Comparative Study of Thallium Emission Myocardial Tomography with 180° and 360° Data Collection

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Basic and clinical evaluation of thallium single-photon emission computed tomography (SPECT) using a rotating gamma camera with 180° (LPO to RAO) data collection was carried out and compared with the full 360° rotation. No attenuation correction was used. In a phantom study the reconstructed image from the 180° scan revealed better resolution. Although the 180° scan, when compared with the 360° scan, showed great photon attenuation in the deep location of a line source in water, this problem was not significant in the clinical study of six normal hearts. In 11 cases with myocardial infarction, the perfusion defect was more clearly visualized in the 180° scan. The defect-to-normal (D/N) wall-count ratio was lower in the 180° scan (0.48 ± 0.16; mean ± s.d.) than in the 360° scan (0.61 ± 0.15, $p < 0.05$), indicating superior lesion contrast in the former. These results suggest that for myocardial SPECT the 180° collection method is a more effective technique in the clinical evaluation of coronary artery disease.

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Single-photon emission computed tomography (SPECT), which was first introduced by Kuhl et al. (*1*), has developed rapidly in recent years (*2–5*). We and other investigators reported the clinical usefulness of thallium-201 myocardial SPECT using a rotating gamma camera (*6–10*). However, the long acquisition time and great attenuation through the body due to the low energy and poor count density of Tl-201 are some of the limitations of myocardial SPECT. For these reasons, a 180° data-collection procedure, omitting acquisition from the posterior half of the myocardium, was attempted by us and others in search of improvement (*6,9,10*). In the 180° scan, photon attenuation might become prominent for the deeper structures. To assess this factor, we measured the counts in the posterior- and anterior-wall segments of myocardium reconstructed from both 180° and 360° scans. This paper describes a comparative evaluation of 180° (RAO to LPO) versus 360° data collection regarding spatial resolution, lesion contrast, and photon attenuation in a phantom as well as in a clinical study.

MATERIALS AND METHODS

Imaging system. A large-field-of-view gamma camera with a high-resolution parallel-hole collimator supported by a gantry, revolves through 180° or the full 360° around the long axis of a patient. Sixty-four different views over 360°, or 32 views over 180° , 20 sec each, provide sampling for every 5.8° of revolution of the detector. Total acquisition time was 22 min for the 360° mode and 11 min for the 180° mode. In the latter, data collection started from the left posterior oblique (LPO) view and ended at the right anterior oblique (RAO), so that only the data from anterior half of the myocardium were utilized for SPECT. Consequently, fewer recorded counts were available for reconstruction in this mode.

Transaxial tomograms were reconstructed by a filtered back-projection method with Chesler's filter (*11*)

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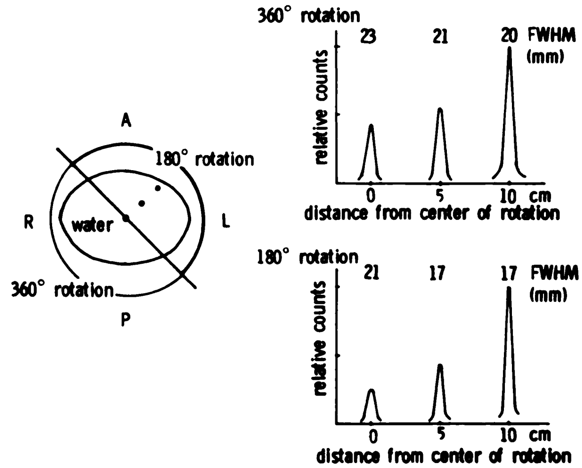

FIG. 1. Thallium-201 line-source response functions obtained along the long axis of a 30 × 20 cm ellipse in water (shown schematically at left) by the 180° and 360° modes. Attenuation is prominent in water, especially with 180° method (right). Spatial resolution, as judged by FWHM, is better for 180° method than for 360°.

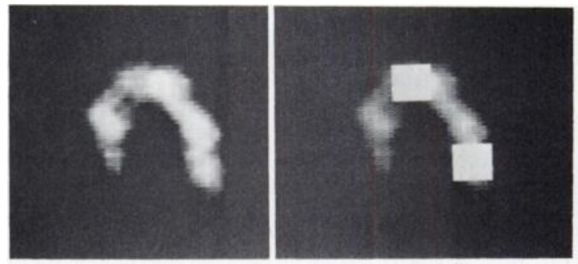

FIG. 2. (a) Transaxial tomogram from normal person. (b) Posterior and apical regions of interest used to calculate P/A ratio.

using a convolution reconstruction algorithm (*6,12*). No attenuation correction was used. Each transaxial tomogram was displayed perpendicular to the long axis of the left ventricle. Thereafter, frontal and sagittal tomograms were reorganized from a series of transaxial tomograms, so that the frontal and sagittal tomograms closely correspond to transverse and longitudinal sections in relation to cardiac axis (*6*). The reconstructed images were displayed in a 64 × 64 matrix.

Resolution and photon attenuation. To determine the spatial resolution and photon attenuation of the 180° and 360° modes of revolution of our imaging system, line-source response functions (*2*) were obtained from a water phantom imitating the chest: 40 cm long and elliptical in cross section, with major and minor axes of 30 and 20 cm. Three Tl-201 line sources, 10 cm long, were placed in the phantom, oriented parallel to the 40-cm axis: one at the center of the ellipse, the second displaced 5 cm from it as if toward a 45° LAO detector, and the third similarly displaced 10 cm (Fig. 1). The degree of attenuation by the water was assessed from the peak heights of the line-spread functions as registered in the 180° and 360° modes of revolution.

Cardiac phantom study. A cone-shaped double-walled cardiac phantom was constructed of plastic. A transmural defect was imitated by placing a cylindrical plastic plug, 2 cm in diam by 1 cm high, between the anterior walls of the phantom. Elsewhere the "cardiac wall" contained 200 μCi of Tl-201 dissolved in 200 cc of water. This cardiac model was placed in the chest phantom, pointing 45° to the left and 30° toward the "feet" (*6*). Thallium-201 background activity was added to the tank until a myocardium-to-background ratio of 2:1 was obtained by planar imaging (*13*). SPECT was performed with 180° and 360° revolutions around the water tank, and the perfusion defects in the two tomographic sections were compared.

Clinical study. With the same 180° and 360° collection modes, we studied six subjects with no clinical evidence of coronary artery disease, and 11 patients who had had myocardial infarctions within 4 wk to 2 yr, as confirmed by electrocardiogram and serum enzyme tests. Two millicuries of thallium were injected intravenously at rest 10–30 min before the imaging. All tomographic images, with 10–20% background subtraction, were interpreted by two independent observers.

To examine the attenuation through the human thorax, differences in attenuation between the superficial (apical) and deep (posterior) areas in the myocardium were assessed. The posterior-to-apical wall-count ratio (P/A ratio) was calculated in six normal subjects by flagging 3 × 3 pixel regions of interest (ROIs) at the center of the posterolateral and apical regions of transaxial tomograms in both techniques (Fig. 2). To obtain a quantitative comparison of lesion contrast, the defect-to-normal wall-count ratio (D/N ratio) was calculted at the transaxial plane in six patients with anterior-wall myocardial infarction and at the frontal plane in five patients with inferoposterior wall infarction. 3 × 3-pixel ROIs were flagged at the center of each perfusion defect and in the adjacent normal wall.

RESULTS

Figure 1 shows the results of resolution measurements, reported as FWHM for the line-source response functions in water, and the relative counts of the line source in the reconstructed images. Resolution was better in the 180° scan than in the 360° scan. In the measurement in water, the effect of attenuation was found to be greater in the 180° scan.

Spatial resolution of the imaging system was studied in the cardiac phantom in thallium-containing water with the 2-cm-diameter transmural perfusion defect in the anterior wall. SPECT was performed with 180° and 360° scans and sections showing the defect in each plane

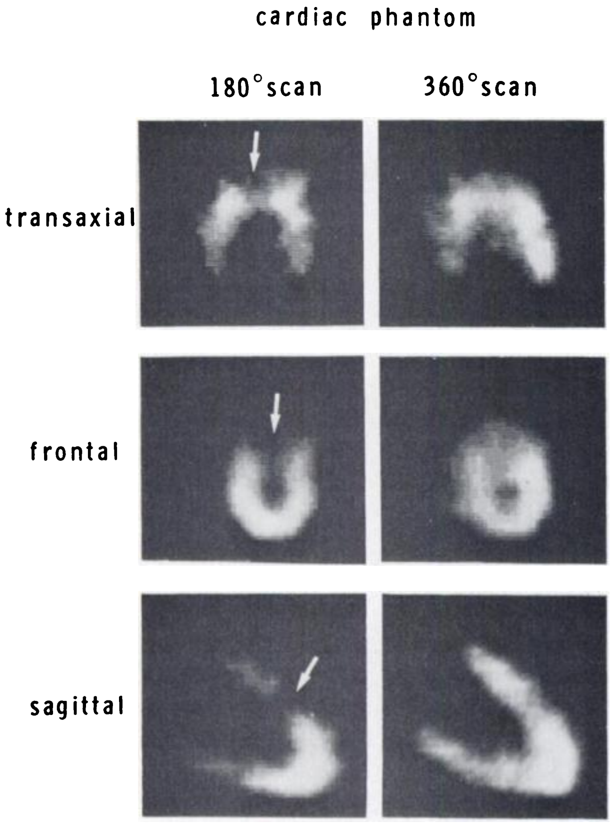

FIG. 3. Reconstructed images of cardiac phantom in water tank with transmural defect 2 cm in diameter in anterior wall, made with 360° and 180° data collection. Defect is seen better with 180° method (arrows).

were displayed (Fig. 3). Myocardial sections reconstructed from the 360° scan were slightly thicker than those from the 180° scan, probably due to poorer spatial resolution in the former. Although more photon attenuation was observed in the deep region in the 180° scan, the perfusion defect is better demonstrated in the 180° scan than in the 360°.

Table 1 summarizes the P/A ratios calculated from the counts in transaxial tomograms of six normal hearts taken in both modes. Although the P/A ratio was slightly lower in the 180° scan, no significant difference was observed. Thus, the 180° scan revealed no greater photon attenuation than the 360° scan when applied to human myocardial imaging.

Figure 4 shows the SPECT images of a normal heart reconstructed from the 180° and 360° scans. A homogeneous thallium distribution in the left-ventricular myocardium can be seen with both scans, but the 180° scan shows better image contrast with less background noise than does the 360° scan.

SPECT images from a patient with posterolateral myocardial infarction are shown in Fig. 5. The sections that showed the defect best were selected in each plane. The perfusion defect, although situated posteriorly, was detected in the transaxial and the frontal sections more clearly with the 180° scan.

TABLE 1. POSTERIOR-TO-APICAL WALL-COUNT RATIOS IN TRANSAXIAL TOMOGRAMS OF SIX NORMAL HEARTS (180° VS. 360° DATA COLLECTION)

Case no.	180° scan	360° scan
1	0.83	0.81
2	0.86	0.92
3	0.92	1.01
4	0.98	1.02
5	0.87	0.86
6	0.94	0.98
mean ± s.d.	0.90 ± 0.05	0.93 ± 0.08
		(N.S.)

In all of our 11 cases with myocardial infarction, the perfusion defects were noted in areas corresponding to the location of the infarct in either scan. But as shown in Table 2, the D/N ratio in each case was lower for the 180° scan (0.48 ± 0.16; mean s.d.) than for the 360° scan (0.61 ± 0.15, $p < 0.05$), indicating a significant difference in the lesion contrast between the two modes.

DISCUSSION

In a previous paper, using 360° sampling and attenuation correction by Sorenson's method (*14*), we reported that myocardial SPECT provided better clinical efficacy than planar imaging in the assessment of coronary artery disease (*6*). In an effort to improve myocardial SPECT further, a previously proposed (*6,9,10*) 180° (LPO to RAO) data-collection method is evaluated in this paper in comparison with the full 360° method.

The myocardium is situated close to the left anterior wall of the thorax, so that posterior images of the heart suffer significantly from the effects of attenuation and loss of spatial resolution due to lung tissue, vertebral bone, and the supporting bed. Because of attenuation and scattering, therefore, such posterior images should contain much less myocardial information, and more noise, than the anterior images—especially with low-energy tracers like thallium-201.

In our basic study of line-source response functions, better spatial resolution was obtained with the 180° scan than with the 360°. Consequently, the myocardial wall was thicker in the 360° scan. In the clinical study of myocardial infarction with 180° scan, a significantly lower D/N ratio was well demonstrated. These results are considered to be due to lower background noise because of minor attenuation and scattering in the case of 180° (LPO to RAO) revolution.

TABLE 2. DEFECT-TO-NORMAL WALL-COUNT RATIOS CALCULATED IN THE TRANSAXIAL (T) OR A FRONTAL (F) PLANE IN 11 PATIENTS WITH PRIOR MYOCARDIAL INFARCTION (180° VS. 360° DATA COLLECTION)

Case no.	Location of defect	180° scan	360° scan	(Plane)
1	apical	0.48	0.67	(T)
2	apical	0.48	0.72	(T)
3	septal	0.58	0.64	(T)
4	septal	0.50	0.63	(T)
5	anterior	0.22	0.38	(T)
6	anterior	0.15	0.32	(T)
7	inferior	0.44	0.49	(F)
8	inferior	0.50	0.66	(F)
9	lateral	0.56	0.69	(F)
10	posterolateral	0.70	0.75	(F)
11	posterolateral	0.72	0.81	(F)
mean ± s.d.		0.48 ± 0.16	0.61 ± 0.15	
			($p < 0.05$)	

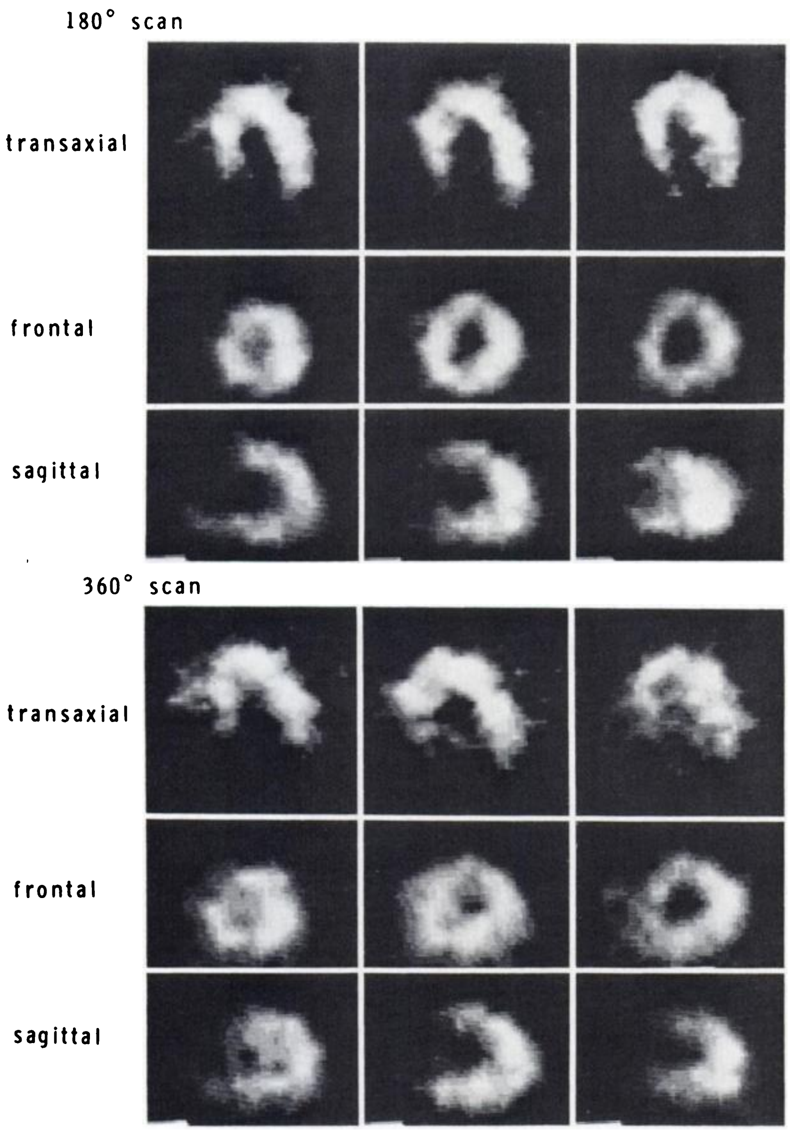

FIG. 4. Thallium myocardial SPECT images of normal person, reconstructed from (a) 180° and (b) 360° data-collection methods. Note lower background noise in 180° SPECT images.

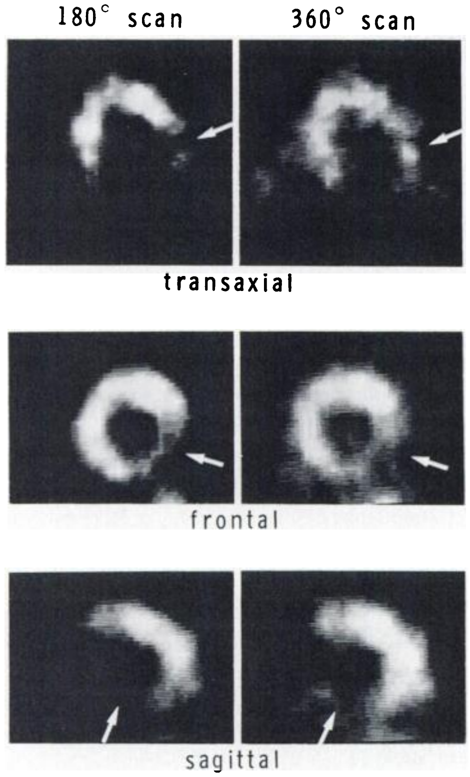

FIG. 5. Thallium myocardial SPECT images from patient with posterior-wall infarction. Perfusion defect in posterolateral wall is visualized more clearly, and with less background noise, in images made by 180° scan (arrows).

In our comparative estimates of photon attenuation in the 180° and 360° scans from the line-source response functions, the effect of attenuation in water was greater in the 180° scan. On the other hand, our study of SPECT tomograms of six normal hearts showed that P/A ratio was not significantly different between the two modes. For this there are several possible reasons. Photon attenuation through the air-containing lung adjacent to the heart seems to be a minor factor in myocardial imaging. Again, the myocardium is relatively small and is situated close to left anterior wall of the thorax, so data collection by posterior view may not provide much information concerning the myocardium and may add distortions and error propagation. Furthermore, in the posterior view, attenuation by the vertebral bone and the supporting bed should be inevitable. Therefore, in the assessment of a perfusion defect, photon attenuation seems to be a relatively minor problem when SPECT is reconstructed only from data of the anterior half of the myocardium.

It has been well established that thallium myocardial SPECT yields high-contrast images that permit easy identification of a perfusion defect (*5–8*). It can also depict a three-dimensional distribution of the thallium, which permits calculation of the size of an infarct (*7*). Although relatively long acquisition time has been one of the inherent limitations of myocardial SPECT in routine clinical applications (*2*), the 180° collection method can shorten the time to only 11 min and can also provide better image contrast and resolution than 360° data collection. This method may also be applicable for dynamic studies such as ECG-gated imaging (*15*).

In conclusion, the 180° (LPO to RAO) mode of revolution for thallium myocardial SPECT provides an improved and feasible technique for the clinical evaluation of coronary artery disease.

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REFERENCES

1. KUHL DE, EDWARDS RQ, RICCI AR, et al: The Mark IV system for radionuclide computed tomography of the brain. *Radiology* 121:405–413, 1976
2. MURPHY PH, THOMPSON WL, MOORE ML, et al: Radionuclide computed tomography of the body using routine radiopharmaceuticals. I. System characterization. *J Nucl Med* 20:102–107, 1979
3. HILL TC, COSTELLO P, GRAMM HF, et al: Early clinical experience with a radionuclide emission computed tomographic brain imaging system. *Radiology* 128:803–806, 1978
4. BUDINGER TF, CAHOON JL, DERENZO SE, et al: Three dimensional imaging of the myocardium with radionuclides. *Radiology* 125:433–439, 1977
5. HOLMAN BL, HILL TC, WYNNE J, et al: Single-photon transaxial emission tomography of the heart in normal subjects and in patients with infarction. *J Nucl Med* 20: 736–740, 1979
6. TAMAKI N, MUKAI T, ISHII Y, et al: Clinical evaluation of thallium-201 emission myocardial tomography using a rotating gamma camera: Comparison with seven-pinhole tomography. *J Nucl Med* 22:849–855, 1981
7. KEYES JW, BRADY TJ, LEONARD PF, et al: Calculation of viable and infarcted myocardial mass from thallium-201 tomograms. *J Nucl Med* 22:339–343, 1981
8. MAUBLANT J, CASSAGNESS J, JOURDE M, VEYRE A, et al: Myocardial emission tomography with thallium-201. *Eur J Nucl Med* 6:289–294, 1981
9. RITCHIE JL, OLSON DO, WILLIAMS DL, et al: Transaxial computed tomography with ^{201}Tl in patients with prior myocardial infarction. *J Nucl Med* 22:P11, 1981 (abst)
10. BESOZZI MC, RIZI HR, ROGERS WL, et al: Rotating gamma camera ECT of Tl-201 in the human heart. *J Nucl Med* 22:P11, 1981 (abst)
11. CHESLER DA, RIEDERE SJ: Ripple suppression during reconstruction in transverse tomography. *Physic Med Biol* 20:632–636, 1975
12. MUKAI T, MINATO K, TORIZUKA K, et al: Characteristic of ECT by a rotating gamma camera. 3rd Symposium on Physical and Technical Aspects on Transmission and Emission Computed Tomography Jointed with 7th ICCR, Tokyo, 1980, p 86
13. WILLIAMS DL, RITCHIE JL, HARP GD, et al: In vivo sim-

ulation of thallium-201 myocardial scintigraphy by seven-pinhole emission tomography. *J Nucl Med* 21:821–828, 1980

14. SORENSON JA: Quantitative measurement of radioactivity in vivo by whole body counting. In *Instrumentation in Nuclear Medicine.* Hine GJ, Sorenson JA, Eds. Vol. 2, New York, Academic Press, 1974, p 311

15. MUKAI T, ISHII Y, YAMAMOTO K, et al: Clinical usefulness of emission CT by a rotating gamma camera. *J Nucl Med* 22:P61, 1981 (abst)