Usefulness of Electrocardiographic-Gated Stress Technetium-99m Sestamibi Single-Photon Emission Computed Tomography to Differentiate Ischemic from Nonischemic Cardiomyopathy

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The noninvasive differentiation between ischemic and nonischemic cardiomyopathy is frequently difficult. We examined the clinical value of stress electrocardiographic gated (ECG-gated) single-photon emission computed tomography (SPECT) to identify ischemic cardiomyopathy and detect coronary artery disease (CAD) in 164 patients without known CAD, ejection fraction ≤40% by ECG-gated SPECT, and subsequent coronary angiography. Summed stress, rest, and difference scores were measured from the SPECT studies, and regional wall motion variance was calculated from the ECG-gated images. Sensitivity and 95% confidence intervals for the diagnosis of ischemic cardiomyopathy and for detection of any CAD (>50% diameter stenosis) were estimated using previously defined cutoffs for summed stress score and regional wall motion variance. For the diagnosis of ischemic cardiomyopathy, sensitivity of stress SPECT (summed stress score >8) was 87% (95% confidence interval [CI] 78 to 95), with a specificity of 63% (95% CI 60 to 82). The addition of wall motion information (summed stress score >8 or regional wall motion variance >0.114) increased sensitivity to 88% (95% CI 80 to 96) and decreased specificity to 45% (95% CI 35 to 55). If reversibility was also taken into account (summed stress score >8, regional wall motion variance >0.114, or summed difference score >0), sensitivity further increased to 94% (95% CI 88 to 100) and specificity decreased to 32% (95% CI 23 to 41). For detection of any CAD, the combined approach using stress perfusion, reversibility, and region of wall motion had a sensitivity of 94% (95% CI 89 to 99) and a specificity of 45% (95% CI 35 to 57). Therefore, ECG-gated SPECT is very sensitive for detection of ischemic cardiomyopathy and CAD among patients with moderate to severe systolic dysfunction.

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When patients present with left ventricular dysfunction and chest pain, an early invasive evaluation with conventional coronary angiography is recommended.[1] For many patients and particularly those without chest pain, an initial reliable noninvasive approach would be preferable because coronary angiography has a low risk for serious complications.[2] The success of noninvasive approaches to distinguish among etiologies of cardiomyopathy, including echocardiography,[3–5] radionuclide ventriculography,[6,7] and stress myocardial perfusion imaging[8–12] has been variable. In a relatively small study involving patients with clearly defined etiology of left ventricular systolic dysfunction, a combined approach of stress myocardial perfusion and function using electrocardiographic-gated (ECG-gated) single-photon emission computed tomography (SPECT) after stress was reported to distinguish between ischemic and nonischemic cardiomyopathy.[13] However, data from small well-controlled trials may not be applicable to unselected patients. Accordingly, we examined the clinical usefulness of stress technetium-99m sestamibi ECG-gated SPECT in the differentiation of ischemic cardiomyopathy from nonischemic cardiomyopathy in a consecutive series of patients with moderate to severe left ventricular systolic dysfunction who were referred for stress myocardial perfusion imaging and subsequently underwent coronary angiography.

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METHODS

Data collection: We queried the electronic database of the Cardiology Division of Hartford Hospital (Hartford, Connecticut) and identified patients who underwent stress technetium-99m sestamibi ECG-gated SPECT between July 15, 1995 and March 30, 2003, followed by cardiac catheterization within 90 days, and had left ventricular ejection fraction ≤40% by ECG-gated SPECT. Patients were excluded if they

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had known significant coronary artery disease (CAD) at the time of ECG-gated SPECT after stress (≥50% stenosis in any major coronary artery by angiography) or a history of myocardial infarction.

Image acquisition and processing: A 1- (at rest and after stress) or 2-day protocol using technetium-99m sestamibi (Bristol Myers Squibb Medical Imaging, Billerica, Massachusetts) was used. For imaging after stress, 30 to 45 mCi (1.11 to 1.67 GBq) of technetium-99m sestamibi was administered at peak stress and images were acquired 15 to 60 minutes after injection (depending on the mode of stress). Images were acquired 45 to 60 minutes after injection of 30 to 45 mCi (1.11 to 1.67 GBq) of technetium-99m sestamibi for the 2-day protocol and 10 to 15 mCi (0.37 to 0.56 GBq) for the 1-day protocol. All images were acquired with ADAC/Philips single- or dual-head gamma cameras (ADAC/Philips Medical Systems, Milpitas, California) equipped with low-energy, high-resolution collimators. Each data set was acquired over a 180° arc, from 45° right anterior oblique to 45° left posterior oblique. Sixty-four projections were acquired (20 to 25 seconds/projection for stress and 30 seconds/ projection for rest) and images were stored in a 64 × 64 × 16 matrix. The photopeak window was set at 140 keV ± 20% and a 40% acceptance window. ECG-gated SPECT acquisitions were performed for all patients without significant arrhythmias. Filtered back-projection was performed by using a low-pass Butterworth filter with a cut-off frequency of 0.6 cycles/cm and an order of 5.0 for the transaxial slices to a thickness of 6.6 mm. Attenuation correction was not used.

Image interpretation: All images were reinterpreted for myocardial perfusion and function by a consensus of 3 experienced observers unaware of patient identity and any clinical or catheterization data. A 17-segment model[14] was used for grading perfusion and function, as previously described.[13] In brief, for assessment of perfusion, each segment was graded on a scale of 0 to 4 for at rest and stress (0 = normal activity; 1 = mild; 2 = moderate; 3 = severe decrease in photon counts; 4 = complete absence of photon). For each image, a summed stress score and a summed score at rest were calculated by adding the scores for all 17 segments. A summed difference score was derived by subtracting the summed score at rest from the summed stress score. Left and right ventricular sizes at stress and at rest were scored on a scale of 0 to 3 (0 = normal; 1 = mild; 2 = moderate; 3 = severe dilation). Evaluation of systolic function was performed by visually assessing the endocardial border excursion and region of wall thickening of the ECG-gated SPECT images. Each segment was scored on a scale of 0 to 5 (0 = normal; 1 = mild; 2 = moderate; 3 = severe hypokinesia; 4 = akinesia; 5 = dyskinesia). The variability in regional wall motion was expressed as the regional wall motion variance, which is the variance of the average wall motion score for patient coronary territories. Left ventricular ejection fraction was calculated using an automated quantitative method[15] and confirmed visually.

Cardiac catheterization: All cardiac catheterization films were reviewed and visually assessed by 1 experienced observer unaware of any clinical or ECG-gated SPECT data. Patients were classified as having significant CAD if any major coronary artery had ≥50% diameter stenosis. Criteria to define ischemic cardiomyopathy included (1) left main coronary artery with ≥50% diameter stenosis, (2) left anterior descending coronary artery with proximal (before the first diagonal branch) ≥75% diameter stenosis, or (3) ≥2 major epicardial coronary arteries with ≥75% diameter stenosis.[16]

Data analysis: Data from a previous pilot study from our laboratory suggested that patients with ischemic cardiomyopathy have a much higher summed stress score and regional wall motion variance than do patients with nonischemic cardiomyopathy.[13] Accordingly, we chose the previously identified 95% upper confidence intervals (CIs) for nonischemic cardiomyopathy (8.39 for summed stress score and 0.114 for regional wall motion variance) as cutoffs to examine the sensitivity, specificity, and accuracy of ECG-gated SPECT for detection of ischemic cardiomyopathy. The potential additional utility of reversibility (expressed as the summed difference score), which in principle should identify patients with stress-induced ischemia, was also examined.

Statistical analysis: All numerical values are presented as mean ± SD (range) unless otherwise indicated. Patients were classified as having (1) CAD versus no CAD and (2) ischemic versus nonischemic cardiomyopathy from the angiographic data, which were considered the reference standard against which the sensitivity, specificity, and accuracy of ECG-gated SPECT were examined. Logistic regression analysis was used to identify variables that could discriminate between patients with ischemic cardiomyopathy and those with nonischemic cardiomyopathy. A forward stepwise model included parameters that on the univariate analysis were associated at $p \leq 0.1$. Missing values were excluded from multivariate analysis. Odds ratios and 95% CIs were determined. A p value <0.05 was considered statistically significant.

RESULTS

Patient characteristics: One hundred sixty-four consecutive patients (age 62 ± 11 years, range 38 to 87) met the entry criteria and were included in this analysis. For 97 patients (59%), the presence of ventricular dysfunction was known at the time of stress imaging.

The indications for stress ECG-gated SPECT were (1) symptoms suggestive of CAD in 66% of patients (n = 108); (2) abnormal electrocardiogram, documented left ventricular dysfunction, or recent congestive heart failure in 18% (n = 29); (3) preoperative evaluation for noncardiac surgery in 10% (n = 16); and (4) syncope or arrhythmia in 6% (n = 11). One hundred twenty-nine patients (79%) underwent a 1-day rest or stress protocol, with ECG-gating performed during acquisition of the stress images. The

TABLE 1 Demographic Characteristics of Patients With Ischemic Cardiomyopathy (IC) and Nonischemic Cardiomyopathy (NIC)

Variable	IC (n = 67)	NIC (n = 97)	p Value
Women	22 (33%)	37 (38%)	NS
Age (yrs)	66 ± 12	59 ± 10	<0.001
Systemic hypertension	45 (67%)	61 (63%)	NS
Hypercholesterolemia	36 (54%)	38 (39%)	0.080
Cigarette smoking	36 (54%)	49 (51%)	NS
Diabetes mellitus	34 (51%)	31 (32%)	<0.05
β Blockers	24 (38%)	35 (38%)	NS
Calcium antagonists	13 (20%)	11 (12%)	NS
Angiotensin-converting enzyme inhibitors	38 (59%)	53 (56%)	NS
Nitrates	5 (8%)	9 (10%)	NS
Aspirin	31 (48%)	34 (37%)	NS
Digoxin	7 (11%)	17 (18%)	NS
Amiodarone	0 (0%)	1 (1%)	NS
Exercise	21 (31%)	29 (30%)	NS
Pharmacologic stress	38 (57%)	47 (48%)	NS
Pharmacologic stress plus exercise	8 (12%)	21 (22%)	NS

TABLE 2 Comparison of Perfusion and Left Ventricular Regional and Global Functional Data in Patients With Ischemic (IC) and Nonischemic Cardiomyopathy (NIC)

	IC (n = 67)	NIC (n = 97)	p Value
Left ventricular ejection fraction (%)	30 ± 11 (n = 50)	33 ± 10 (n = 88)	NS
Left ventricular cavity size after stress	1.2 ± 0.9	1.4 ± 1.0	NS
Left ventricular cavity size at rest	0.9 ± 0.9	1.4 ± 1.0	<0.01
Regional wall motion variance	0.35 ± 0.33	0.38 ± 0.68	NS
Summed stress score	15.7 ± 7.7	7.9 ± 5.2	<0.001
Summed rest score	10.1 ± 6.8	6.1 ± 5.0	<0.001
Summed difference score	5.6 ± 5.0	1.7 ± 2.6	<0.001

remaining 35 patients (21%) were imaged according to a 2-day rest and stress protocol, with ECG-gating performed at rest (n = 12) or after stress (n = 23). Forty-nine patients (30%) had left bundle branch block on the electrocardiogram at rest.

In the study group (164 patients), cardiac catheterization was performed 12 ± 16 days after the stress test. Based on our definition of ischemic cardiomyopathy, 67 patients (41%) had ischemic cardiomyopathy and 97 (59%) had nonischemic cardiomyopathy. Among those with nonischemic cardiomyopathy, 28 patients (29%) had significant CAD (≥50% diameter stenosis) without fulfilling criteria for ischemic cardiomyopathy. The demographic and clinical characteristics of patients with ischemic or nonischemic cardiomyopathy are presented in Table 1. Findings from ECG-gated SPECT in patients with ischemic or nonischemic cardiomyopathy are presented in Table 2.

Electrocardiographic-gated SPECT for detection of ischemic cardiomyopathy: PERFUSION: A summed stress score >8 alone identified 58 of 67 patients with ischemic cardiomyopathy (sensitivity 87%, 95% CI 78 to 95). This cutoff also identified 61 of 97 patients with nonischemic cardiomyopathy (specificity 63%, 95% CI 60 to 82). Thus, the overall accuracy of SPECT myocardial perfusion imaging alone (summed stress score >8) for detecting ischemic cardiomyopathy was 73% (95% CI 66 to 79; Figure 1).

FUNCTION: A regional wall motion variance >0.114 correctly identified 48 of 67 patients with ischemic cardiomyopathy (sensitivity 72%, 95% CI 61 to 82). Of 97 patients with nonischemic cardiomyopathy, region of wall motion correctly identified 50 patients (specificity 52%, 95% CI 42 to 61). Thus, the overall accuracy of increased regional wall motion variance (>0.114) for detecting ischemic cardiomyopathy was 60% (95% CI 52 to 67; Figure 1).

INTEGRATED PERFUSION AND FUNCTION: The integrated use of myocardial perfusion data and region of wall motion (summed stress score >8 or regional wall motion variance >0.114) correctly identified 59 of 67 patients with ischemic cardiomyopathy (sensitivity 88%, 95% CI 80 to 96), with a specificity of 45% (95% CI 35 to 55) and overall accuracy of 63% (95% CI 55 to 70; Figure 1).

When any reversibility (summed difference score >0) was used in addition to the previously mentioned integrated perfusion/function approach (cut-off summed stress score >8, regional wall motion variance >0.114, or summed difference score >0), 63 of 67 patients with ischemic cardiomyopathy were correctly identified, corresponding to a sensitivity of 94% (95% CI 88 to 100). The corresponding specificity was 32% (95% CI 23 to 41) and overall accuracy was 57% (95% CI 50 to 65; Figure 1).

Electrocardiographic-gated SPECT for detection of any CAD (>50% diameter stenosis): PERFUSION: Technetium-99m SPECT myocardial perfusion imaging (summed stress score >8) had a sensitivity of 76% (95% CI 67 to 84), a specificity of 71% (95% CI 60 to 82), and an accuracy of 74% (95% CI 67 to 81) for detection of any CAD (Figure 2).

FUNCTION: Increased regional wall motion variance (>0.114) on ECG-gated SPECT images had a sensitivity of 70% (95% CI 61 to 79), a specificity of 60% (95% CI 48 to 72), and an overall accuracy of 66% (95% CI 59 to 73) for detection of any CAD (Figure 2).

INTEGRATED PERFUSION AND FUNCTION: ECG-gated SPECT with summed stress score >8 or regional wall motion variance >0.114 had a sensitivity of 83% (95% CI 75 to 90), a specificity of 54% (95% CI 42 to 66), and an overall accuracy of 71% (95% CI 64 to 78) for detection of any CAD (Figure 2).

When any reversibility (summed difference score >0) was combined with the integrated ECG-gated SPECT approach, there was a sensitivity of 94% (95% CI 89 to 99), a specificity of 45% (95% CI 35 to 57),

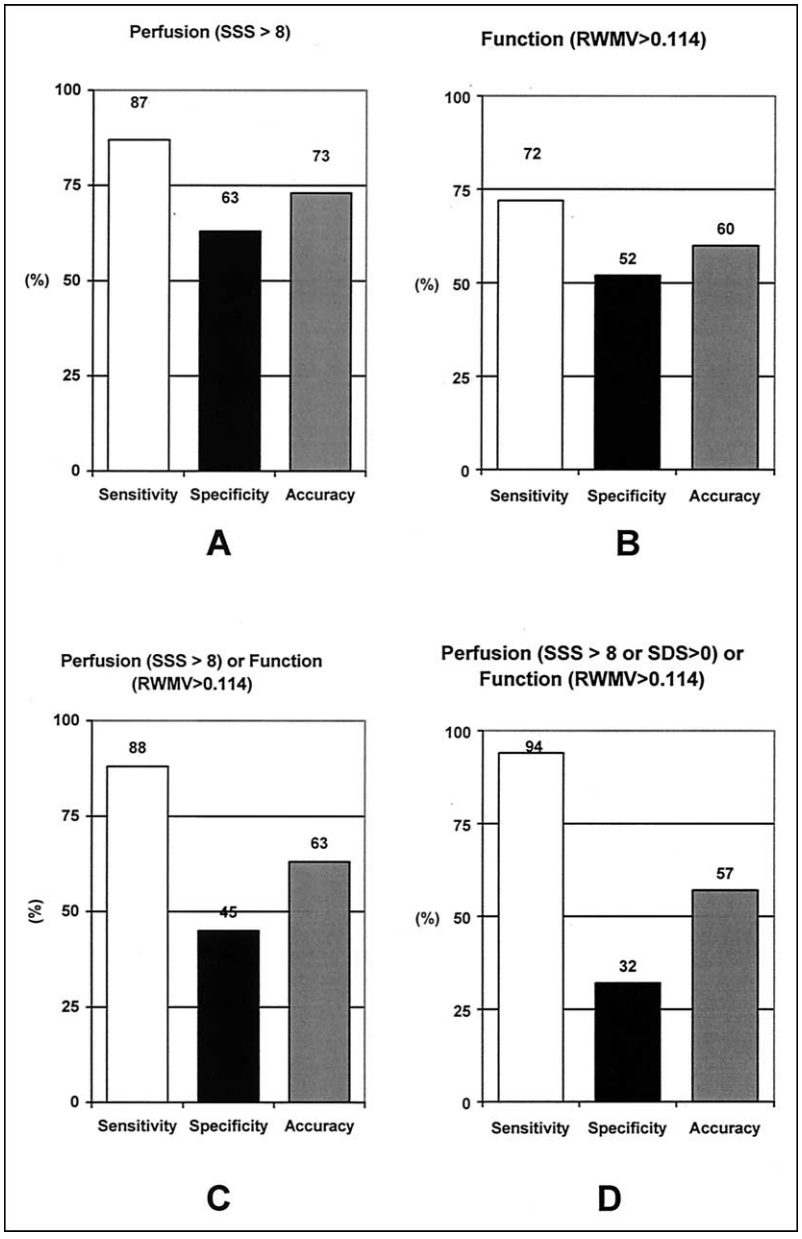

FIGURE 1. Sensitivity, specificity, and accuracy for detection of ischemic cardiomyopathy. *(A)* Summed stress score (SSS) >8. *(B)* Regional wall motion variance (RWMV) >0.114. *(C)* SSS >8 or RWMV >0.114. *(D)* SSS >8, RWMV >0.114, or summed difference score (SDS) >0.

and an overall accuracy of 74% (95% CI 68 to 81) for the detection of any CAD (Figure 2).

Discriminants of ischemic versus nonischemic cardiomyopathy: By logistic regression, a 2-factor model (2 clinical and 2 imaging) accounted for >77% of all cases. A summed stress score >8 was the single most significant factor in the model ($p < 0.001$), followed by age ≥70 years ($p < 0.005$), reversible left ventricular cavity dilation ($p < 0.01$), and smoking ($p < 0.05$; Table 3). Age also played a significant role in the model at cutoffs of ≥50 and ≥60 years, but at a lower level of significance and with a lower overall ability to predict the etiology of cardiomyopathy.

DISCUSSION

In a large cohort of 164 consecutive patients, we demonstrated that stress ECG-gated technetium-99m sestamibi SPECT has clinical utility for assessing patients with cardiomyopathy and offers a high sensitivity for detecting those with ischemic cardiomyopathy. The stress perfusion defect score was the most important variable to distinguish ischemic from nonischemic cardiomyopathy and correctly identified most of the patients (87%) with ischemic cardiomyopathy. The addition of regional systolic dysfunction or presence of defect reversibility further enhanced sensitivity for detection of ischemic cardiomyopathy (94%).

Studies of myocardial perfusion using thallium-201,[8,9,11,17–21] technetium-99m,[13] and fluoride-18 fluorodeoxyglucose positron emission tomography[10,12,22] have shown that patients with ischemic cardiomyopathy have more severe perfusion defects than do those with nonischemic cardiomyopathy. Our findings are consistent with these observations. The stress perfusion defects in ischemic cardiomyopathy are due to previous infarctions, myocardial hibernation in regions with decreased blood flow of long duration, reversible ischemia, or a combination of mechanisms. Stress perfusion is more sensitive for detection of ischemic cardiomyopathy and CAD than is perfusion at rest, because the latter does not take the ischemic burden into account.

In nonischemic cardiomyopathy, mild fixed defects are occasionally encountered, typically in the inferior wall, and are likely due to attenuation associated with the severely dilated left ventricular cavity and supine imaging.[10,13] The presence of such mild defects may account for some overlap between ischemic and nonischemic cardiomyopathy when perfusion is used as the only criterion to differentiate between the 2 entities. In these patients and in those with "mixed" cardiomyopathy (primarily nonischemic cardiomyopathy with co-existent CAD), the addition of ECG-gated and reversibility data would likely confer the greatest benefit. In our study, mixed cardiomyopathies accounted for approximately 15% of all cases, a number that was too small to provide a reliable subgroup analysis. Nevertheless, the systolic function of these patients typically does not significantly improve with restoration of blood flow in the diseased arteries, and

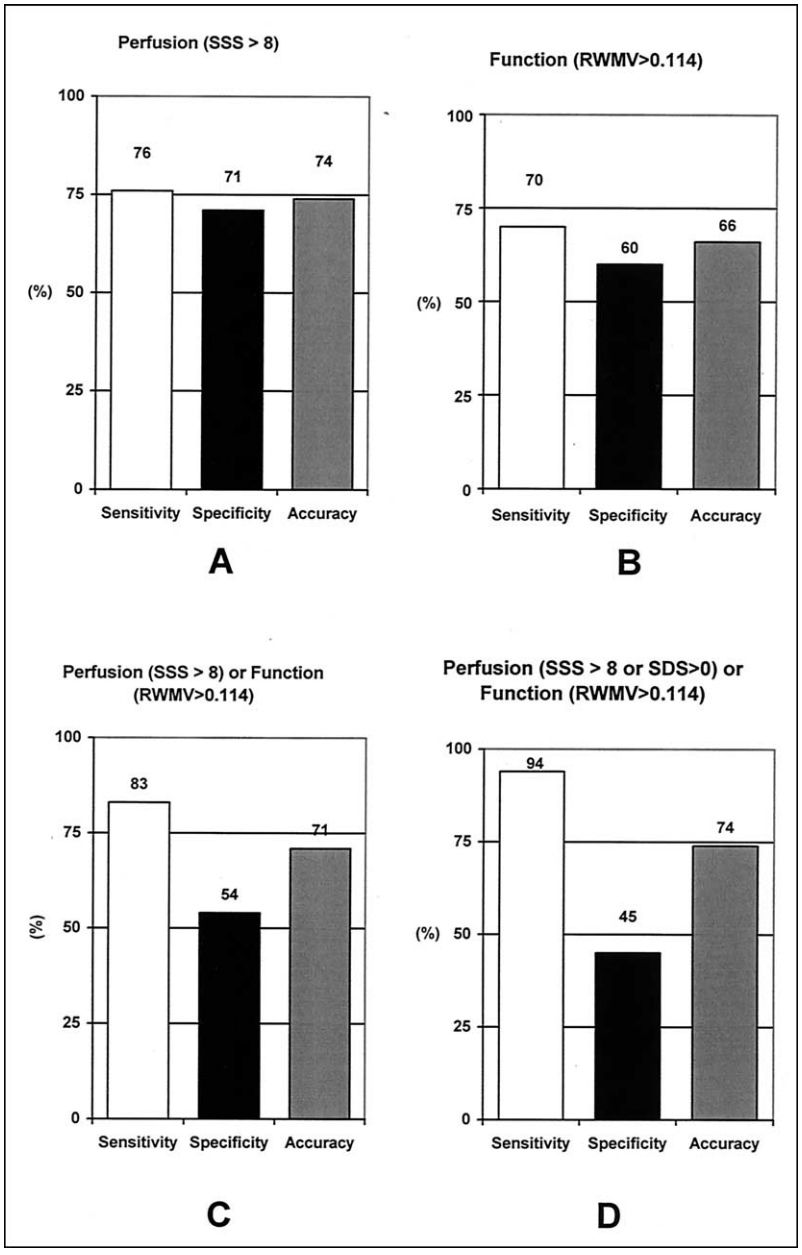

FIGURE 2. Sensitivity, specificity, and accuracy for detection of any CAD (>50% diameter stenosis). *(A)* SSS >8. *(B)* RWMV >0.114. *(C)* SSS >8 or RWMV >0.114. *(D)* SSS >8, RWMV >0.114, or SDS >0. Abbreviations as in Figure 1.

TABLE 3 Logistic Regression Analysis for Distinction Between Ischemic and Nonischemic Cardiomyopathy

	OR	95% CI	p Value
Imaging parameters			
Summed stress score	11.8	4.9–28.7	<0.001
Reversibility of left ventricular dilation	6.6	1.6–27.2	<0.01
Clinical parameters			
Age (≥70 yrs)	3.9	1.6–9.3	<0.005
Smoker	2.2	1.0–5.0	<0.05

95% CI = 95% confidence interval; OR = odds ratio.

their overall prognosis is very similar to those with "pure" nonischemic cardiomyopathy.[16]

In our previous pilot study, which assessed the value of ECG-gated SPECT to distinguish ischemic from nonischemic cardiomyopathy,[13] ischemia (measured by the summed difference score) of either type was not a significant discriminating factor, likely due to a small sample size and preferential selection of patients with stable ischemic cardiomyopathy and little, if any, angina. However, intuitively, the presence of ischemia should be a good way to identify patients with CAD (and ischemic cardiomyopathy). In this study, the presence of reversible defects enhanced the sensitivity for detection of CAD (from 76% to 94%) and ischemic cardiomyopathy (from 87% to 94%) compared with the summed stress score alone. Previous studies have shown the potential value of reversibility,[8] whereas others have not found it to be helpful.[11] Therefore, the value of defect reversibility to identify CAD (and ischemic cardiomyopathy) merits further investigation in prospective studies.

We conclude that ECG-gated technetium-99m sestamibi SPECT stress myocardial perfusion imaging is very sensitive for identification of ischemic cardiomyopathy and CAD among patients with moderate to severe left ventricular dysfunction. These findings support a clinical role for noninvasive testing as an initial evaluation for patients with cardiomyopathy.

1. Hunt SA, Baker DW, Chin MH, Cinquegrani MP, Feldman AM, Francis GS, Ganiats TG, Goldstein S, Gregoratos G, Jessup ML, et al. ACC/AHA guidelines for the evaluation and management of chronic heart failure in the adult: executive summary. A report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (committee to revise the 1995 guidelines for the evaluation and management of heart failure). *J Am Coll Cardiol* 2001; 38:2101–2113.

2. Johnson LW, Lozner EC, Johnson S, Krone R, Pichard AD, Vetrovec GW, Noto TJ. Coronary arteriography 1984–1987: a report of the Registry of the Society for Cardiac Angiography and Interventions. I. Results and complications. *Cathet Cardiovasc Diagn* 1989;17:5–10.

3. Diaz RA, Nihoyannopoulos P, Athanassopoulos G, Oakley CM. Usefulness of echocardiography to differentiate dilated cardiomyopathy from coronary-induced congestive heart failure. *Am J Cardiol* 1991;68:1224–1227.

4. Cohen A, Chauvel C, Benhalima B, Guyon P, Desert I, Valty J. Is dobutamine stress echocardiography useful for noninvasive differentiation of ischemic from idiopathic dilated cardiomyopathy? *Angiology* 1997;48:783–793.

5. Vigna C, Russo A, De Rito V, Perna GP, Testa M, Lombardo A, Lanna P, Langialonga T, Salvatori MP, Fanelli R, Loperfido F. Regional wall motion analysis by dobutamine stess echocardiography to distinguish between ischemic and nonischemic dilated cardiomyopathy. *Am Heart J* 1996;131:537–543.

6. Glamann DB, Lange RA, Corbett JR, Hillis LD. Utility of various radionuclide

techniques for distinguishing ischemic from nonischemic dilated cardiomyopathy. *Arch Intern Med* 1992;152:769–772.
7. Wallis DE, O'Connell JB, Henkin RE, Costanzo-Nordin MR, Scanlon PJ. Segmental wall motion abnormalities in dilated cardiomyopathy: a common finding and good prognostic sign. *J Am Coll Cardiol* 1984;4:674–679.
8. Chikamori T, Doi YL, Yonezawa Y, Yamada M, Seo H, Ozawa T. Value of dipyridamole thallium-201 imaging in noninvasive differentiation of idiopathic dilated cardiomyopathy from coronary artery disease with left ventricular dysfunction. *Am J Cardiol* 1992;69:650–653.
9. Iskandrian AS, Hakki AH, Kane S. Resting thallium-201 myocardial perfusion patterns in patients with severe left ventricular dysfunction: differences between patients with primary cardiomyopathy, chronic coronary artery disease, or acute myocardial infarction. *Am Heart J* 1986;111:760–767.
10. Mody FV, Brunken RC, Stevenson LW, Nienaber CA, Phelps ME, Schelbert HR. Differentiating cardiomyopathy of coronary artery disease from nonischemic dilated cardiomyopathy utilizing positron emission tomography. *J Am Coll Cardiol* 1991;17:373–383.
11. Tauberg SG, Orie JE, Barthalliumett BE, Cottington EM, Flores AR. Usefulness of thallium-201 for distinction of ischemic from idiopathic dilated cardiomyopathy. *Am J Cardiol* 1993;71:674–680.
12. Tian Y, Liu X, Shi R, Liu Y, Wu Q, Zhang X. Radionuclide techniques for evaluating dilated cardiomyopathy and ischemic cardiomyopathy. *Chin Med J (Engl)* 2000;113:392–395.
13. Danias PG, Ahlberg AW, Clark BA III, Messineo F, Levine MG, McGill CC, Mann A, Clive J, Dougherty JE, Waters DD, Heller GV. Combined assessment of myocardial perfusion and left ventricular function with exercise technetium-99m sestamibi gated single-photon emission computed tomography can differentiate between ischemic and nonischemic dilated cardiomyopathy. *Am J Cardiol* 1998;82:1253–1258.
14. Aepfelbacher FC, Johnson RB, Schwartz JG, Chen L, Parker RA, Parker JA, Danias PG. Validation of a model of left ventricular segmentation for interpretation of SPECT myocardial perfusion images. *Eur J Nucl Med* 2001;28:1624–1629.
15. Germano G, Kiat H, Kavanagh PB, Moriel M, Mazzanti M, Su HT, Van Train KF, Berman DS. Automatic quantification of ejection fraction from gated myocardial perfusion SPECT. *J Nucl Med* 1995;36:2138–2147.
16. Felker GM, Shaw LK, O'Connor CM. A standardized definition of ischemic cardiomyopathy for use in clinical research. *J Am Coll Cardiol* 2002;39:210–218.
17. Bulkley BH, Hutechnetiumhins GM, Bailey I, Strauss HW, Pitt B. Thallium 201 imaging and gated cardiac blood pool scans in patients with ischemic and idiopathic congestive cardiomyopathy. A clinical and pathologic study. *Circulation* 1977;55:753–760.
18. Dunn RF, Uren RF, Sadick N, Bautovich G, McLaughlin A, Hiroe M, Kelly DT. Comparison of thallium-201 scanning in idiopathic dilated cardiomyopathy and severe coronary artery disease. *Circulation* 1982;66:804–810.
19. Eichhorn EJ, Kosinski EJ, Lewis SM, Hill T, Emond LH, Leland OS. Usefulness of dipyridamole-thallium-201 perfusion scanning for distinguishing ischemic from nonischemic cardiomyopathy. *Am J Cardiol* 1988;62:945–951.
20. Juilliere Y, Marie PY, Danchin N, Gillet C, Paille F, Karcher G, Bertrand A, Cherrier F. Radionuclide assessment of regional differences in left ventricular wall motion and myocardial perfusion in idiopathic dilated cardiomyopathy. *Eur Heart J* 1993;14:1163–1169.
21. Saltissi S, Hockings B, Croft DN, Webb-Peploe MM. Thallium-201 myocardial imaging in patients with dilated and ischaemic cardiomyopathy. *Br Heart J* 1981;46:290–295.
22. Eisenberg JD, Sobel BE, Geltman EM. Differentiation of ischemic from nonischemic cardiomyopathy with positron emission tomography. *Am J Cardiol* 1987;59:1410–1414.