An Optimized Collimator for Single-Photon Computed Tomography with a Scintillation Camera

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The problem of nonuniform response, which is inherent in scintillation-camera emission computed tomography, can be minimized by proper collimator design. A specially fabricated collimator, optimized for emission computed tomography, was designed. This collimator has a calculated full width at half maximum of 1 cm at 15 cm in front of the collimator. When this collimator is used in conjunction with averaged opposed views, excellent uniformity across the reconstruction plane is achievable.

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Emission computed tomography (ECT) can be accomplished using a standard gamma-camera detector (*1,2*). Since conventional radionuclides, which emit only a single gamma photon per disintegration, are used in conjunction with the camera, this technique has come to be known as single-photon ECT in contrast to the positron coincidence techniques of ECT. A number of authors have pointed out that potentially serious problems arise when this approach to ECT is taken (*2–5*). Among these are marked nonuniformity in resolution across the reconstruction plane. Kay (*3*) has demonstrated, however, that this problem can be reduced if 180° opposed views are obtained for all projection angles and averaged before the final reconstruction is accomplished. The averaging technique has the effect of reducing the falloff in line-spread response across the reconstruction field, so that the result is approximately equal to that of the camera-and-collimator combination as measured at a distance equal to the radius of rotation used during the acquisition of projection views. Jaszczak et al. (*1*) have demonstrated a similar result.

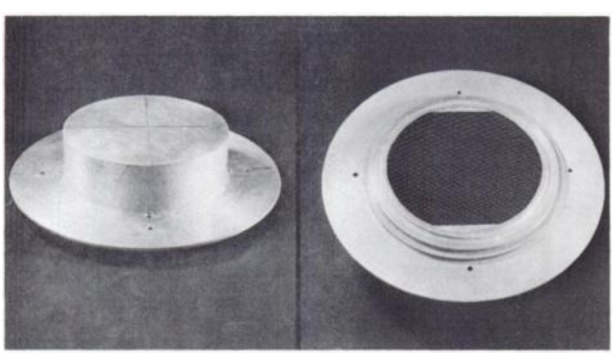

FIG. 1. Tomo-collimator insert. Left: front face of insert showing forward projection. Right: back face of collimator showing lead fillets and closely packed tantalum tubes.

This technique produces best results if the line-spread function of the camera-collimator does not change too markedly across the diameter of the reconstruction field. In addition, best resolution will be obtained if the collimator used still has a reasonably good resolution at a depth equal to the radius of rotation. If a parallel-hole collimator is to be used, these statements imply that best results will be achieved with a fairly high-resolution collimator having holes considerably longer than those currently used for conventional imaging. We describe here a parallel-hole collimator that was designed specifically for tomographic imaging, incorporating the above characteristics.

Collimator description. Swann et al. (*6*) have described a technique for collimator fabrication using tantalum tubes. This allows parallel-hole collimators to be designed and built by individual laboratories to meet their specific needs. We have made use of their approach.

The collimator was designed to have a geometric resolution of 1 cm at 15 cm from the fact of the collimator. Collimator thickness (hole length) was set at 10 cm and a permissible septal penetration of 0.05% was specified. Given these parameters and the known absorption of tantalum, the other collimator dimensions could be calculated from standard formulas. These gave an individual channel diameter of 3.77 mm and a wall thickness of 0.11 mm.

Tantalum tubes of the requisite dimensions, sufficient to cover a 25-cm circle in close-packed, hexagonal array, were obtained from a commercial supplier*. The individual tubes were packed into a special housing designed so that it could be mounted in place of the standard Searle Div-Con collimator insert on the Div-Con collimator ring. The collimator insert is shown in Fig. 1. The protruding aluminum can within which the individual tubes are packed is lined with 2.5-mm-thick lead sheet to minimize lateral penetration,

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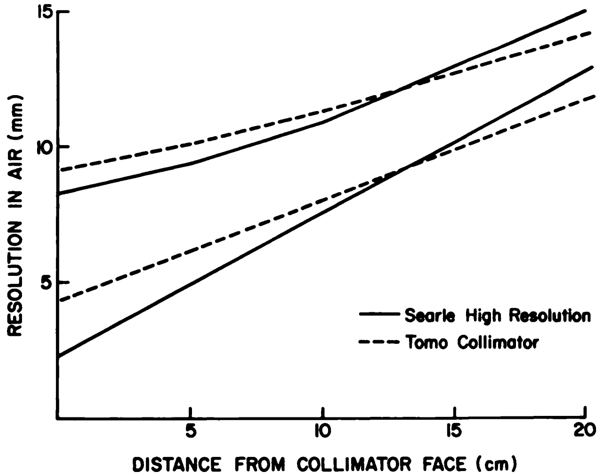

FIG. 2. Comparative responses of tomo-collimator and Searle high-resolution collimator. Lower pair shows the calculated geometric resolutions of the collimators alone, upper pair the calculated camera-collimator system response curves with a Searle Pho/Gamma HP.

and additional shielding is provided around the base of the insert where this interfaces with the hole in the Div-Con collimator ring.

Performance and discussion. Figure 2 illustrates the theoretical performance of this collimator compared with that of the Searle high-resolution collimator. As can be seen, the rate at which the resolution degrades as one moves away from the face of the collimator is significantly lower than that of the high-resolution collimator, although the resolution at the collimator face is somewhat worse than that of the high-resolution. Beyond about 12 cm, the resolution of the tomo-collimator is better than that of the high-resolution.

Figure 2 also illustrates the calculated overall system response of our camera with the two collimators. Experimental measurements have confirmed these theoretical projections exactly. Figure 3 shows the system response functions obtained from tomograms of a Tc-99m line source embedded in a tissue-equivalent polystyrene absorber 15 cm in diameter, centered on the axis of rotation. A 15-cm radius of rotation was used and the reconstructions were corrected for absorption using the "mean exponential" technique of Kay (*3*). It is apparent that the uniformity obtained under these circumstances is very good.

We have found this collimator to be advantageous for a number of reasons other than its resolution properties. Since the resolution of parallel-hole collimators degrades as a function of distance, it is best to bring the collimator face as close to the patient as possible while projections are being obtained for computed tomography. For studies of the head and face, the closeness of the collimator to the patient's head is limited by the need to have the collimator support ring clear the patient's shoulders during rotation. The long forward projection of the tomo-collimator in front of the support ring allows adequate clearance of the shoulders while maintaining close apposition of the collimator face to the patient's head.

The only major shortcoming to the collimator design described is its relatively poor sensitivity. The measured sensitivity for plane sources is approximately 53% that of the Searle high-resolution collimator. Although this is relatively poor, we have not found it to be a significant drawback for imaging with technetium agents. Imaging times of 15–30 min have proven quite adequate to do complete reconstructions of the face and brain using this collimator with conventional doses of radiopharmaceuticals.

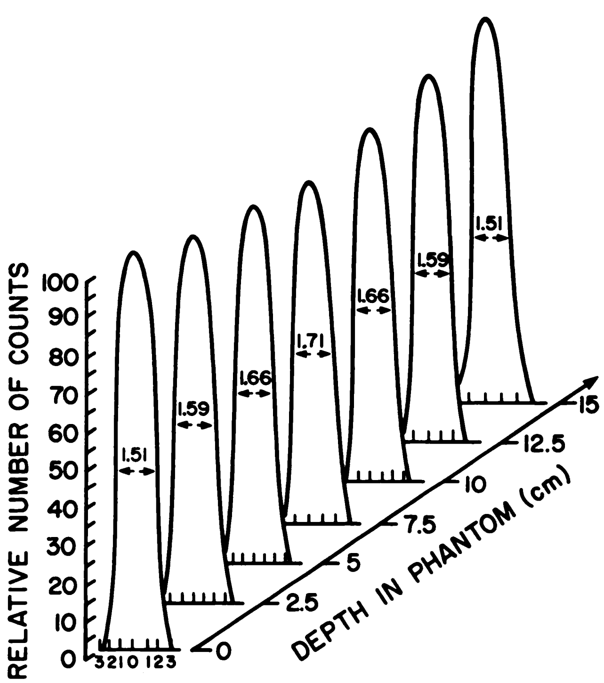

FIG. 3. System response functions for tomograms of a Tc-99m source embedded in a tissue-equivalent absorber 15 cm in diameter; obtained with tomo-collimator and Searle Pho/Gamma HP camera, using a 15-cm radius of rotation and attenuation correction.

FOOTNOTE

* Uniform Tubes, Inc., Collegeville, Penn.

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