Value of Stress Thallium-201 Emission Tomography for Predicting Improvement after Coronary Bypass Grafting and Assessing Graft Patency

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SUMMARY

To examine the value of stress and redistribution thallium-201 single photon emission computed tomography (SPECT) for predicting improvement after coronary artery bypass grafting (CABG) and for assessing graft patency, 17 patients underwent SPECT before and after CABG. Preoperatively, 16 patients (94%) showed reversible ischemia with redistribution, and defect score decreased from 16.4±7.6 to 8.3±5.8 (p<0.001) on 2 hour delayed images. Stress electrocardiography was positive in 15 cases (88%). The stress defect score was reduced postoperatively (7.8±6.3) as compared to the preoperative score (16.4±7.6) (p<0.001). Postoperatively, 7 cases (41%) showed reversible ischemia and the defect score decreased from 11.3±6.5 to 6.1±4.7 (p<0.05), while 4 cases (23.5%) showed positive stress electrocardiograms (ECG). Resting left ventricular (LV) ejection fraction (EF) improved in 6 cases (48.3±5.4% preoperatively to 56.8±7.4% postoperatively, p<0.05) and showed a reduction in 11 (56.2±10.5% to 47.5±9.4%, p<0.01). Grafts were occluded in 6 cases, and redistribution was evident on the delayed thallium images in all cases (100%), while stress ECG was positive in only 3 (50%).

Thus, stress and redistribution SPECT is valuable for identifying patients who will improve after surgery and assessing graft patency more accurately than stress ECG. Resting LVEF was less useful for assessing improvement in LV function.

Additional Indexing Words:
Thallium-201 Emission computed tomography Coronary artery disease Coronary bypass surgery Stress test

STRESS thallium myocardial scintigraphy has been found to be a useful, noninvasive method for the evaluation of coronary artery disease,1–4
and has been used to assess graft patency in patients who have undergone coronary artery bypass grafting (CABG). However, the conventional planar imaging is a two-dimensional expression of the three-dimensional thallium distribution in the myocardium, and hence has its limitations. To solve this limitation single photon emission computed tomography (SPECT) has been employed for three-dimensional distribution of myocardial perfusion. SPECT is particularly useful in assessing the presence and extent of myocardial ischemia and infarction, and has improved sensitivity and specificity in the detection of coronary artery disease.

In this study, we analyzed stress and delayed thallium-201 SPECT for predicting improvement after CABG and for assessing graft patency.

METHODS

The study group consisted of 16 males and 1 female ranging in age from 34–67 years who underwent CABG surgery. All patients had severe, stable angina pectoris and 12 of them also had old myocardial infarction. They were identified after cardiac catheterization and selective coronary angiography. Coronary artery stenosis of 75% or greater was considered significant. Stress and redistribution SPECT studies were performed preoperatively and repeated 1 month after myocardial revascularization. Resting radionuclide ventriculograms were obtained in each patient before and after CABG.

Symptom-limited exercise was performed on a bicycle ergometer in an upright position. Exercise work load was increased by 25 watts every 3 min starting at 25 watts. A 12-lead electrocardiogram was taken at rest and an intravenous catheter was placed in an antecubital vein to facilitate administration of thallium-201. Heart rate, brachial arterial cuff pressure and electrocardiographic leads aVF, V2, and V5 were recorded at 1 min intervals. Two to 2.5 mCi of Tl-201 were administered through the antecubital vein at the time of symptom-limited peak exercise (ST depression 0.2 mV on the electrocardiograph, chest pain or exhaustion) and patients were instructed to continue to exercise one more minute at the same work load after the injection. Imaging was begun 5 min later using SPECT as a postexercise scan. In addition, the SPECT images were again obtained 2 hours after exercise as a delayed scan.

The stress electrocardiogram was considered abnormal for ischemia if there was 1 mm or greater horizontal or down-sloping ST segment depression below the isoelectric baseline, 0.08 sec from the J point, during or at peak exercise. The electrocardiogram was called equivocal for the diagnosis of
ischemia, regardless of the degree of exercise-induced ST segment depression, if the baseline ST segment was depressed greater than 1 mm. Negative tests in which 85% of the maximal predicted heart rate for age was not reached were classified as suboptimal studies.

The SPECT acquisition was performed using a rotating gamma camera (General Electric, 400 AC/T) interfaced to a digital computer (Digital Equipment Corporation, PDP 11/60 or General Electric, MaxiStar). The camera was rotated from the 135° left posterior oblique to the 45° right anterior oblique patient position, collecting 32 views over 180°, with 30 sec taken for each view. The total acquisition time was 16 min.

A series of transaxial (transverse) tomograms were reconstructed by filtered back projection algorithm. No attenuation correction was used. A series of long-axis and short-axis tomograms orthogonal to the cardiac axis were then reorganized from a series of transaxial tomograms. Multiple sections (12 mm) were obtained contiguously in each plane, each slice contained 100 to 150 kilocounts. Postexercise SPECT images were compared with those of delayed images to assess the presence of redistribution. Redistribution was considered to have occurred when there was “filling in” of the defects, partially or completely. The postoperative SPECT images were compared with those obtained preoperatively.

The series of transaxial, short axis and the long-axis sections of the SPECT images were interpreted visually. The most representative sections of the transaxial, short-axis and long-axis sections of the left ventricle were selected from the stress and delayed studies and each divided into 5 segments. Defect score was calculated as follows: normal, 0; mildly decreased, 1+; moderately decreased, 2+; severely decreased 3+.

The thallium images were interpreted by 2 observers without knowledge of the radionuclide data or stress test results. There were no major disagreements between the 2 observers related to the presence or absence of perfusion defects or to redistribution. Minor disagreements related to the scoring or extent of the defects were resolved by discussion.

Electrocardiograms were interpreted by 2 independent observers who had no knowledge of the patients' identity, coronary anatomy or scintigraphic findings. There was complete agreement in most of the studies. In the case of a minor disagreement, assessment was determined by consensus with the aid of a third observer.

Selective coronary angiography with visualization of grafts and the native coronary circulation was performed using the Sones’ or Judkins’ technique 1 month after CABG. A graft was considered to be patent when the entire graft and the vessel being perfused by the graft were visualized angiography-
A graft was considered to be occluded if the stump was visualized or if the graft was not seen on an aortic root angiogram. The degree of coronary and graft stenosis was also determined by agreement of 2 independent observers who were unaware of the results of scintigraphy or stress testing. Narrowing of the luminal diameter by 75% or more in a graft or the coronary artery distal to the graft or a major coronary artery that had not been grafted was considered significant.

All data are presented as mean±standard deviation. Data were analyzed for significant differences by the paired t-test and a p value of less than 0.05 was considered significant.

**Results**

Three patients had left main trunk disease, 1 patient had 1-vessel disease, 5 patients had 2-vessel disease and 8 patients had 3-vessel disease. The resting electrocardiograms showed previous transmural infarction in 12 patients. There was no incidence of perioperative infarction. Forty six grafts were inserted into vessels that had at least 75% stenosis of the luminal diameter. Thirty six grafts were patent and 10 were occluded at the time of postoperative catheterization 1 month after CABG. In 11 patients all of the grafts were patent.

Pre-and postoperative exercise stress electrocardiogram:

The results of preoperative and postoperative exercise testing are shown in Fig. 1. Preoperatively, the stress test was positive in 15 patients, in 1 the test was negative and in 1 it was inconclusive because of rate-dependent left bundle branch block. Postoperatively, only 4 had positive stress tests. Three of those with positive stress tests had occluded grafts. Thirteen patients had negative stress tests and 3 of them had occluded grafts.

Comparison of pre- and postoperative thallium-201 SPECT studies defect score:

Preoperatively, all patients showed perfusion defects. The delayed images showed visual improvement in the perfusion defects (redistribution) in 16 studies (Fig. 2). Stress scintigraphy was positive in 1 patient in whom left bundle branch block was induced with exercise. The defect score decreased from 16.4±7.6 at stress imaging to 8.3±5.8 at delayed imaging (p<0.001, Fig. 3).

Postoperatively, the defect score decreased from 7.8±6.3 at stress imaging to 5.9±4.8 at delayed imaging (p<0.05, Fig. 4), but the stress defect score decreased postoperatively (7.8±6.3) as compared to that preoperatively (16.4±7.6, p<0.001). Ten patients showed no redistribution on delayed imaging (Fig. 2). Two of them showed normal scintigrams, and the remaining
8 patients showed fixed perfusion defects without redistribution. These 8 patients, who after CABG showed only fixed perfusion defects, showed reversible perfusion defects preoperatively with a decrease in the defect score from $17.3 \pm 7.1$ at stress imaging to $8.6 \pm 6.36$ at delayed imaging. Postoperatively, 7 patients showed redistribution and the defect score decreased from $11.3 \pm 6.5$ to $6.1 \pm 4.7$ (p<0.05). Six had occluded grafts. Segmental analysis demonstrated that these 6 patients had occlusions in the grafts perfusing
the segments showing scintigraphic abnormalities. There was only 1 patient showing a less firm correlation. Postoperatively, 1 patient who showed a reduction in defect score on delayed imaging in comparison to the stress-
induced defect score (10 to 4) had all grafts patent. Thus, redistribution analysis on thallium scan identified occluded grafts in all 6 patients (100%), while stress electrocardiogram accurately detected occlusions in only 3 (50%).

An example of stress and delayed short-axis SPECT images in a patient with patent grafts is shown in Fig. 5. The stress-induced perfusion defects in the anteroseptal and anterior segments seen preoperatively were not seen in the stress images after CABG. The inferior perfusion defect was fixed and showed no change between the stress and reperfusion images, indicating an area of myocardial scarring.

Figure 6 illustrates another case with occluded grafts. Stress-induced perfusion defects were noted in the apical, anterolateral and posterolateral...
segments, preoperatively, which became enlarged in the postoperative stress image. Postoperatively, the stress defect score was 16, a value higher than the preoperative stress defect score of 9. In this patient the grafts to the circumflex and right coronary arteries were occluded.

Comparison of pre- and postoperative LVEF:

Six patients showed an improvement in EF after CABG (from 48.3%±5.4% to 56.8%±7.4%, p<0.05). Of these, 2 patients who showed improvement in EF had graft occlusion, but both patients had patent grafts to the left anterior descending artery with occluded grafts to the distal segments of the right coronary and circumflex arteries. Eleven patients showed a decrease in EF postoperatively, but demonstrated no wall motion abnormality, except in the septum. The EF decreased from 61.5%±9.4% preoperatively to 50.3%±8.5% postoperatively (p<0.01, Fig. 7). Four of these patients had graft occlusions. One patient who received 5 grafts with occlusion only of the graft to the left anterior descending artery showed a decrease in EF.

![Graph](image-url)

**Fig. 7.** Preoperative and postoperative ejection fraction. (A) Improvement in ejection fraction, (B) no improvement. PRE OP=preoperative; POST OP=postoperative.
from 65% to 50% postoperatively. The remaining 3 patients showed occluded grafts to the left anterior descending artery in 2 and to the posterior descending artery in 1, and in all of them the EF decreased by 6%±2.6% postoperatively. There was no enzymatic or electrocardiographic evidence of perioperative myocardial infarction. Generally, there was no worsening of wall motion except in the septum, where the motion was pendular postoperatively.

**DISCUSSION**

Over the past few years, there have been many reports describing thallium imaging using the conventional technique in studying patients before and after CABG. Stress thallium SPECT is a useful adjunct in the field of nuclear cardiology, providing high sensitivity and specificity for diagnosing coronary artery disease and identifying individual coronary artery involvement. Because of the three-dimensional tomographic presentation, each myocardial segment was recognized separately with high contrast. Consequently, segmental analysis of stress SPECT images allowed identification of regions highly specific for the involvement of the grafted coronary arteries.

A stress perfusion defect usually represents ischemia or fibrosis and its status can be further clarified by performing redistribution studies. Previous studies indicated that with stress and rest thallium testing it may be possible to assess graft patency after CABG. Myocardial revascularization is usually associated with improvement in early Tl-201 uptake in segments with initial defects and redistribution preoperatively, since these segments with transient perfusion defects contain ischemic but viable myocardium. Our results of pre- and postoperative stress and delayed imaging imply that improved perfusion and no change between the stress and redistribution studies postoperatively indicate a high graft patency rate. Development of new resting defects or persistence of reversible ischemia postoperatively was consistent with graft closure or incomplete revascularization. The patient with false positive findings had associated hypertrophic cardiomyopathy. The results were consistent with both Ritchie et al and Zaret et al who concluded that the presence of an exercise defect in the postoperative study was associated with low graft patency rates. In our patients, improved perfusion was seen in patients with successful revascularization.

Recent reports showed an improvement in regional function after revascularization in some segments with persistent perfusion defects on preoperative scan. Thus, the assessment of thallium redistribution even using the SPECT technique may underestimate the presence of myocardial viability.
However, those with transient perfusion defects which should contain viable myocardium are most likely to improve regional perfusion after CABG.

Changes in LV function after CABG have been extensively studied, however, the results remain conflicting. In our series resting LVEF was a poor indicator of graft patency. Two patients with improvement in LVEF postoperatively had occluded grafts. It may be said that isolated occlusion of the grafts to the distal coronary lesions, with a small area of jeopardized myocardium, may not be of adverse functional significance if other grafts remain open. But 6 patients with patent grafts also showed a decrease in ejection fraction. Preoperatively, 5 of these patients had ejection fractions greater than 50% and in 1 case it was 47%. Our results are consistent with those of Rozanski et al who showed that resting left ventricular ejection fraction was generally unchanged postoperatively. Depression of LV function postoperatively may be due to perioperative infarction, myocardial ischemia or injury during cardioplegic arrest. It should be emphasized that our results are related to resting LV function. Improvements in exercise LV function have been reported in most patients after coronary artery bypass surgery. Follow-up studies after 3 months, 6 months and 1 year may be helpful in determining improvement in function in relation to patent grafts. Exercise regional ventricular function may yet be a better index of functional improvement and response of damaged or jeopardized myocardium to successful surgical revascularization.

Stress electrocardiogram detected only 50% of the patients with graft occlusion. Although improved exercise tolerance was associated with revascularization, individual variation was great and prediction of graft patency is often associated with danger. Hence, other parameters to evaluate cardiac status in postoperative patients are needed. In this sense, postoperative stress radionuclide studies may provide a more reliable indicator of graft occlusion, as compared to the stress electrocardiogram alone.

Since myocardial scintigrams reflect relative differences in perfusion, hearts with multi-vessel disease may often reveal generalized perfusion defects in most ischemic areas, even when the tomographic technique is employed. Hence, after CABG those areas which were less ischemic preoperatively and did not receive grafts may become obvious postoperatively, causing false positive results. This may be an inherent limitation of myocardial imaging which provides data concerning relative myocardial perfusion.
Conclusion

Stress thallium-201 SPECT is a promising noninvasive technique for assessing myocardial perfusion before and after CABG. A comparison of pre- and postoperative studies can be used to document the effects of surgery. Improvement in function can be noted by improvement in perfusion postoperatively. Postoperative redistribution on delayed images is usually associated with graft occlusion. Stress electrocardiogram when used alone provides a low predictive value for detecting occluded grafts postoperatively. Resting LVEF does not appear to improve significantly after CABG and is a poor indicator of graft patency. Therefore, stress TI-201 SPECT should serve as a useful noninvasive technique for the future evaluation of the postcoronary patient.

References

6. Iskandrian AS, Hakki AH, Kane SA, Goel IP, Mundth ED, Hakki AH, Segal BL: Rest and redistribution thallium-201 myocardial scintigraphy to predict improvement in left ventricular function after coronary arterial bypass grafting. Am J Cardiol 51: 1312, 1982
29. Hamby RI, Tabrah F, Aintablian A, Hartstein ML, Wisoff BG: Left ventricular hemody-
namics and contractile pattern after aortocoronary bypass surgery. Am Heart J 88: 149, 1974


33. Isom OW, Spencer FC, Glassman E, Dembrow JM, Pasternack BS: Long-term survival following coronary bypass surgery in patients with significant improvement of left ventricular function. Circulation 52 (suppl I): 1-141, 1975


