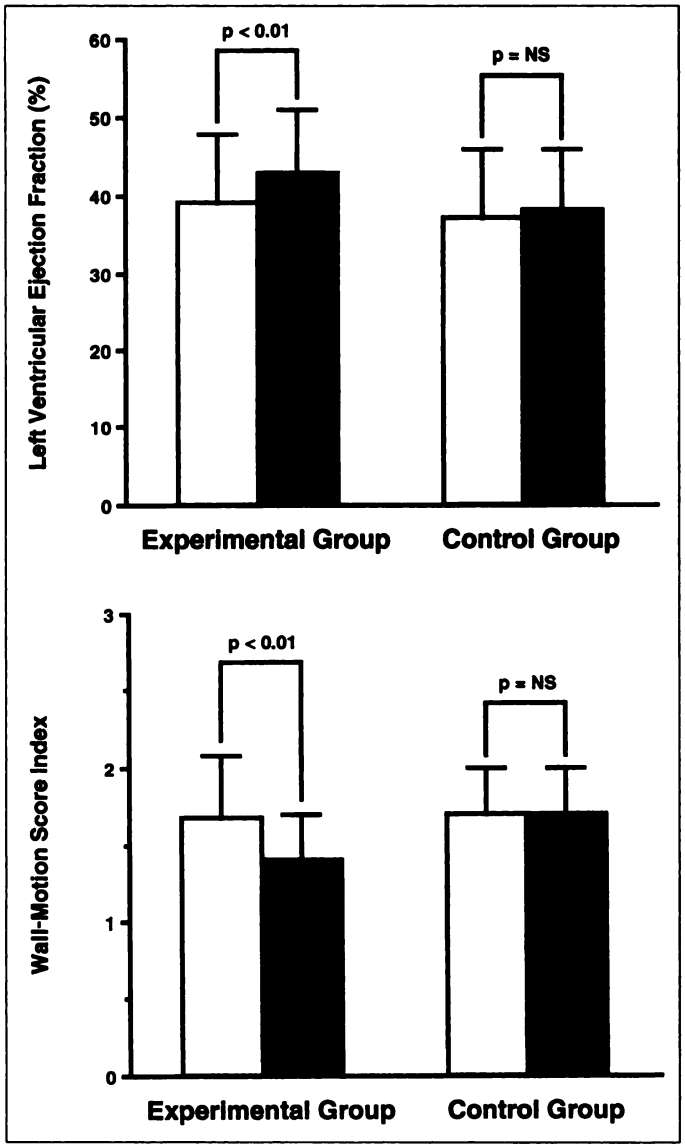

FIGURE 2. Bar graph showing left ventricular ejection fraction (upper) and wall-motion score index (lower) at baseline (open bars) and after 1-yr follow-up (solid bars) in the experimental and control groups.

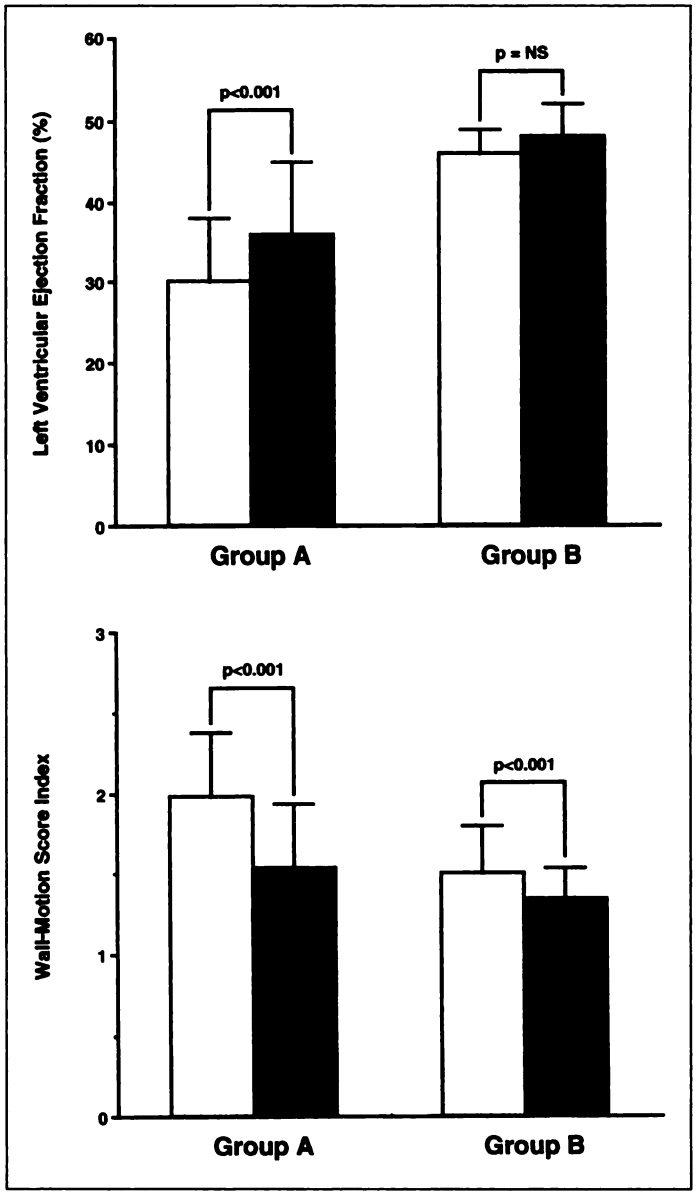

FIGURE 3. Bar graph showing left ventricular ejection fraction (upper) and wall-motion score index (lower) at baseline (open bars) and after 1-yr follow-up (solid bars) in the 15 patients with an ejection fraction ≤40% (Group A) and in the 23 patients with an ejection fraction between 41% and 49% (Group B) at baseline.

study. In particular, our data demonstrate that 75% of the dysfunctional segments at baseline with preserved thallium uptake on redistribution images that were revascularized showed improved function after revascularization. On the contrary, only 19% of the segments with severe dysfunction at baseline and severe reduction of thallium uptake that were revascularized demonstrated functional recovery. Thus, preserved thallium uptake in dysfunctional regions is predictive of functional improvement at 1-yr follow-up after revascularization. Interestingly, when only akinetic and dyskinetic segments were considered, the specificity of thallium imaging significantly increased as compared with the results obtained in all dysfunctional segments (65% versus 48%, $p < 0.01$). These data are in agreement with the results recently reported by Qureshi et al. (*9*), which demonstrate that specificity of quantitative thallium tomography in predicting functional recovery, after short-term follow-up, was 41% in hypokinetic segments and 64% ($p < 0.05$) in akinetic or dyskinetic segments.

Functional Response to Coronary Revascularization

Dysfunctional, but still viable, myocardial regions frequently show improvement of contractility after restoration of coronary blood flow. Although there is clear evidence that coronary revascularization may improve myocardial perfusion and ventricular function in patients with chronic ischemic LV dysfunction (*3–9*), these studies were performed only after a short-term follow-up period. In particular, Ragosta et al. (*4*) demonstrated that in patients with CAD and impaired LV function, preoperative rest-redistribution thallium planar imaging identifies viability in many asynergic segments, and these segments frequently improve function after CABG. However, in this latter study, LV function was evaluated before and 8 wk (mean 64 ± 23 days) after revascularization. Similarly, vom Dahl et al. (*5*) and Tamaki et al. (*6*) demonstrated that metabolic imaging with PET identifies dysfunctional, but metabolically active, tissue, which benefits from coronary revascularization. However, in these studies functional outcome was assessed only 4–8 wk after revascularization. La Canna et al. (*17*) reported that

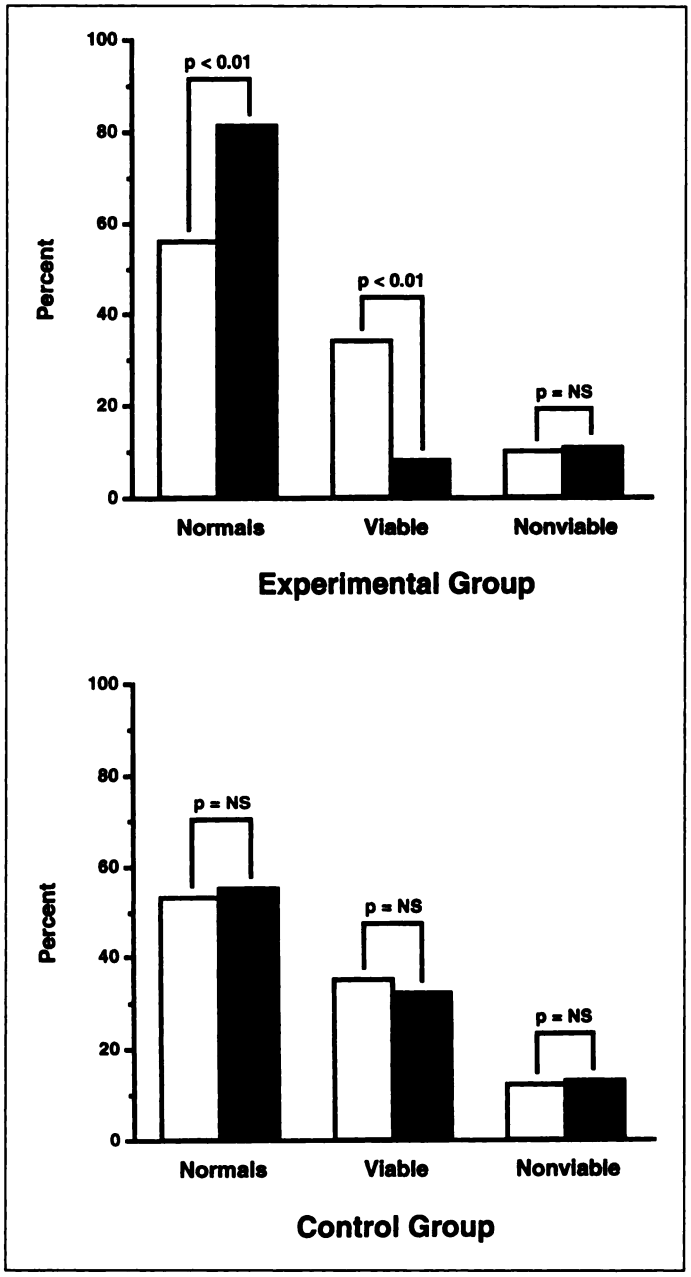

FIGURE 4. Bar graph showing the percentage of normal, viable and nonviable segments at baseline (open bars) and after 1-yr follow-up (solid bars) in the experimental group (upper) and control group (lower).

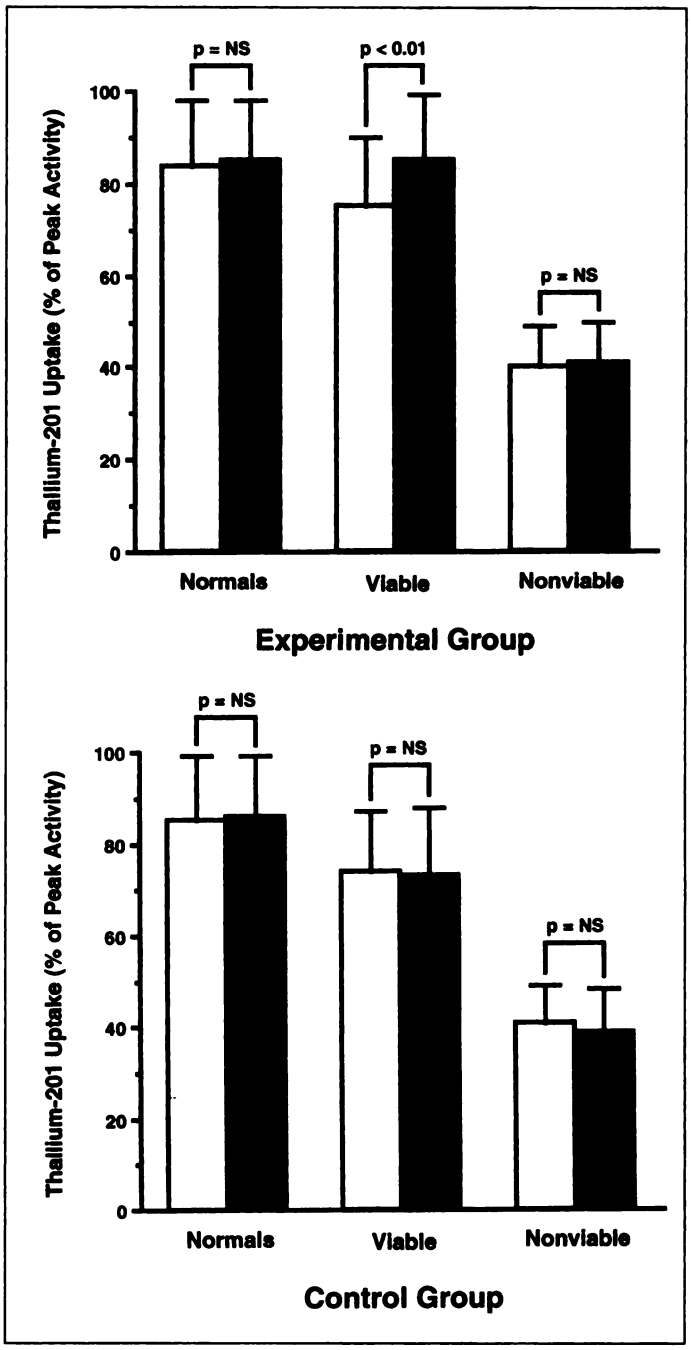

FIGURE 5. Bar graph showing delayed thallium uptake at baseline (open bars) and after 1-yr follow-up (solid bars) in segments that were normal, viable and nonviable at basal imaging studies in the experimental group (upper) and control group (lower).

dobutamine echocardiography predicts recovery of regional wall motion that is still detectable 3 mo after CABG. More recently, Di Carli et al. (*31*) demonstrated, in a study with a follow-up period of 25 ± 14 mo after CABG in patients with CAD and depressed LV function, a stable improvement in heart failure symptoms that correlates with the preoperative extent of myocardial viability, as assessed by PET. However, their study did not include a systematic assessment of myocardial perfusion and LV function after CABG.

This study addresses the issue whether, in patients with chronic CAD, the improvement in regional perfusion and ventricular function is detectable 1 yr after successful revascularization procedures. The data obtained in the experimental group were compared with those observed in a control group of patients who were not revascularized and completed a follow-up period of the same length. The results of our study demonstrate that, excluding patients with angiographically documented coronary restenosis, revascularization induces a significant and stable improvement in both regional and global LV function. Furthermore, the degree of functional improvement after revascularization is related to the severity of LV dysfunction at baseline.

In this study, only patients with chronic CAD and myocardial infarction older than 8 mo were included. This is particularly important because the time course of the recovery of myocardial perfusion and function after myocardial infarction is still unclear. Although most improvement takes place within the first 2 wk (*32,33*), myocardial dysfunction may persist well beyond this period despite adequate anterograde reperfusion, and some recovery may be observed up to 6 mo later (*34,35*). Galli et al. (*10*) demonstrated in a recent study that the recovery of perfusion and wall motion may continue well after the subacute phase of myocardial infarction. This delayed improve-

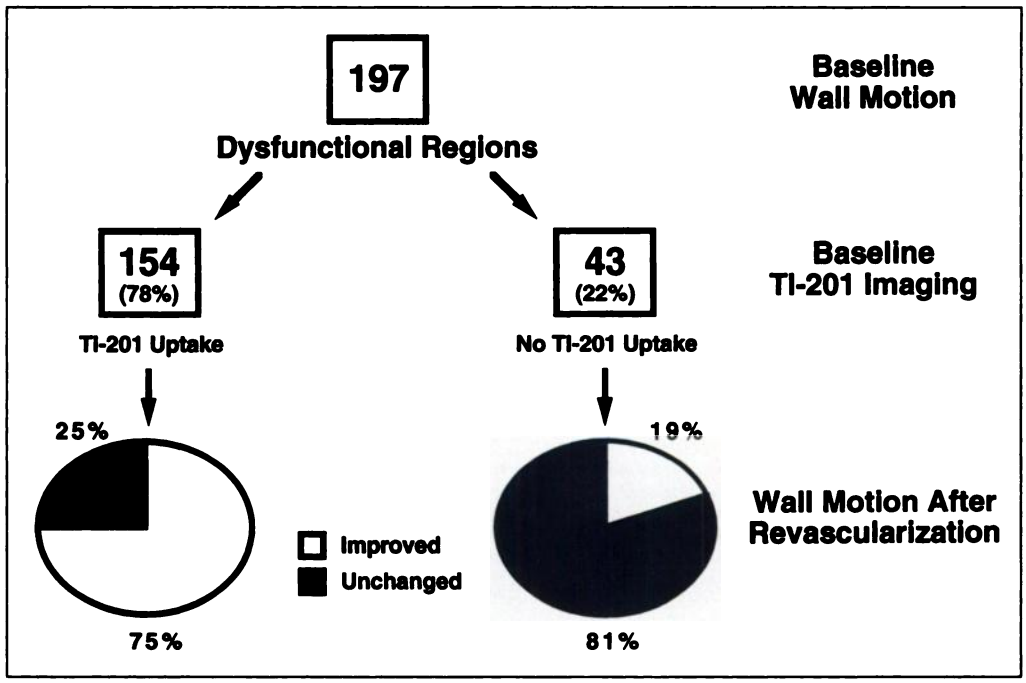

FIGURE 6. Flow diagram showing wall motion after coronary revascularization in dysfunctional segments with (viable) or without (nonviable) preserved thallium uptake at baseline.

ment of perfusion was associated with a delayed improvement of contractile function in the infarcted area after the first 5 wk, which may continue for up to 7 mo, suggesting the presence of hibernating myocardium in the infarcted area (*10*). Keeping in mind these findings, it should be considered that the majority of the studies evaluating the functional outcome after coronary revascularization were performed in patient populations that also included patients at subacute phase of myocardial infarction (*3–9*). Therefore, to avoid the influence of spontaneous delayed recovery of perfusion and contraction after myocardial infarction, we studied only patients in stable hemodynamic conditions and with myocardial infarction older than 8 mo. Using these criteria for patient selection, it has been possible to separate the revascularization-related effects on myocardial perfusion and LV function from those induced by the spontaneous perfusional and functional recovery. This assumption seems to be confirmed by the lack of change in myocardial perfusion and LV function in patients of the control group who completed the follow-up.

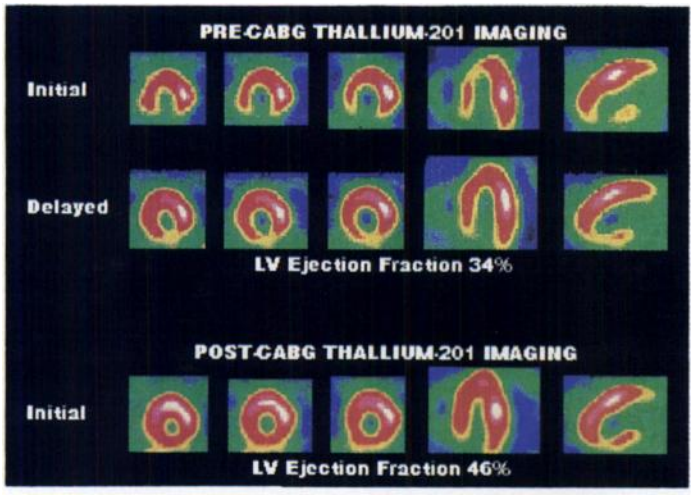

FIGURE 7. Short-axis and long-axis tomograms in a patient (Patient 6 in Tables 1 and 4) with two-vessel coronary artery disease and wall-motion abnormalities in the septal, apical and inferior regions showing reversible thallium defects involving the inferior and septal segments before (Pre-CABG) and enhanced tracer uptake after coronary revascularization (Post-CABG).

CONCLUSION

This study demonstrates that, in patients with chronic CAD and evidence of dysfunctional but viable myocardium shown in thallium imaging, the beneficial effects of successful coronary revascularization on regional myocardial perfusion and LV function are detectable after 1-yr follow-up. These effects are greater in patients with more severe LV dysfunction at baseline. Our results also show that preserved thallium uptake, in dysfunctional myocardial regions, predicts functional recovery in the long run after revascularization. These findings support the use of thallium tomographic imaging in the selection of patients with impaired LV function as candidates for coronary revascularization procedures.

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