180° Compared with 360° Sampling in SPECT

Two articles in this issue [Coleman et al. (*1*) and Tamaki et al. (*2*)] are concerned with the possibility of single-photon emission computed tomography (SPECT) of the myocardium with Tl-201, using the data from only a 180-degree sweep as opposed to the 360-degree data collections that are usually used in SPECT. Tamaki et al. conclude that 180° data collection is superior because lesion contrast is higher and the length of study is shorter, whereas Coleman et al. conclude that the 360° sweep is better for the special circumstance of their dual-headed camera, although they do not attempt to make a strong case for the 360° data-collection scheme in general. Whether or not a 180° SPECT sweep is adequate can have a serious impact on the utility of the technique in the future. A 180° sweep halves the study time and nearly doubles the number of patients that can be studied. The validity and utility of 180° SPECT depends upon (a) the clinical question being asked of the study, (b) the distribution of the radiopharmaceutical, and (c) the response of the imaging system to the particular radionuclide.

If the clinical question is relatively simple—such as, is there a lesion and is it relatively large or small—the requirements of the data are less stringent. SPECT with the 180° sweep could be treated as an image-enhancement technique that has higher contrast than the planar image, and the nuclear medicine physician could learn to read those images just as he has learned to read the usual planar image. This would be done by using a combination of anatomy, physiology, and pattern recognition from reading a large number of patient studies, as is done currently with planar images. If the information required is more quantitative—such as the size of the lesion or the concentration of the radiopharmaceutical—the requirements of the data become fairly rigorous and approximate methods such as the use of the 180° sweep can quickly invalidate the whole technique.

The reconstruction mathematics are based upon the assumption that each data point is simply the sum of the activity along a ray through the body perpendicular to the scan profile. Any property of the instrument or radionuclide that compromises this assumption will compromise the ability of the instrument to do quantitative measurements. A primary difficulty in SPECT is variable spatial resolution with distance from the camera. However, it has been shown that by using data-averaging techniques—such as taking the geometric mean of opposing views in 360° sweeps—adequate uniformity of resolution can be achieved, at least for Tc-99m (*3,4*). With 180° sweeps, this approach is impossible. In addition, scattered photons that produce background events, as in all nuclear medicine imaging, are particularly troublesome in SPECT. The attenuation of Tc-99m photons across a 20- to 30-cm thickness of a human body is on the order of a factor of 16 to 64, and almost all of the attenuated photons are scattered rather than completely absorbed. In order to obtain quantitative information about lesion size or nuclide concentration, it is necessary to correct the data for the effects of photon attenuation. Attenuation correction schemes would require correction factors for the distal areas in a 180° sweep on the order of 16 to 64. Since most of the interactions producing attenuation also produce scattered photons, there will be a large scatter background from the distal portions of the body and a relatively weak unscattered component in the data, both of which would be increased by the attenuation correction factor. In addition to the extra scatter background, the spatial resolution in the distal areas of the scan will be significantly poorer than in the proximal areas. With a 360° sweep the average attenuation would be lower and the average signal higher, since data are collected on both sides (distal and proximal) of the object. On the average, there is both a higher signal-to-noise ratio, and more uniform spatial resolution in the image, in the 360° scan.

Although the spatial distribution of Tl-201 in the thorax allows a reasonable use of a 180° sweep, other distributions of the radionuclide can just as adversely affect even qualitative applications of the 180° sweep. Consider for instance SPECT imaging with [^{123}I]iodoamphetamine (*5,6*) as an indicator of cerebral blood flow. Since the tracer is distributed essentially symmetrically in the brain (right to left), a 180° sweep on the right or left side would nullify the diagnostic utility of the symmetry of the brain. An anterior or posterior 180° sweep would have problems less clearly defined, but would require a prediagnosis of anterior or posterior lesion, reducing the study to a procedure designed for confirmation rather than actual diagnosis.

The use of 180° scanning with Tl-201 for myocardial studies is a special circumstance and generalizations should not be inferred from results obtained in that particular application. The myocardium is in the left anterior part of the thorax, and the mercury x-rays, which are the photons used in Tl-201 imaging, must traverse 15 to 20 cm of tissue to reach the camera in right-side and posterior views. Assuming an average linear attenuation coefficient of 0.18/cm, only 3 to 7% of the photons reach the camera unattenuated. The mercury x-rays range in energy from 68.9 to 82.5 keV, with a weighted mean energy of 72.4 keV. If a 25% energy window is placed symmetrically at this energy, photons of the lowest x-ray energy, if scattered as much as 70°, are accepted by the pulse-height analyzer, and essentially all the singly-scattered photons from the highest-energy x-ray are accepted. In this energy range the photoelectric effect in soft tissue is less than 10%, thus a large fraction of the attenuated photons, which no longer carry spatial information, are still available to be detected as scatter background in the right-side and posterior views of a 360° sweep. This background may be several times the magnitude of the useful data. The effect of these scatter photons on image quality, when they are included in the image data, is clearly seen in all the comparisons of 180° and 360° images shown by Tamaki et al. (*2*) as a loss in image contrast. Also, in the tables of Coleman et al. (*1*), the contrast is systematically better for the 180° sweep, although only modestly better.

The use of 180° SPECT scans of Tl-201 in the heart may be partially justifiable, but only because the several low energies of the Tl-201 emission amplify the problems of attenuation, scatter, and scatter rejection. In addition, the asymmetric location of the myocardium causes such a large disparity in the data quality between left anterior and right posterior views that the resultant apparent high quality of the 180° sweep looks very attractive. However, with the probable introduction of new myocardial imaging agents utilizing Tc-99m (*7*) and I-123 (*8*), the net attenuation of the radiation from these emitters will be about a factor of two less across the body, the scatter fraction will be smaller, scatter rejection by pulse-height analysis will be more effective, and spatial resolution will improve relative to Tl-201. This eventuality will outweigh the advantages of the 180° sweep.

The usefulness of the 180° SPECT scan is an artifact of the use of a radionuclide with photon energies particularly unsuited to the requirements of the instrumentation and scanning technique. While the image is sharper for the Tl-201 scan, it is severely distorted by the attenuation of the body, and the apparent high contrast is an artifact due to the suppression of the activity levels in the center of the body. In addition, the unique capability of SPECT for quantitation of lesion size and activity levels is very difficult to implement in the 180° scan. While the better lesion contrast of SPECT may be important in diagnosis, the lower contrast of planar images can be largely offset by spending a bit more time with each planar view without the added difficulties of SPECT. If SPECT is to become a significant part of nuclear medicine, it must provide more than increased image contrast. The obvious area in which SPECT might excel is in quantitative measurements of tracer concentrations of new radiopharmaceuticals which, we hope, will have properties that will allow measurement of physiological rather than anatomical parameters. Ill-considered shortcuts will bring SPECT no closer to this goal.

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REFERENCES

1. Coleman RE, Jaszczak RJ, Cobb FR: Comparison of 180 Deg and 360 Deg Data Collection in Thallium-201 Imaging Using Single Photon Emission Computed Tomography (SPECT) *J Nucl Med* 23:655–660, 1982

2. TAMAKI N, TAKAO M, ISHII Y, et al: Comparative Study of Thallium Emission Myocardial Tomography by a 180 Deg and 360 Deg Data Collection. *J Nucl Med* 23:661-666, 1982
3. JASZCZAK RJ, MURPHY PH, HUARD D, et al: Radionuclide Emission Computed Tomography of the Head with ^{99m}Tc and a Scintillation Camera. *J Nucl Med* 18:373-380, 1977
4. BUDINGER TF, DERENZO SE, GULLBERG GT, et al: Emission Computer Assisted Tomography with Single-Photon and Positron Annihilation Photon Emitters. *J Comput Assist Tomogr* 1:131-145, 1982
5. KUHL DE, BARRIO JR, HUANG SC, et al: Quantifying Local Cerebral Blood Flow by N-Isopropyl-p-[123-I]-Iodoamphetamine (IMP) Tomography. *J Nucl Med* 23:196-203, 1982
6. HILL TC, HOLMAN BL, LOVETT R, et al: Initial Experience with SPECT (Single-Photon Computerized Tomography) of the brain Using N-isopropyl I-123 p-iodoamphetamine: Concise Communication. *J Nucl Med* 23:191-195, 1982
7. DEUTSCH E, BUSHONG W, GLAVAN KA, et al: Heart Imaging with Cationic Complexes of Technetium. *Science* 214:85-86, 1981
8. VAN DER WALL EE, HEIDENDAL GAK, DEN HOLLANDER W, et al: I-123 Labelled Hexadecenoic Acid in Comparison with 201-thallium for Myocardial Imaging in Coronary Heart Disease. A preliminary study. *Eur J Nucl Med* 5:401-405, 1980

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