# Reverse Redistribution in Resting Thallium-201 Myocardial Scintigraphy in Chronic Coronary Artery Disease: An Index of Myocardial Viability

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The aim of this study was to evaluate whether segments with reverse redistribution on rest-redistribution $^{201}$Tl scintigraphy represent viable tissue or scar. **Methods:** Nineteen patients (17 men, 2 women; mean age 53 ± 8 yr) with coronary artery disease underwent rest-redistribution $^{201}$Tl study before coronary revascularization. Regional $^{201}$Tl uptake was analyzed quantitatively. Regional left ventricular wall motion was assessed before and after coronary revascularization using two-dimensional echocardiography and a three-point scale (1 = normal, 2 = hypokinetic, 3 = akinetic/dyskinetic). Two patterns of reverse redistribution were identified: pattern with normal $^{201}$Tl uptake in rest and abnormal in redistribution images and pattern with abnormal $^{201}$Tl uptake in rest and a significant decrease in redistribution images. **Results:** Of the 247 segments analyzed, 85 were classified as normal, 37 as reversible defects, 83 as fixed defects and 42 as reverse redistribution (19 RR-A, 23 RR-B). Segments with RR-A differed from those with RR-B in wall motion score (1.4 ± 0.7 versus 2.0 ± 1.0). Electrocardiographic Q-waves were present in 26% of segments with RR-A and in 57% of segments with pattern B. After revascularization, all dyssynergic segments with pattern A showed improved wall motion, while only 40% of segments with pattern B and abnormal wall motion had such improvement. **Conclusion:** Our results suggest that dyssynergic segments with pattern A should be considered viable, while more caution should be used in classifying those with pattern B.

**Key Words:** thallium-201; reverse redistribution; myocardial viability

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The pattern of reverse redistribution, with $^{201}$Tl defect being present or more prominent only on redistribution images, has been investigated by several authors (*1–10*). Reverse redistribution has been described either in exercise (or dipyridamole) redistribution (*1–3,8,10*) and rest-redistribution (*4,9*) myocardial scintigraphy. It has been proposed that the clinical significance of reverse redistribution is different in relation to different clinical situations:

1. After reperfusion of acute myocardial infarction, reverse redistribution represents evidence of infarct-related artery patency.
2. In patients with chronic coronary artery disease (CAD), reverse redistribution can be interpreted as evidence of myocardial scar within a segment containing viable myocardium.
3. In subjects with a low pretest likelihood of heart disease, reverse redistribution may represent only normal variability of $^{201}$Tl clearance (*11*).

Recently, Marin-Neto et al. compared the results of stress-reinjection $^{201}$Tl myocardial scintigraphy with those of PET in patients with chronic CAD and found that most of the segments showing reverse redistribution reflect viable myocardium (*10*). Moreover, it has been shown that two patterns of reverse redistribution can be identified on rest-redistribution $^{201}$Tl myocardial scintigraphy: one with normal $^{201}$Tl uptake on rest images and reduced uptake on redistribution (pattern A) and the other with a $^{201}$Tl defect on rest images and a further decrease of $^{201}$Tl uptake at redistribution (pattern B) (*9*). Myocardial segments with pattern A have been shown to have worse wall motion and $^{99m}$Tc-methoxy isobutyl isonitrile uptake (used as an index of myocardial perfusion) than those showing normal $^{201}$Tl uptake both at rest and redistribution (*9*). On the other hand, myocardial segments with pattern B resemble those showing fixed $^{201}$Tl defects (*9*).

The aim of the present study was to assess whether segments with reverse redistribution on rest-redistribution $^{201}$Tl myocardial scintigraphy are viable and thus capable of improving their wall motion after coronary revascularization.

## MATERIALS AND METHODS

### Patients

From a series of 50 patients, referred for rest-redistribution $^{201}$Tl myocardial scintigraphy to identify the presence of viable

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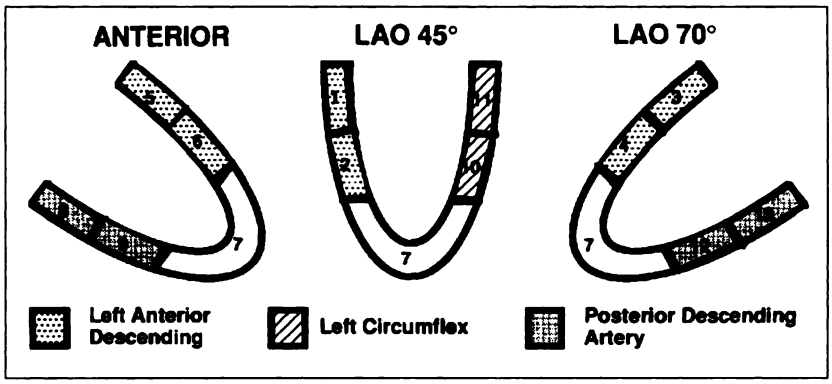


**FIGURE 1.** Diagram of standard segmentation scheme used for regional thallium uptake and assignment of coronary vascular territories. Assignment of the left ventricular apex was variable and based on the presence of adjacent perfusion defects. LAO = left anterior oblique view.

myocardium, 19 consecutive patients (17 men, 2 women; mean age 53 ± 8 yr) who underwent coronary revascularization were included in this study. All patients had previous myocardial infarction, but no patient had an acute myocardial infarction or unstable angina within 6 mo of the study. Mean LVEF by radionuclide angiography was 44% ± 11%. In all patients, two-dimensional echocardiography and rest-redistribution $^{201}$Tl cardiac imaging were performed after withdrawal of all antianginal medications. Nine patients underwent coronary artery bypass grafting (CABG) (three had three-vessel and six had two-vessel CABG) and ten patients underwent percutaneous coronary angioplasty (PTCA) (eight had one-vessel and two had two-vessel PTCA). In all patients, two-dimensional echocardiography was repeated after coronary revascularization (mean interval 3.8 ± 1.6 mo). In all patients, peri- or postoperative acute myocardial infarction was excluded on the basis of clinical data. Patients were not taking beta-blockers or any inotropic drug at the time of the second two-dimensional echocardiography study. All patients gave written, informed consent.

### Coronary Angiography

Coronary angiography was performed by Judkins' technique within 3 wk of radionuclide studies in all patients. Each artery was filmed in four to six projections, including angulated views in the sagittal plane. All images were recorded on 35-mm film at 50 frames/sec, reviewed on a Tagarno projector and interpreted by a consensus of three independent observers unaware of the clinical condition of the patients. Coronary stenoses were coded according to the criteria of the American Heart Association (*12*). Significant stenoses were defined as a reduction ≥50% in the luminal diameter of at least one of the three major epicardial coronary vessels. The cineruns were continued to record images of collaterals which filled late, after visualization of the major coronary vessel. Arteries with partial or complete filling of the epicardial segment by the collaterals were defined as having an efficient collateral circulation.

### Thallium-201 Myocardial Scintigraphy

All patients underwent rest-redistribution $^{201}$Tl myocardial scintigraphy as previously described (*9*). After an overnight fast, $^{201}$Tl images were acquired 15 min postintravenous injection of 2 mCi $^{201}$Tl (rest images); 4 hr postinjection $^{201}$Tl images were again obtained (redistribution images). A small field of view gamma camera, equipped with a low-energy, general-purpose collimator and connected to a dedicated computer system, was used for image acquisition. Both rest and redistribution $^{201}$Tl images were acquired for 10 min/image in the anterior, 45° and 70° left anterior oblique views by use of a 128 × 128 word matrix. During the interval between the rest and redistribution images, the patients remained in the fasting state.

### Data Analysis

In each patient, analysis of regional $^{201}$Tl myocardial uptake and of regional left ventricular wall motion was performed by dividing each image into 13 myocardial segments in each patient (Fig. 1). Each myocardial segment was assigned to one of the three major coronary artery territories (Fig. 1). In each view, the myocardial region with the maximum counts was used as the normal reference region for that view. Thallium-201 uptake in all other myocardial segments was then expressed as a percentage of the activity measured in the reference region. Myocardial segments were classified on rest-redistribution $^{201}$Tl images according to the results obtained in normal subjects, in whom the mean value of $^{201}$Tl uptake at rest was 94% ± 7% (a value equal to the mean minus 2 s.d., i.e., 80% was chosen as the lower normal limit), as previously described (*9*).

When relative $^{201}$Tl uptake measured 80% or more of the normal reference region on both rest and redistribution images, myocardial segments were considered normal. Myocardial segments with relative $^{201}$Tl uptake measuring less than 80% of the reference region on rest image were considered $^{201}$Tl defects. A $^{201}$Tl defect was defined as reversible when relative tracer uptake increased more than 7% (i.e., 1 s.d. in the normal group) on the corresponding redistribution image. A thallium defect was defined as fixed when relative tracer uptake was below normal limits and remained unchanged or increased less than 7% on the corresponding redistribution image. Two patterns of reverse redistribution were identified: pattern A, when relative $^{201}$Tl uptake was normal (≥80%) on the rest image and reduced (<80%, with a decrease of at least 7%) on the redistribution image, and pattern B, when relative $^{201}$Tl uptake was reduced (<80%) on the rest image and decreased at least 7% on the redistribution image (*9*).

### Echocardiography

Two-dimensional images of the left ventricle were obtained at rest with the patient lying in the left lateral decubitus position using multiple imaging sections, including parasternal long and short axes and apical two- and four-chamber views. The echocardiographic images were recorded on videotape and interpreted by two experienced observers unaware of the scintigraphic and angiographic findings. A third investigator blindly reviewed the echocardiograms when the first two investigators did not agree. The left ventricle was divided into 13 segments: apex, proximal and distal septal, anterior, anterolateral, posterolateral, posterior and inferior wall (*13*). This segmentation was adopted following the model proposed by the American Society of Echocardiography (*13*), with

only two septal segments considered to match the radionuclide imaging segmentation scheme. According to the recommendations of the American Society of Echocardiography (*14*), segmental left ventricular wall motion was graded as: normal = 1, hypokinetic = 2 and akinetic/dyskinetic = 3.

To directly compare the results of two-dimensional echocardiography and $^{201}$Tl scintigraphy, each ventricular segment was assigned to one of the major coronary vascular territories, as previously described (*15*). Particularly, the anterior, anterolateral, proximal and distal septal wall were assigned to the left anterior descending artery, the posterolateral wall was assigned to the left circumflex artery and the posterior and inferior walls were assigned to the posterior descending artery. The assignment of the left ventricular apex was variable and was based on the presence of adjacent wall motion abnormalities and coronary lesions.

A myocardial segment with abnormal wall motion was defined as viable if its wall motion score decreased ≥ 1 after coronary revascularization.

### Statistical Analysis

Data are expressed as mean ± 1 s.d. Differences between mean values were analyzed with the Student's t-test for unpaired data. Chi square analysis was used to assess differences between proportions. Probability values $< 0.05$ were considered significant.

## RESULTS

In all 19 patients, a significant stenosis (≥50% reduction in luminal diameter) was found in at least one major coronary vessel. Five patients had stenosis in three major coronary arteries, twelve had stenosis in two and two had stenosis in one coronary artery. There were 19 coronary arteries totally occluded, and 12 of these had well-developed collaterals.

A total of 247 segments were analyzed in the 19 patients. On the basis of quantitative analysis, 85 (34%) segments were classified as normal, 37 (15%) as reversible defects, 83 (34%) as fixed defects and 42 (17%) as showing reverse redistribution. Of these 42 segments, 19 (8%) demonstrated pattern A and 23 (9%) demonstrated pattern B. Of the 19 myocardial segments with pattern A, 15 were supplied by significantly stenosed vessels (8 in the territory of the left anterior descending artery, 5 in the territory of the posterior descending artery, and 2 in the territory of the left circumflex artery) (Table 1). Of these 19 segments, 6 (32%) were supplied by a totally occluded coronary artery and well-developed collaterals were present in 4 (67%). Of the 23 myocardial segments with reverse redistribution pattern B, 20 were supplied by significantly stenosed vessels (5 in the territory of the left anterior descending artery, 11 in the territory of the posterior descending artery and 4 in the territory of the left circumflex) (Table 1). Of these 23 segments, 11 (48%, p-ns compared to reverse redistribution pattern A) were supplied by a totally occluded coronary artery, and well-developed collaterals were present in 6 (55%, p-ns compared to reverse redistribution pattern A) (Table 1). Segments with pattern A had a significantly lower mean wall motion score than segments with pattern B (1.4 ± 0.7 versus 2.0 ± 1.0, respectively, $p < 0.05$). Of the 19 segments with reverse redistribution pattern A, 12

**TABLE 1**
Myocardial Segments with Reverse Redistribution

| Patient no. | Segment no. | Reverse redistribution pattern | Echo | Coronary angiography | |
|---|---|---|---|---|---|
| | | | | % Stenosis | Collaterals |
| 1 | 8 | RRA | 3 | 100 PDA | Present |
| 2 | 9 | RRA | 1 | 90 PDA | |
| | 2 | RRB | 3 | 100 LAD | Present |
| 3 | 3 | RRA | 1 | 90 PDA | |
| | 11 | RRA | 2 | 100 LCx | Present |
| | 9 | RRA | 2 | <50 PDA | |
| | 10 | RRB | 3 | 100 LCx | Present |
| 4 | 13 | RRA | 1 | 70 PDA | |
| | 12 | RRB | 1 | 70 PDA | |
| 5 | 5 | RRB | 1 | 100 LAD | Absent |
| | 10 | RRB | 2 | 100 LCx | Present |
| 6 | 8 | RRB | 3 | 100 PDA | Present |
| | 9 | RRB | 3 | 100 PDA | Present |
| 7 | 1 | RRA | 2 | 80 LAD | |
| 8 | 4 | RRA | 3 | 75 LAD | |
| | 9 | RRA | 1 | <50 PDA | |
| 9 | 13 | RRB | 1 | 90 PDA | |
| | 12 | RRB | 3 | 90 PDA | |
| | 9 | RRB | 3 | 90 PDA | |
| | 8 | RRB | 3 | 90 PDA | |
| 10 | 13 | RRA | 1 | 50 PDA | |
| | 4 | RRA | 1 | 100 LAD | Present |
| | 5 | RRA | 1 | 100 LAD | Present |
| | 11 | RRA | 1 | <50 LCx | |
| | 10 | RRB | 1 | <50 LCx | |
| 11 | 6 | RRA | 1 | 100 LAD | Absent |
| | 7 | RRA | 2 | 100 LAD | Absent |
| | 9 | RRB | 1 | 100 PDA | Present |
| | 5 | RRB | 1 | 100 LAD | Absent |
| | 10 | RRB | 1 | <50 LCx | |
| 12 | 3 | RRA | 1 | 75 LAD | |
| | 1 | RRA | 1 | 75 LAD | |
| | 13 | RRB | 1 | 100 PDA | Absent |
| | 12 | RRB | 2 | 100 PDA | Absent |
| | 7 | RRB | 3 | 100 PDA | Absent |
| 13 | 10 | RRA | 2 | 75 LCx | |
| | 11 | RRB | 2 | 75 LCx | |
| 14 | 12 | RRA | 1 | <50 PDA | |
| | 7 | RRB | 1 | 75 LAD | |
| | 3 | RRB | 1 | 75 LAD | |
| | 11 | RRB | 3 | 90 LCx | |
| | 13 | RRB | 3 | <50 PDA | |

Echo = wall motion score by two-dimensional echocardiography before coronary revascularization; RRA = reverse redistribution pattern A; RRB = reverse redistribution pattern B; LAD = left anterior descending artery; PDA = posterior descending artery; LCx = left circumflex artery. Segments are numbered as in Figure 1.

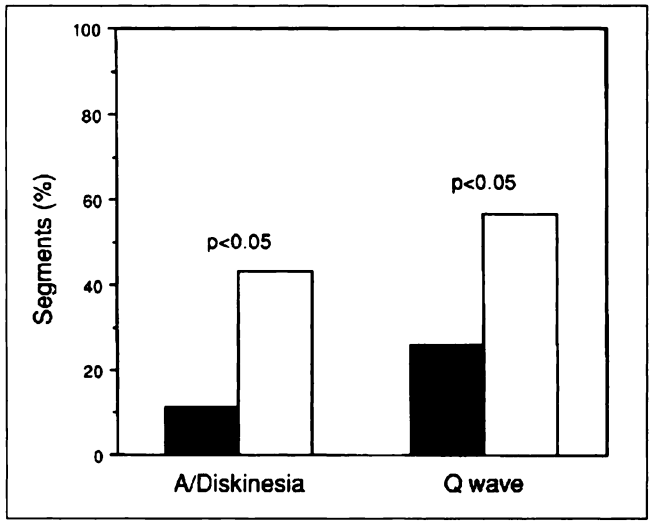


**FIGURE 2.** Percent of segments with akinesia/dyskinesia and electrocardiographic Q-waves in myocardial segments with reverse redistribution pattern A (closed bars) and those with pattern B (open bars).

(63%) had normal wall motion, 5 (26%) were hypokinetic and 2 (11%) were akinetic/dyskinetic (Table 1). Of the 23 segments with reverse redistribution pattern B, 10 (43%) had normal wall motion, 3 (14%) were hypokinetic and 10 (43%) were akinetic/dyskinetic ($p < 0.05$ versus pattern A) (Fig. 2). Electrocardiographic Q-waves were present in 5/19 (26%) segments with reverse redistribution pattern A and in 13/23 (57%) segments with pattern B ($p < 0.05$ versus pattern A) (Fig. 2).

Five segments with reverse redistribution pattern A and abnormal wall motion were involved in coronary revascularization. All of them showed improved wall motion after coronary revascularization (Table 2). Of these, four were hypokinetic and one was akinetic/dyskinetic before coronary revascularization. On the other hand, 10 segments with reverse redistribution pattern B and abnormal wall motion were involved in coronary revascularization. Two segments were hypokinetic before coronary revascularization and one showed improved wall motion after revascularization, while eight were akinetic/dyskinetic before coronary revascularization and three had improved wall motion scores after revascularization. Thus, 4/10 (40%) segments with reverse redistribution pattern B and abnormal wall motion before coronary revascularization had improved wall motion after revascularization ($p < 0.05$ versus segments with reverse redistribution pattern A) (Table 3).

**TABLE 2**
Myocardial Segments with Reverse Redistribution Pattern A: Effects of Coronary Revascularization

| Segment* no. | $^{201}$Tl rest† (%) | $^{201}$Tl redist.† (%) | Echo 1 (Score) | Coronary rev. | Echo 2 (Score) |
|---|---|---|---|---|---|
| 11 | 81 | 63 | 2 | CABG | 1 |
| 7 | 85 | 69 | 2 | PTCA | 1 |
| 10 | 85 | 68 | 2 | PTCA | 1 |
| 1 | 82 | 67 | 2 | PTCA | 1 |
| 4 | 85 | 67 | 3 | CABG | 2 |

*Segments are numbered as in Figure 1.
†Expressed as percent of peak activity.
Echo 1 = two-dimensional echocardiography before coronary revascularization; Echo 2 = two-dimensional echocardiography after coronary revascularization; Coronary rev. = coronary revascularization; Redist. = redistribution; PTCA = percutaneous transluminal coronary angioplasty; CABG = coronary artery bypass grafting.

**TABLE 3**
Myocardial Segments with Reverse Redistribution Pattern B: Effects of Coronary Revascularization

| Segment no. | $^{201}$Tl rest (%) | $^{201}$Tl redist. (%) | Echo 1 (Score) | Coronary rev. | Echo 2 (Score) |
|---|---|---|---|---|---|
| 11 | 60 | 45 | 2 | PTCA | 2 |
| 10 | 71 | 60 | 2 | CABG | 1 |
| 12 | 40 | 33 | 3 | CABG | 3 |
| 8 | 56 | 49 | 3 | PTCA | 3 |
| 10 | 56 | 43 | 3 | CABG | 3 |
| 9 | 64 | 51 | 3 | CABG | 2 |
| 9 | 65 | 51 | 3 | PTCA | 2 |
| 8 | 70 | 59 | 3 | CABG | 3 |
| 2 | 73 | 62 | 3 | CABG | 3 |
| 11 | 74 | 55 | 3 | PTCA | 1 |

Abbreviations as in Table 2.

## DISCUSSION

In our patients, we found an overall incidence of reverse redistribution of 17% (42/247). Myocardial segments with reverse redistribution were divided in two groups: those with normal $^{201}$Tl uptake on rest images (pattern A) and those with reduced $^{201}$Tl uptake on rest images (pattern B) (*9*). In a previous article, we found that segments with pattern A, although having normal $^{201}$Tl uptake on rest images, are clearly different from those classified as normal on rest-redistribution scintigraphy in wall motion, coronary anatomy and myocardial blood flow (*9*). In the present study, the two subgroups of segments with reverse redistribution differed significantly in wall motion and in the relation to electrocardiographic Q-waves. In particular, a larger percentage of akinetic segments, as well as a more severe wall motion score, was found among those with reverse redistribution pattern B compared to those with pattern A. Electrocardiographic Q-waves were present in a larger number of segments with reverse redistribution pattern B than in segments with pattern A. These data suggest that segments with reverse redistribution pattern B differ from those with pattern A. In addition, in segments with reverse redistribution pattern B, there was a trend toward a higher percentage of occluded coronary arteries (48% versus 32% in segments with pattern A) as well as a trend toward a lower percentage of presence of well-developed collateral circulation (55% versus 67% in segments with pattern A),

although these differences did not reach a statistically significant level.

Of the 42 segments with reverse redistribution, 22 (47%) had normal wall motion before coronary revascularization. This figure is similar to that found by Marin-Neto et al. (i.e., 46%) (*10*). They also found higher percentage of segments with normal wall motion in the group with enhanced tracer uptake after reinjection (*10*). In our study, a higher, although not statistically significant, percentage (63%) of segments with pattern A had normal wall motion than segments with pattern B (43%). In line with these observations, Weiss et al. found that 52% of segments with reverse redistribution on rest-redistribution $^{201}$Tl scintigraphy had normal wall motion (*4*). These authors also found a higher percentage of segments with normal wall motion among those segments with marked reverse redistribution and interpreted this finding as further evidence for the presence of viable tissue (*4*).

It has been suggested that one of the most probable explanations for the reverse redistribution phenomenon in patients with chronic CAD is the presence of an admixture of scar and viable myocardium in the same segment (*9,11*). On the basis of the differences found in this study between the two groups of segments with reverse redistribution, it could be argued that segments with reverse redistribution pattern B contain a higher amount of scar than segments with pattern A. If this is the case, dyssynergic segments with pattern A would more frequently have benefit from coronary revascularization than those with pattern B. All patients in this study underwent two-dimensional echocardiography after CABG or PTCA; therefore, we were able to assess any improvement in wall motion. All dyssynergic segments with reverse redistribution pattern A before coronary revascularization showed an improvement after revascularization. On other hand, only 40% of the segments with pattern B and abnormal wall motion before coronary revascularization had subsequent improvement. These findings suggest that these two groups of segments with reverse redistribution are different, and that segments with pattern A and abnormal wall motion should be considered viable, while more caution should be used in classifying segments with pattern B.

Marin-Neto et al. (*10*) addressed the issue of myocardial viability in segments with reverse redistribution. In a group of patients with chronic CAD, they compared the results of $^{201}$Tl stress-reinjection scintigraphy, which is an useful technique for detecting myocardial viability (*16,17*), with those of PET. They found that regions with reverse redistribution and enhanced $^{201}$Tl uptake after reinjection showed a lower incidence of electrocardiographic Q-waves and of akinetic/dyskinetic wall motion. These segments also had a higher percentage of collateral circulation than regions with reverse redistribution without such enhancement (*10*). Moreover, myocardial segments with reverse redistribution and normal or mismatch patterns of [$^{18}$F]fluorodeoxyglucose uptake and flow showed enhanced $^{201}$Tl uptake after reinjection, while regions classified as scar on PET analysis did not show such enhancement (*10*). Their data suggest that regions with reverse redistribution can be further classified as viable or nonviable on the basis of $^{201}$Tl reinjection. Although PET has been considered an accurate technique to assess myocardial viability, the ultimate gold standard is improved wall motion after coronary revascularization.

If myocardial segments with abnormal wall motion and reverse redistribution not involved in coronary revascularization were excluded from the analysis, myocardial viability could be found in 84% (31/37) of segments with reverse redistribution on the basis of either normal wall motion or improved wall motion after revascularization.

## CONCLUSION

Although our small patient group, and thus small number of regions with reverse redistribution, precludes forming definite conclusions, our results suggest that segments with abnormal wall motion and reverse redistribution on rest-redistribution scintigraphy can be considered as viable (i.e., capable of improved wall motion after revascularization) or nonviable on the basis of different reverse redistribution patterns. Segments with normal $^{201}$Tl uptake on rest images and abnormal $^{201}$Tl uptake on redistribution images (reverse redistribution pattern A) and hypokinesia or akinesia/dyskinesia should be considered viable because improved wall motion was observed after revascularization.

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