

Clinical Comparison of Circular versus Noncircular Acquisition Using Technetium-99m Myocardial Perfusion SPECT Imaging

Michael P. White, April Russell, Victor A. Mascitelli, Robert S. Morris, Adel R. Shehata and Gary V. Heller

Nuclear Cardiology Laboratory, Division of Cardiology, Hartford Hospital, Hartford; and University of Connecticut School of Medicine, Farmington, Connecticut

The optimal orbit for myocardial SPECT imaging has not yet been determined. In order to evaluate differences in image quality and reader interpretation between orbiting methods, 50 patients scheduled for routine stress/rest ^{99m}Tc -sestamibi imaging had both a circular and a noncircular study using an ADAC Vertex dual-head imaging system.

Methods: Each study was acquired using a 64×64 matrix, 64 stops at 25 sec per stop. Images were processed using a Butterworth filter with a frequency cutoff of 0.6 and an order of 5.0. Studies were interpreted by three experienced readers without knowledge of patient name or orbiting technique for normal and abnormal segments and overall image quality.

Results: There was no significant difference in the semi-quantitative assessment of either defect extent or reversibility or in the quantitative assessment of defect size between the two types of orbits. However, while all 50 noncircular studies were read as good or fair quality, 23 circular studies were read as fair or poor ($p = < 0.0002$).

Conclusion: Qualitative and quantitative analysis revealed similar size and extent of perfusion defects using either circular or noncircular orbit, but images with the noncircular orbit were of significantly better image quality and may be preferable to a circular orbit with ^{99m}Tc -sestamibi.

Key Words: myocardial SPECT imaging; technetium-99m-sestamibi; circular versus noncircular acquisition

J Nucl Med Technol 1997; 25:37-40

SPECT imaging is well established in nuclear cardiology for evaluating the presence and extent of coronary artery disease. Approximately 80% of all myocardial perfusion scans are now obtained using this technique (1). SPECT imaging has been associated with improved detection of coronary disease and with better localization of culprit vascular territories (2,3). However, in parallel with these advances, specificity has de-

creased due to a greater propensity for artifact than with planar imaging (4).

Artifacts associated with tomographic imaging have several possible sources, including soft tissue attenuation, patient motion and instrumentation (5,6). In attempts to eliminate or reduce artifacts, imaging parameters in which the camera head is contoured closer to the body than with standard circular orbits have been proposed. Unfortunately, with ^{201}Tl , more artifacts have been reported to be created by body contour orbits than with conventional orbiting. These artifacts typically include apical defects in the anteroseptal and inferoseptal regions. These defects are thought to be related to varying spatial resolution with varying distance from the heart throughout the study (7,8).

Recently, several ^{99m}Tc -labeled myocardial perfusion imaging agents have been approved for clinical use (9,10). Technetium-based agents have higher photon energies and shorter half-lives than ^{201}Tl (11,12). These characteristics have resulted in improved count statistics, better target-to-organ ratios and reduced artifacts with routine circular imaging, and may be advantageous if used with other orbiting techniques. However, the impact of using a noncircular orbit with technetium-labeled imaging agents has not yet been evaluated. Therefore, the purpose of this study was to compare the effects of circular versus noncircular acquisition on the image quality and clinical interpretation of myocardial perfusion imaging studies using stress ^{99m}Tc -sestamibi SPECT.

MATERIALS AND METHODS

Study Design

Patients referred for routine stress/rest myocardial perfusion imaging and able to tolerate two separate acquisitions were prospectively enrolled. All patients underwent standard exercise or pharmacologic stress and rest testing followed by ^{99m}Tc -sestamibi SPECT imaging using both circular and noncircular orbits in a randomized order. All images were evaluated for overall quality and clinical interpretation.

For correspondence or reprints contact: Michael P. White, CNMT, Hartford Hospital, Nuclear Cardiology Laboratory, 80 Seymour St., Hartford, CT 06102.

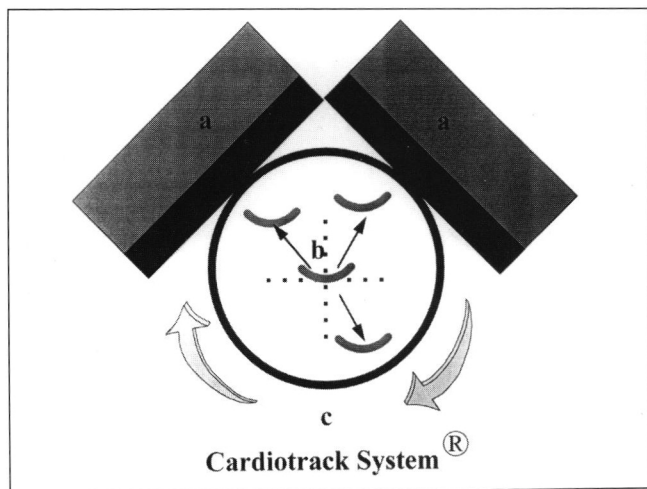


FIGURE 1. Description of cardi-track system. (A) Camera detectors are fixed at 90° angle, while the (B) palette or table tracks the patient's motion for both circular and noncircular orbits in both x and y translations. (C) The zoom is coordinated with the gantry motion.

Stress Protocols

A total of 50 patients were enrolled in the study. Forty-one patients underwent standard exercise testing and nine pharmacologic stress (seven dipyridamole, two dobutamine). Technetium-99m-sestamibi was injected at peak stress (symptom limited for treadmill exercise patients, at 8 min after the infusion of dipyridamole, and either at 14 min from the start of the dobutamine infusion or as the patient became symptomatic or demonstrated evidence of ischemia). For patients undergoing a one-day study, 10.2 ± 0.6 mCi of ^{99m}Tc -sestamibi was injected for the initial imaging (either stress or rest) followed by a second injection at least 3 hr later of 30.4 ± 0.9 mCi ^{99m}Tc -sestamibi for the corresponding image set. Patients undergoing a separate day protocol were injected with 24.7 ± 3.3 mCi on each of the 2 days. Image acquisition for either the rest or pharmacologic stress began 50–90 min postinjection while treadmill exercise patients were imaged approximately 20–45 min postinjection.

Image Acquisition and Processing Parameters

An ADAC Vertex dual-head camera equipped with long-bore, high-resolution collimators with heads locked in the 90° position was used for this study. For noncircular orbits, the patient was positioned as close as possible to both heads with a computer-derived contoured orbit based on the points selected by the operator. For circular orbits the patient's body was centered in the field of view of each camera head. Specific to this equipment is the Cardi-track® system (ADAC Laboratories, Milpitas, CA) (Fig. 1) This system tracks the motion of the patient in both the x and y translation with the zoom coordinated to the gantry motion to allow optimal small organ magnification and prevent truncation.

Images were acquired using a 64×64 matrix, in a 180° arc from right anterior oblique to left posterior oblique, 64 frames at 25 sec per stop for the 2-day studies. For the same day

protocols, 40 sec per stop was used for the low-dose acquisition and 25 sec per stop for the subsequent study. Processing was performed using a Butterworth filter with a frequency cutoff of 0.6 and an order of 5 for the high-dose studies, and 0.5 and 10, respectively, for the low-dose studies.

Image Interpretation

Images were interpreted by three experienced nuclear cardiologists without knowledge of patient identity, stress protocol or orbit type. A 17-segment scoring method was used, analyzing short-axis and vertical long-axis slices. Each of the 17 segments was scored from 0–4 (0 = normal, 1 = mildly reduced activity, 2 = moderate reduction, 3 = severe reduction and 4 = absent photon activity). Analysis included overall image quality as well as defect extent, location and reversibility. Agreement was by consensus. Image quality was then evaluated and defined as good, fair or poor quality. In addition, CEQUAL® analysis was applied separately to all studies for a quantitative assessment of defect presence, location and size (13).

Statistics

Regression analysis was performed on each of the datasets representing percent defect extent and percent reversibility from the CEQUAL analysis and the total number of abnormal segments from the segmental analysis. The reversibility score represents the difference between the stress defect score and the resting defect score. Differences in scan quality were assessed by a nonparametric analysis. A p-value of <0.05 was established for significance.

RESULTS

Patient Demographics

Demographic information for the 50 patients undergoing circular and noncircular orbit is summarized in Table 1. These demographics suggest that patients were representative of a general population presenting for myocardial perfusion studies.

Image Quality

Image quality assessment is summarized in Figure 2. Both circular and noncircular orbits provided a high percentage of good quality images: 52% for circular and 76% for noncircular. Ten percent of the circular orbit studies were rated as poor quality, while none of the noncircular orbit studies were rated below fair ($p = <0.0002$). An example of differences in image quality is shown in Figure 3. The noncircular orbiting method shown in the upper portion of the figure demonstrates better image quality than the circular method, shown at the bottom.

Qualitative Results

The results from the qualitative interpretation are shown in Figure 4. Using the 17-segment scoring system, a good correlation between circular and noncircular orbit was noted for both defect extent and percent reversibility (r-value of 0.927 and 0.922) with no statistically significant difference between the two orbiting methods.

TABLE 1
Patient Demographics

	Total (n = 50)	Exercise (n = 41)	Pharmacologic (n = 9)	
			Dipyridamole	Dobutamine
Male	36 (72%)	30 (60%)	4 (8%)	2 (4%)
Female	14 (28%)	11 (22%)	3 (6%)	0
Age (yr)	55 ± 13	54 ± 14.6	68 ± 8.2	61 ± 7.1
Height (in.)	67 ± 3.1	66.8 ± 3.2	68.6 ± 3.7	70 ± 2.8
Weight (lb)	184.6 ± 42.7	185.8 ± 45.4	179.4 ± 21.2	169 ± 43.8
Hypertension	26 (48%)	22 (40%)	2 (4%)	2 (4%)
Hypercholesterolemia	23 (46%)	21 (42%)	2 (4%)	0
Diabetes	15 (30%)	13 (26%)	2 (4%)	0
Prior MI	9 (18%)	5 (10%)	4 (8%)	0
Prior PTCA	14 (28%)	10 (20%)	3 (6%)	1 (2%)
Prior CABG	8 (16%)	6 (12%)	2 (4%)	0

MI = myocardial infarction; PTCA = percutaneous transluminal coronary angioplasty; CABG = coronary artery bypass graft.

Quantitative Results

The results for the quantitative analysis are summarized in Figure 5. Quantitative analysis demonstrated an excellent concordance between circular and noncircular orbiting. There was an excellent correlation between methods for both defect extent ($r = 0.923$, $p = ns$) and percent reversibility ($r = 0.927$, $p = ns$).

DISCUSSION

To evaluate differences in imaging characteristics between circular and noncircular orbiting, 50 patients underwent both techniques. Qualitative and quantitative analysis revealed similar defect location and size, but acquisitions that used a noncircular orbit demonstrated consistently better image quality. These findings suggest noncircular orbiting may be preferable to circular orbiting when using ^{99m}Tc -sestamibi.

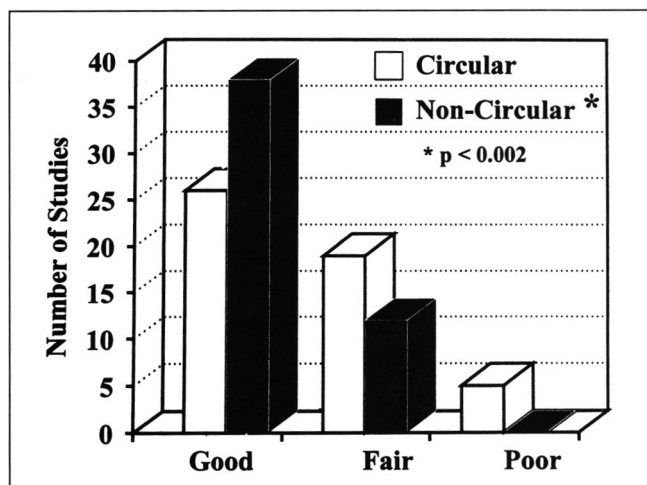


FIGURE 2. Evaluation of image quality using consensus reading without knowledge of patient or orbiting technique. Noncircular image acquisition provided better quality images than circular acquisitions.

Literature Comparison

Theoretically, the noncircular or elliptical orbit should offer better quality images due to the close proximity of the camera detectors to the patient's chest wall, giving increased count statistics and improved spatial resolution (14). However, phantom studies with ^{201}Tl reported that noncircular orbiting resulted in imaging artifacts that were not present with the circular orbit. Since those studies were reported, the technology of noncircular orbiting has improved and technetium-based imaging products are now available.

The goal of this study was to test these methods in a clinical setting using the most up-to-date instrumentation and software along with a technetium-based myocardial perfusion imaging agent (^{99m}Tc -sestamibi). Our results confirm that, using newer instrumentation and a technetium imaging agent, image quality is improved with a noncircular orbiting. Our data are consistent with a preliminary study by VanTrain et al. (15).

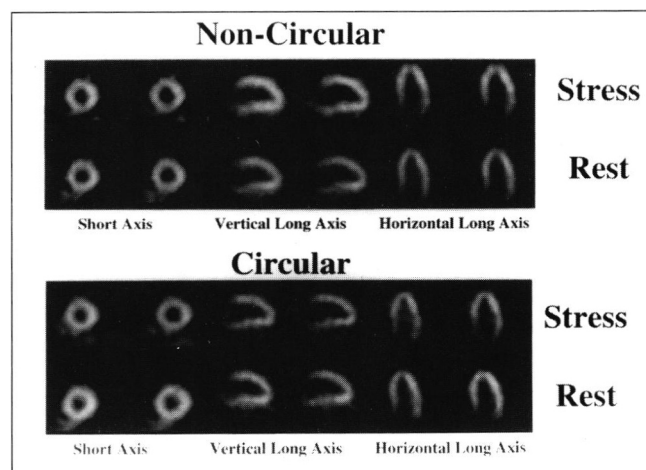


FIGURE 3. Example of a normal study from the same patient using noncircular (top) and circular (bottom) orbits. Improved image quality was noted when a noncircular orbit was used.

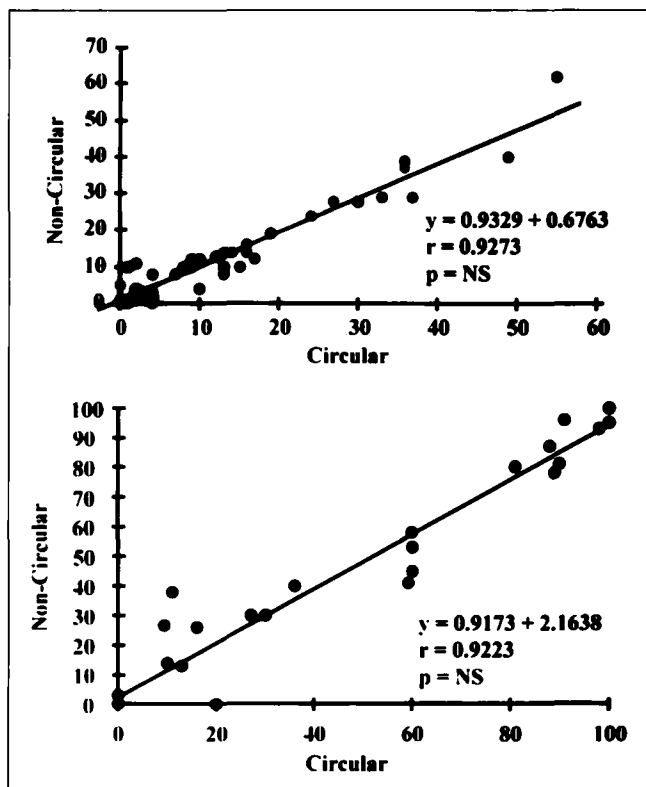


FIGURE 4. Qualitative analysis of defect extent by consensus reading using the 17-segment scoring system. The top graph shows the defect extent for the circular and noncircular orbits expressed as a percentage, while the bottom graph shows the percent reversibility for the same image sets.

Limitations

Orbit-related artifacts are not seen in all patients and such artifacts may be overwhelmed in patients with true perfusion abnormalities. Thus, a larger number of patients with a lower likelihood of coronary artery disease may be necessary to determine the true extent of potential artifact produced by noncircular orbiting. However, the subjects enrolled in the

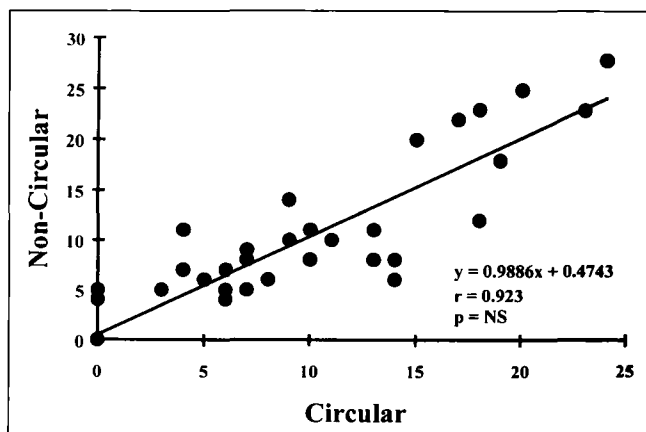


FIGURE 5. Quantitative analysis of the circular and noncircular data using the CEQUAL program to evaluate defect extent.

study were selected on a random basis, and the primary focus of the study was to compare the overall image quality and clinical interpretation rather than to assess artifact. To demonstrate changes in the sensitivity or specificity of this method, however, is beyond the scope of this project and would require considerably more patients for comparison.

Clinical Relevance

This study demonstrates improved image quality of using a noncircular orbit over a circular orbit in the same patients using ^{99m}Tc -sestamibi in a clinical setting. The improved image quality suggests that this technique could lead to improved diagnostic accuracy by providing a better image to interpret. Results from this study suggest that use of a noncircular orbiting may be the preferred technique in routine practice.

ACKNOWLEDGMENTS

We thank Chris Schumann, Horace Hines and ADAC Laboratories for their technical assistance on this project. This study was presented in part at the 42nd Annual Meeting of the Society of Nuclear Medicine, Minneapolis, MN, June 1995.

REFERENCES

- DePuey EG, Berman DS, Garcia EV, eds. *Cardiac SPECT imaging*. New York: Raven Press; 1995:xi.
- Maddahi J, Kiat H, Van Train KF, et al. Myocardial perfusion imaging with technetium-99m-sestamibi SPECT in the evaluation of coronary artery disease. *Am J Cardiol* 1990;55E-62E.
- Kiat H, Berman DS, Maddahi J. Comparison of planar and tomographic exercise thallium-201 imaging methods for the evaluation of coronary artery disease. *J Am Coll Cardiol* 1989;13:613-616.
- Smith WH, Watson DD. Technical aspects of myocardial planar imaging with technetium-99m-sestamibi. *Am J Cardiol* 1990;66:16E-22E.
- DePuey EG. How to detect, avoid myocardial perfusion SPECT artifacts. *J Nucl Med* 1994;35:699-702.
- DePuey EG. Artifacts in SPECT myocardial perfusion imaging. In: DePuey EG, Berman DS, Garcia EV, eds. *Cardiac SPECT imaging*. New York: Raven Press; 1995:169-200.
- Maniowski PJ, Morgan HT, Wackers FJ. Orbit-related variation in spatial resolution as a source of artifactual defects in thallium-201 SPECT. *J Nucl Med* 1991;32:871-875.
- Keyes JW Jr. SPECT and artifacts—in search of the imaginary lesion. *J Nucl Med* 1991;32:875-877.
- Berman DS, Kiat H, Maddahi J. The new ^{99m}Tc myocardial perfusion imaging agents: ^{99m}Tc -sestamibi and ^{99m}Tc -teboroxime. *Circulation* 1991;84(suppl 3):I7-I21.
- Johnson LL, Seldin DW. Clinical experience with technetium-99m-teboroxime: a neutral, lipophilic myocardial perfusion imaging agent. *Am J Cardiol* 1990;63E-67E.
- Garcia EV, Cooke CD, VanTrain KF, et al. Technical aspects of myocardial SPECT imaging with technetium-99m-sestamibi. *Am J Cardiol* 1990;66:23E-31E.
- Kiat H, Maddahi J, Roy LT, et al. Comparison for technetium-99m-methoxyisobutylisonitrile and thallium-201 for evaluation of coronary artery disease by planar and tomographic methods. *Am Heart J* 1989;117:1-11.
- VanTrain 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;35:609-618.
- Kojima A, Matsumoto M, Takahashi M, et al. Effect of spatial resolution on SPECT quantification values. *J Nucl Med* 1989;30:508-514.
- VanTrain KF, Siligan G, Germano G, et al. Noncircular versus circular orbits in quantitative analysis of myocardial perfusion SPECT [Abstract]. *J Nucl Med* 1995;36:46P.