Value of Gating of Technetium-99m Sestamibi Single-Photon Emission Computed Tomographic Imaging

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Objectives. **The purpose of this study was to determine how frequently and for what reasons the addition of electrocardiographically gated technetium-99m (Tc-99m) sestamibi single-photon emission computed tomographic (SPECT) images add value to nongated SPECT perfusion images.**

Background. **Electrocardiographic gating of Tc-99m sestamibi SPECT images permits assessment of regional and global left ventricular function and may assist in differentiating attenuation artifacts from myocardial scar.**

Methods. **A total of 285 consecutive patients (143 women and 142 men; mean age 57.6 ± 11.5 years) underwent gated SPECT Tc-99m sestamibi imaging (212 with exercise, 63 with dipyridamole and 10 with dobutamine). The conventional stress and rest tomograms were interpreted first by means of a 14-segment scoring system, and then the studies were reinterpreted while the gated images were viewed.**

Results. **In the total group of 285 patients, the number of "borderline" interpretations was reduced from 89 to 29. In the 137 patients with a ≤10% pretest likelihood of coronary artery disease, the addition of gated images added significantly to the percentage of interpretations that were designated "normal" (74% [101 of 137] vs. 93% [127 of 137], p < 0.0001), due to a reduction in borderline normal and borderline abnormal readings. In 49 patients with a previous infarction or recent angiography with ≥70% stenosis, or both, the addition of gated images changed the percentage of "abnormal" scan interpretations from 78% (38 of 49) to 92% (45 of 49). This result was not significant (p = 0.09, two-tailed), but the trend was toward a greater number of unequivocal abnormal interpretations in this subgroup.**

Conclusions. **The addition of electrocardiographically gated Tc-99m sestamibi SPECT images to the reading of stress and rest perfusion images alone resulted in shifting the final scan interpretations to a more normal designation in patients with a low pretest likelihood of coronary artery disease, and to more abnormal defects consistent with coronary artery disease in patients with known coronary artery disease. The number of "borderline normal" and "borderline abnormal" interpretations are significantly reduced when gated SPECT images are interpreted simultaneously with stress and rest perfusion images.**

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The addition of electrocardiographic (ECG) gating to technetium-99m (Tc-99m) sestamibi single-photon emission computed tomography (SPECT) perfusion imaging can provide additional and potentially useful information (1–17). This complementary information can be used to help evaluate the severity of transient regional ischemia and the extent of myocardial viability. Assessment of global function should be useful for determining prognosis and in differentiating ischemic from nonischemic cardiomyopathy.

Gated SPECT images can also assist in evaluating the significance of questionable perfusion defects (12). Attenuation artifacts are ubiquitous and problematic for Tc-99m as well as for thallium-201, particularly when persistent defects raise the question of myocardial scar versus artifact. The presence of corresponding normal or abnormal wall motion might resolve the question.

The purpose of this study was to determine how frequently and for what reasons the addition of gated images provided added value to nongated Tc-99m sestamibi SPECT myocardial perfusion images.

Methods

Patient selection. Two hundred eighty-five consecutive patients who underwent gated Tc-99m sestamibi SPECT perfusion imaging were studied. Of these, 212 underwent exercise stress, 63 underwent dipyridamole stress and the remaining 10 underwent dobutamine stress imaging. There were 143 women and 142 men with a mean age of 57.6 ± 11.5 years (range 32 to 87). Nine patients had chest pain with normal coronary angiograms; 97 had a ≤5% likelihood of coronary artery disease (18) and did not undergo coronary angiography; 31 had

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Abbreviations and Acronyms

ECG	=	electrocardiographic
SPECT	=	single-photon emission computed tomography (tomographic)
Tc-99m	=	technetium-99m

a >5% and ≤10% likelihood of coronary artery disease and did not undergo coronary angiography; 60 had a >10% likelihood of coronary artery disease without clinical evidence of disease and did not undergo coronary angiography; 37 had documented coronary artery disease with ≥50% stenosis on coronary angiography and no previous infarction; 34 had previous coronary artery bypass graft surgery or percutaneous transluminal coronary angioplasty; and the remaining 17 had a documented previous myocardial infarction.

Procedure. The scintigraphic methods have been described in detail by Smith et al. (19) and Calnon et al. (20). Briefly, gated images were acquired on a Picker Prism 3000 triple-headed gamma camera using a low energy, high resolution, parallel-hole collimator. Image resolution was 64 × 64 pixels. Sixty projection images were acquired using the step-and-shoot method, with 20 stops of 50 to 60 s each. An ECG R wave detector provided a gate to acquire 8 frames/cardiac cycle.

Three sets of SPECT slices representing summed, end-diastolic and end-systolic images were formed for computer display and also on film. The summed image set was normalized conventionally for comparison of stress and rest images. The gated images were all normalized to the region of highest activity on the end-systolic image set. The result of this (19,20) is that the partial volume effect causes the image intensity to change in response to changes in myocardial wall thickness when comparing end-systolic and end-diastolic frames. With this type of normalization, changes in regional wall thickness can be appreciated by noting increased image intensity in the end-systolic image compared with the same segment of the end-diastolic image. This technique has been validated by Calnon et al. (20).

Scintigraphic interpretation. All Tc-99m sestamibi SPECT studies were read in blinded manner by two observers (G.A.B., D.D.W.) to derive a consensus interpretation. Readers were given high quality, multiple planar projection images from which to judge attenuation artifacts. Gender could usually be inferred by the presence or absence of breast attenuation shadow. The readers were given no other information from which to determine the pretest probability of coronary artery disease. The conventional stress and rest perfusion tomographic images were interpreted first. After scoring of the perfusion images was completed, the gated end-systolic and end-diastolic images were interpreted and the segmental scoring was repeated to derive a final reading.

The myocardium was divided into 14 segments for analysis of both regional perfusion and function. The segments scored included the distal and proximal short-axis and the vertical long-axis tomographic views. The 14 segments on the stress and rest perfusion images were individually scored as either normal (which included easily recognized artifacts), borderline normal, borderline abnormal, abnormal with a moderate defect and abnormal with a severe defect. When compared with the rest tomograms, defects were further classified as partially or totally reversible or fixed. Categories for scoring segments on the gated tomograms were normal, hypokinesia, akinesia, dyskinesia and nonvisible. The "nonvisible" classification was used if a perfusion defect in the region was so severe that the residual tracer activity in that region was judged to be insufficient for adequate evaluation of wall motion. The same final overall interpretation procedure was repeated after the gated tomographic images were viewed. Then, the gated and nongated interpretations were compared to identify where the assessment of the gated tomogram altered the final interpretation of the study. For example, a segment could be scored as "borderline normal" after reviewing only the stress and rest perfusion tomogram, and as "normal" after viewing the gated tomographic images with the perfusion images.

Statistical methods. The Fisher exact test was used to test for the significance of differences in the number of successful test outcomes, using perfusion imaging alone and with the addition of function imaging. A successful test outcome was defined as being the expected result (i.e., a normal test for patients in the normal control group and an abnormal test for patients in the group with known coronary artery disease).

Results

The results of 106 patients with a ≤5% pretest likelihood of coronary artery disease are shown in Figure 1A. The addition of gated SPECT resulted in an increase in normal interpretations from 80 to 99 and a reduction in borderline abnormal interpretations from 6 to 2. Patients with a ≤10% pretest likelihood were also analyzed and considered as "normal." This was done because the classification of ≤5% excludes most men in a referred group. Extending the classification to ≤10% produces a more representative control group, without unreasonable contamination with patients having significant coronary artery disease. Of the larger group, there was only one patient with a perfusion defect that appeared typical of coronary artery disease. Including this as a "false positive" result had no significant effect on the statistical outcome.

The results from 137 patients with a ≤10% pretest likelihood of coronary artery disease are shown in Figure 1B. The addition of gated SPECT resulted in an increase in normal interpretations from 101 to 127 and reductions in borderline normal interpretations from 26 to 7 and borderline abnormal interpretations from 10 to 2. The number of abnormal interpretations only increased from 0 to 1 in this low likelihood group.

There were 49 patients with coronary artery stenosis ≥70% on angiography or a documented previous myocardial infarction, or both (Fig. 2). From perfusion studies alone, 38 of these were interpreted as abnormal, 9 as borderline and 1 as

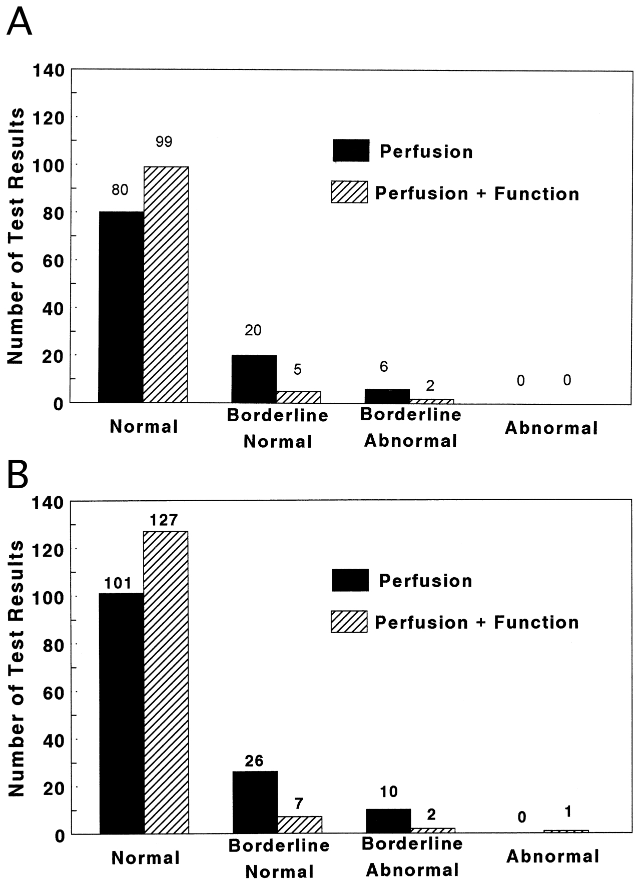


Figure 1. Number of various test results in 106 patients with a ≤5% (**A**) and 137 with a ≤10% (**B**) pretest likelihood of coronary artery disease (CAD) after interpretation of stress and rest Tc-99m sestamibi SPECT images alone **(solid bars)** and after repeat interpretation of perfusion images together with the end-diastolic and end-systolic gated images **(hatched bars)**. See text for definitions of test results.

definitely normal. When gating was added, the number of borderline interpretations was reduced from 9 to 3. There was one additional false negative result. Thus, five of the six reclassifications in this subgroup were correct, and one borderline normal interpretation by perfusion imaging was reclassified incorrectly to normal with the addition of gated images.

When all subsets are considered together (Fig. 3), 89 patients (31%) had borderline normal or borderline abnormal interpretations based on perfusion images alone. When the gated tomograms and stress and rest perfusion images were interpreted together, the number of these uncertain designations fell from 89 (32%) to 29 (10%) of the total group. This shift was not associated with an increase in the number of abnormal interpretations, consistent with coronary artery disease in patients with a <10% pretest likelihood of coronary artery disease, but it was associated with a greater number of such abnormal interpretations in patients with documented coronary artery disease. These shifts resulted in enhanced specificity of Tc-99m sestamibi for the detection of coronary artery disease, because more final normal readings ensued from interpretation of gated tomograms with perfusion images

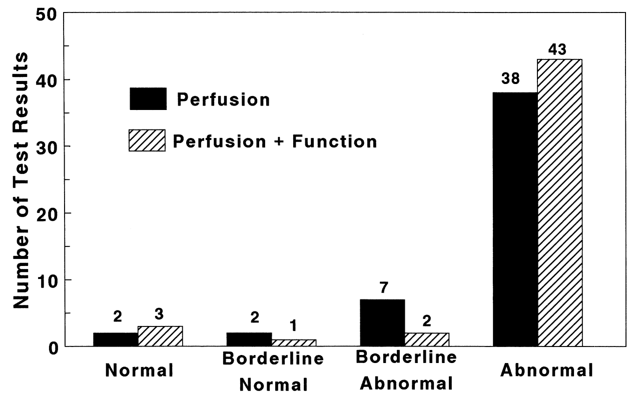
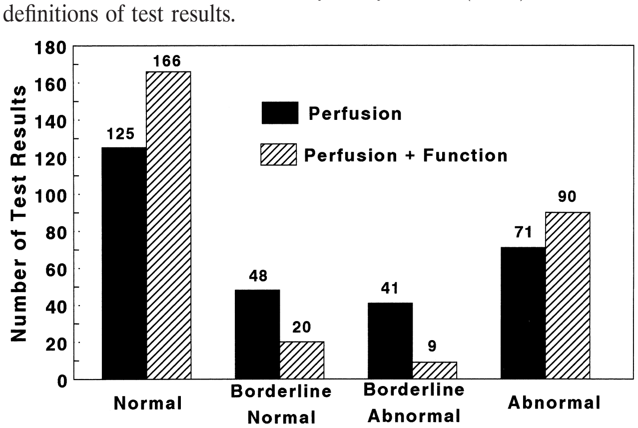


Figure 2. Number of various test results in 49 patients with known angiographic coronary artery disease (CAD) or a previous myocardial infarction (MI) after interpretation of stress and rest Tc-99m sestamibi SPECT images alone **(solid bars)** and after repeat interpretation of perfusion images together with the end-diastolic and end-systolic gated images **(hatched bars)**. See text for definitions of test results.

in patients with a ≤10% pretest likelihood of coronary artery disease and more abnormal final readings in patients with known coronary artery disease.

Figure 4 is a pie chart that summarizes the fraction of studies with unchanged overall readings and the reasons found for changing or adding to the interpretation of the perfusion images after reviewing the gated images. Gated images were judged to add significant information to about half (45%) of all the studies. Added value was indicated only if reviewing the gated images revealed additional information. For example, observing a wall motion defect in the segment of a large, fixed perfusion defect was not listed as adding significant information. The 22 segments in the "revealed wall motion abnormality" category were segments where the observation of a wall motion defect changed our interpretation of a (questionable) perfusion defect. The category "aided viability assessment" means, for example, that the finding of preserved wall motion in a region with a severe perfusion defect leads to the

Figure 3. Changes in test interpretations after interpretation of perfusion and function images **(hatched bars)** compared with stress and rest perfusion images alone **(solid bars)** for all 285 patients in the study referred for evaluation for coronary artery disease (CAD). See text for definitions of test results.



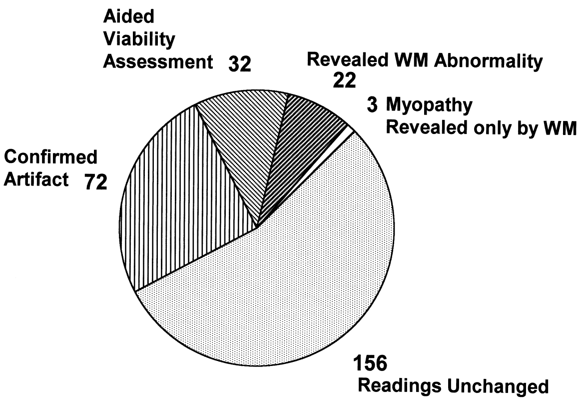


Figure 4. Gated SPECT in 285 patients. Summary of fraction of studies with unchanged overall readings when perfusion and function images were interpreted together and the reasons found for changing or adding to the interpretation of the perfusion images after reviewing the gated images. WM = wall motion.

implication that there was more residual myocardial viability than would have been judged solely from the perfusion images. Another example would be the absence of systolic thickening in a myocardial segment that had significant (>50%) tracer uptake. This would lead to a consideration of hibernating or stunned myocardium. Similarly, the indication of "myopathy" means that there were only three patients who could be identified only by reduced function but not identified by the typical pattern of dilated myopathy when reading the perfusion images.

Data analysis. The addition of segmental wall motion to perfusion images adds information not contained in the perfusion images alone. The question regarding the additional information is not whether it is "statistically significant" but whether it is clinically useful. The wall motion information is also used to assist in deciding if the perfusion images are normal or abnormal, which can be tested to see whether the addition of wall motion information increases the accuracy of this classification of the perfusion images.

If one considers the 106 patients with a ≤5% likelihood of coronary artery disease and uses "normal" as the only successful test outcome, then the addition of gated images adds significantly (75% vs. 93%, $p = 0.0005$). If one considers the more representative group of 137 patients with a ≤10% pretest likelihood of coronary artery disease to be "normal" and uses "normal" as the only successful test outcome, then the addition of gated images adds significantly (74% vs. 93%, $p < 0.0001$ by the Fisher exact test). For the low-likelihood group of patients, if one includes either "normal" or "borderline normal" as a successful outcome, then the differences are not significant. Specifically, for the ≤5% group we have 94% vs. 98%, $p = 0.28$, and for the ≤10% group we have 93% vs. 98%, $p = 0.08$. In either case, the addition of gating leads more frequently to altering the previous interpretation correctly than to altering it incorrectly, as judged from these subgroups in which "normal" could be expected as the correct interpretation.

There were 49 patients in this study with coronary artery stenoses ≥70% on angiography or with a documented previous myocardial infarction. This is the subgroup for which we can most confidently certify "abnormal" as the correct interpretation of the perfusion images. The interpretations with and without the addition of gating are shown for this subgroup in Figure 2. For this subgroup of 49 patients, if we consider "abnormal" as the only correct response, the sensitivity by perfusion imaging alone was 78% compared with 92% with the addition of gating. This result is not significant ($p = 0.09$, two-tailed). If we included "borderline abnormal" as a correct response, there was no difference.

As previously noted, this is a consecutive study of clinically referred patients. It is not designed to accurately indicate test sensitivity or specificity. The subgroup of 49 patients discussed in the previous paragraph was the group most likely to have an abnormal interpretation. If we exclude the patients with a previous myocardial infarction and use ≥70% for the angiographic classification of coronary artery disease, then sensitivity is 91% (29 of 32 patients), including borderline abnormal as being correct. If we exclude the patients with a previous myocardial infarction and use ≥50% for angiographic classification of coronary artery disease, then sensitivity is 86% (32 of 37 patients).

Thus, the addition of gated images leads to correctly interpreting significantly more normal scans and more abnormal scans without equivocation. Test specificity was increased by the addition of gated images, whereas sensitivity was not significantly changed.

Discussion

This study, which was undertaken in a sequential group of heterogeneous patients referred to the Nuclear Cardiology Laboratory for testing, showed that the addition of gated SPECT acquisition for the assessment of regional systolic function reduces the degree of uncertainty in the interpretation of stress and rest Tc-99m sestamibi SPECT perfusion studies. The number of "borderline normal" and "borderline abnormal" interpretations when perfusion images were read without the gated images were significantly reduced when the gated tomograms were interpreted simultaneously with perfusion images, yielding better separation of normal from abnormal studies for coronary artery disease detection. It should be pointed out that when artifacts (e.g., breast attenuation, diaphragmatic attenuation) were unequivocally identified on perfusion images, those studies were read as normal or borderline normal. The "borderline abnormal" designation was used only when the interpreters could not clearly identify that the defect was truly artifactual or that it was clearly characteristic of a moderate or severe, reversible or nonreversible defect attributable to coronary artery disease. As shown in Figures 1 to 3, the major advantage of gating is to shift the final scan interpretations to a more normal designation in patients with a low likelihood of coronary artery disease and to more abnormal defects consistent with known coronary artery disease.

In recent years, new Tc-99m-labeled perfusion agents have emerged for use with SPECT imaging for detecting coronary artery disease (21–27) and assessing prognosis (28–35). One of the major advantages of Tc-99m perfusion agents is the high count density, which permits the acquisition of gated tomograms synchronized to the ECG while sustaining adequate count density in individual cardiac frames. The ability to electrocardiographically gate Tc-99m sestamibi tomograms permits the simultaneous assessment of perfusion and regional systolic thickening. The method used in the present study was based on the observation that wall thickening is reflected by an increase in myocardial count density during systole. Regions showing Tc-99m sestamibi uptake and preserved systolic thickening are judged to represent viable myocardium. Regions that demonstrate a nonreversible reduction in Tc-99m sestamibi uptake on stress to rest images but normal systolic thickening on stress tomograms would provide evidence to the supposition that the mild, nonreversible defect in question was due to an attenuation artifact rather than scar. This is particularly the case when such a mild reduction in Tc-99m sestamibi uptake with preserved thickening is seen in the anterior wall in women or in the high posterobasal region in both men and women. Regions showing a persistent reduction in Tc-99m sestamibi uptake with absent systolic thickening would indicate a zone of irreversible myocardial injury or myocardial hibernation or stunning. These last two states are more likely to be associated with a mild to moderate reduction in tracer uptake in association with the absence of thickening.

Najm et al. (4) reported that the measurement of fractional shortening on the anterior Tc-99m sestamibi images derived from analysis of diastolic and systolic images correlated closely (r = 0.89) with echocardiographic fractional shortening. Tischler et al. (7) reported excellent intraobserver and intraobserver agreement for global and segmental Tc-99m sestamibi wall motion analysis. These investigators also showed excellent agreement with echocardiographic wall motion assessment. Chua et al. (6) also found that gated SPECT acquisition of stress-injected Tc-99m sestamibi correlated well with echocardiographic assessment of regional function (r = 0.96).

One significant feature of gated Tc-99m sestamibi SPECT is the ability to distinguish fixed myocardial defects due to infarction from fixed defects due to artifact. DePuey and Rozanski (12) performed gated stress Tc-99m sestamibi imaging in 551 consecutive patients referred for evaluation of coronary artery disease. In that study, in 96% of the fixed defects in patients with clinical documentation of infarction, regional function was abnormal, whereas in 77% of the fixed defects in patients without previous documented clinical infarction, regional function was normal. Because 91% of the fixed defects with normal systolic function occurred in either women with anterior fixed defects or men with inferior fixed defects, they were considered to be most likely due to attenuation artifacts. The data from the present study are consistent with the data of DePuey and Rozanski (12), in that assessment of the gated images resulted in a significant reduction in the number of borderline normal or questionable artifact interpretations. In the present study, a mild reduction in Tc-99m sestamibi activity associated with normal systolic thickening was interpreted in the final reading as a normal segment.

More recently, several groups of investigators have shown that the left ventricular ejection fraction can also be measured from gated Tc-99m sestamibi SPECT imaging (14–17). Some of these methods use automatic ejection fraction quantitation, whereas others require that the endocardial borders be manually traced by an observer. In all these studies, left ventricular ejection fraction calculated from gated Tc-99m sestamibi SPECT images correlate well with other techniques, such as radionuclide angiography and contrast ventriculography.

Thus, both regional and global function can be evaluated on the gated Tc-99m sestamibi tomograms, allowing for the simultaneous assessment of perfusion and function. Not only will this functional assessment enhance the sensitivity and specificity of gated Tc-99m sestamibi SPECT imaging for the detection of coronary artery disease, but it should also allow for the determination of viability in fixed defects and provide supplementary information for prognosis with measurement of the global left ventricular ejection fraction.

Study limitations. One of the limitations of the study is that not all patients underwent coronary angiography. Even among those who did, we have no absolute standard to determine the reserve capacity of individual coronary arteries or the contribution of collateral flow to regions supplied by arteries with anatomic obstruction. Because we do not know if an individual segment should or should not have a perfusion defect, we cannot determine with certainty if the classification or reclassification of an individual myocardial segment is correct. We can show that the addition of gated tomograms resulted in a greater number of "normal" classifications in the group of patients with a low likelihood of having significant coronary artery disease and a greater number of "abnormal" classifications within the group of patients with a high likelihood or with proven coronary artery disease. We therefore infer that the addition of wall motion information is more likely to lead us to a correct interpretation than to an incorrect interpretation.

Another limitation of the study was that no follow-up was performed to determine whether the patients who had final interpretations of normal or abnormal studies had different cardiac event rates. However, another study from our group did show that patients with a normal Tc-99m sestamibi SPECT perfusion scan had an excellent 1-year event-free survival rate (34). It would be expected that a similar low event rate would be the result in the patients in the present study, who were finally designated as having a normal or borderline normal perfusion scan.

Clinical implications. The major clinical implication of this study is that the addition of gated acquisition for exercise or pharmacologic stress Tc-99m sestamibi SPECT myocardial perfusion imaging should result in less uncertainty in interpreting studies that, on review of SPECT perfusion images alone, might yield interpretations designated as "borderline normal" or "borderline abnormal." This is because attenuation artifacts are more easily distinguished from myocardial scar in such patients.

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References

1. Mazullo P, Marcassa C, Sambuceti G, Parodi O, L'Abbate A. The clinical usefulness of electrocardiogram-gated Tc-99m methoxy-isobutyl-isonitrile images in the detection of basal wall motion abnormalities and reversibility of stress induced perfusion defects. Int J Card Imaging 1992;8:131–41.
2. Marcassa C, Marzullo P, Parodi O, Sambuceti G, L'Abbate A. A new method for noninvasive quantitation of segmental myocardial wall thickening using technetium-99m 2-methoxy-isobutyl-isonitrile scintigraphy—results in normal subjects. J Nucl Med 1990;31:173–7.
3. Villanueva-Meyer J, Mena I, Narahara KA. Simultaneous assessment of left ventricular wall motion and myocardial perfusion with technetium-99m-methoxy isobutyl isonitrile at stress and rest in patients with angina: comparison with thallium-201 SPECT. J Nucl Med 1990;31:457–63.
4. Najm YC, Timmis AD, Maisey MN, et al. The evaluation of ventricular function using gated myocardial imaging with Tc-99m MIBI. Eur Heart J 1989;10:142–8.
5. Mannting F, Morgan-Mannting MG. Gated SPECT with technetium-99m-sestamibi for assessment of myocardial perfusion abnormalities. J Nucl Med 1993;34:601–8.
6. Chua T, Kiat H, Germano G, et al. Gated technetium-99m sestamibi for simultaneous assessment of stress myocardial perfusion, postexercise regional ventricular function and myocardial viability: correlation with echocardiography and rest thallium-201 scintigraphy. J Am Coll Cardiol 1994;23:1107–14.
7. Tischler MD, Niggel JB, Battle RW, Fairbank JT, Brown KA. Validation of global and segmental left ventricular contractile function using gated planar technetium-99m sestamibi myocardial perfusion imaging. J Am Coll Cardiol 1994;23:141–5.
8. Nicolai E, Cuocolo A, Pace L, et al. Assessment of systolic wall thickening using technetium-99m methoxyisobutylisonitrile in patients with coronary artery disease: relation to thallium-201 scintigraphy with re-injection. Eur J Nucl Med 1995;22:1017–22.
9. Mazzanti M, Germano G, Kiat H, Friedman J, Berman DS. Fast technetium 99m–labeled sestamibi gated single-photon emission computed tomography for evaluation of myocardial function. J Nucl Cardiol 1996;3:143–9.
10. Christian TF, O'Connor MK, Glynn RB, Rogers PJ, Gibbons RJ. The influence of gating on measurements of myocardium at risk and infarct size during acute myocardial infarction by tomographic technetium 99m–labeled sestamibi imaging. J Nucl Cardiol 1995;2:207–16.
11. Berman DS, Germano G, Kiat H, Friedman J. Simultaneous perfusion/function imaging [editorial]. J Nucl Cardiol 1995;2:271–3.
12. DePuey EG, Rozanski A. Using gated technetium-99m-sestamibi SPECT to characterize fixed myocardial defects as infarct or artifact. J Nucl Med 1995;36:952–5.
13. Williams KA, Taillon LA. Reversible ischemia in severe stress technetium 99m–labeled sestamibi perfusion defects assessed from gated single-photon emission computed tomographic polar map Fourier analysis. J Nucl Cardiol 1995;2:199–206.
14. DePuey EG, Nichols K, Dobrinsky C. Left ventricular ejection fraction assessed from gated technetium-99m-sestamibi SPECT. J Nucl Med 1993;34:1871–6.
15. Germano G, Kiat H, Kavanagh PB, et al. Automatic quantification of ejection fraction from gated myocardial perfusion SPECT. J Nucl Med 1995;36:2138–47.
16. Williams KA, Taillon LA. Left ventricular function in patients with coronary artery disease assessed by gated tomographic myocardial perfusion images: comparison with assessment by contrast ventriculography and first-pass radionuclide angiography. J Am Coll Cardiol 1996;27:173–81.
17. Boonyaprapa S, Ekmahachai M, Thanachaikun N, Jaiprasert W, Sukthomya V, Poramatikul N. Measurement of left ventricular ejection fraction from gated technetium-99m sestamibi myocardial images. Eur J Nucl Med 1995;22:528–31.
18. Diamond GA, Forrester JS. Analysis of probability as an aid in the clinical diagnosis of coronary artery disease. N Engl J Med 1979;300:1350–8.
19. Smith WH, Kastner RJ, Calnon DA, Segalla D, Beller GA, Watson DD. Quantitative gated SPECT imaging: a counts-based method for display and measurement of regional and global ventricular systolic function. J Nucl Cardiol. In press.
20. Calnon DA, Kastner RJ, Smith WH, Segalla D, Beller GA, Watson DD. Validation of a counts-based method for quantitating left ventricular systolic function using gated tomographic technetium-99m sestamibi perfusion images: comparison to equilibrium radionuclide angiography. J Nucl Cardiol. In press.
21. Beller GA. Clinical Nuclear Cardiology. Philadelphia: WB Saunders, 1995: 82–136.
22. Berman DS, Kiat HS, Van Train KF, Germano G, Maddahi J, Friedman JD. Myocardial perfusion imaging with technetium-99m-sestamibi: comparative analysis of available imaging protocols. J Nucl Med 1994;35:681–8.
23. Watson DD, Smith WH, Beller GA, Vinson EL, Taillefer R. Blinded evaluation of planar technetium-99m-sestamibi myocardial perfusion studies. 1992;33:668–75.
24. Berman DS, Kiat H, Friedman JD, et al. Separate acquisition rest thallium-201/stress technetium-99m sestamibi dual-isotope myocardial perfusion single-photon emission computed tomography: a clinical validation study. J Am Coll Cardiol 1993;22:1455–64.
25. Zaret BL, Wackers FJ. Nuclear cardiology [Part 1]. N Engl J Med 1993;329: 775–83.
26. Udelson JE. Choosing a thallium-201 or technetium 99m sestamibi imaging protocol. J Nucl Cardiol 1994;1:S99–S108.
27. Van Train KF, Garcia EV, Maddahi J, et al. Multicenter trial validation for quantitative analysis of same-day rest-stress technetium-99m-sestamibi myocardial tomograms. J Nucl Med 1994;35:609–18.
28. Stratmann HG, Williams GA, Wittry MD, Chaitman BR, Miller DD. Exercise technetium-99m sestamibi tomography for cardiac risk stratification of patients with stable chest pain. Circulation 1994;89:615–22.
29. Brown KA, Altland E, Rowen M. Prognostic value of normal technetium-99m sestamibi cardiac imaging. J Nucl Med 1994;35:554–7.
30. Raiker K, Sinusas AJ, Wackers FJ, Zaret BL. One-year prognosis of patients with normal planar or single-photon emission computed tomographic technetium-99m–labeled sestamibi exercise imaging. J Nucl Cardiol 1994;1:449–56.
31. Berman DS, Hachamovitch R, Kiat H, et al. Incremental value of prognostic testing in patients with known or suspected ischemic heart disease: a basis for optimal utilization of exercise technetium-99m sestamibi myocardial perfusion single-photon emission computed tomography. J Am Coll Cardiol 1995;26:639–47.
32. Hachamovitch R, Berman DS, Kiat H, et al. Exercise myocardial perfusion SPECT in patients without known coronary artery disease: incremental prognostic value and use in risk stratification. Circulation 1996;93:905–14.
33. Hachamovitch R, Berman DS, Kiat H, et al. Effective risk stratification using exercise myocardial perfusion SPECT in women: gender-related differences in prognostic nuclear testing. J Am Coll Cardiol 1996;28:34–44.
34. Boyne TS, Koplan BA, Parsons WJ, Smith WH, Watson DD, Beller GA. Predicting adverse outcome with exercise SPECT technetium-99m sestamibi imaging in patients with suspected or known coronary artery disease. Am J Cardiol 1997;79:270–4.
35. Geleijnse ML, Elhendy A, van Domburg RT, et al. Prognostic value of dobutamine-atropine stress technetium-99m sestamibi perfusion scintigraphy in patients with chest pain. J Am Coll Cardiol 1996;28:447–54.