

**TOMOGRAPHY WITH A GAMMA CAMERA**

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In recent years, improvements in gamma camera systems have resulted in modest improvements in the planar resolution. The need for a layer-by-layer analysis of radioactivity within a deep organ has been apparent, and several methods have been suggested to improve depth resolution. Summaries of these methods of radioisotope tomography (1-3) along with proposals for new devices have been offered by Miraldi (5) and McAfee (4). As with all these methods, the system proposed here views the organ under consideration from multiple positions.

**PRINCIPLES OF THE NEW METHOD OF TOMOGRAPHY**

The proposed system for tomography uses a standard gamma camera, a digital computer and a multi-channel collimator with parallel holes, each of which is inclined at an angle to the plane of the scintillation crystal. Figure 1 illustrates a multihole collimator inclined to the face of a gamma camera crystal. The diagram shows the collimator in two positions (solid lines indicate Position 1, dotted lines show Position 2); information viewed by the two intersecting channels is limited to an area which diminished in cross section with depth. The intersection of Channels 8 and 14 defines Point C in Plane P, and Channels 7 and 15 define Point F in Plane P<sub>1</sub>. If an image at Plane P was desired, the summation of all channels forming the intersection at points A<sub>1</sub>, C<sub>2</sub>, C, C<sub>1</sub>, B<sub>2</sub> . . . etc. would produce this planar distribution by reinforcing the image at these points and blurring data from other planes.

The scintigraphic image at each position of the collimator is acquired in the conventional manner. The number of photons viewed by each collimator channel is recorded and numerically stored as a digital image either in a computer memory or on magnetic tape. The collimator is rotated through a series of fixed angles as shown in Fig. 2, acquiring

an image at each position. The digital images are combined by the computer to produce the images A, B, C and D. When the plane includes a lesion (the circle in Plane B or the square in Plane C of Fig. 2), all the images of the lesion superimpose, and a reinforced image is created (shown in black). If the lesion is not in that plane, the image will be blurred, and will appear as "ghost" images (dotted) around the center of the true position of the lesion. With this method a plurality of planes parallel to the face of the crystal can be reconstructed at different depths by the summation of different channels of the collimator output. Since the image at each position is numerical, tomographic image reconstruction is done by a digital computer, and the resulting longitudinal section at any depth is displayed on an oscilloscope from which a film record can be made.

**RESULTS**

Figure 3 shows results of a phantom obtained using a standard Pho/Gamma III and a special 1 in.-thick, 1,000-hole collimator whose holes are inclined at 30 deg to the crystal face. All digital image reconstruction was performed using a special program on a standard Nuclear Data 50/50 computer system. Image reconstruction using a four-view, 32 × 32 image from computer memory took less than 10 sec per image at any depth.

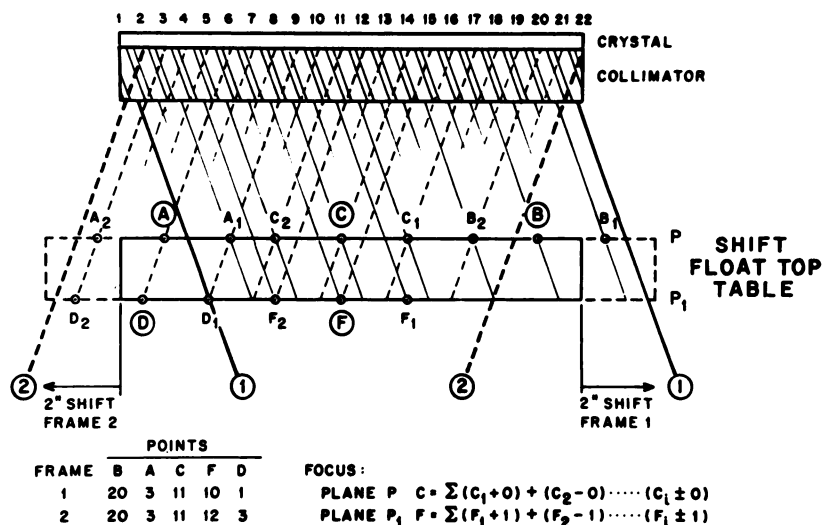
Two small <sup>99m</sup>Tc sources were positioned at 6 and 12 cm below the center of the crystal face directly under each other. Four images at 0, 90, 180 and 270 deg were stored in Memory 1 designated as Frames 1, 2, 3 and 4 in the computer. The activity (counts) from each lesion (7,470 for the lesion at

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**FIG. 1.** Angled collimator is shown in two position; area seen diminishes with increasing depth as included between solid line 1 and dotted line 2 and would include Points C and F but not A, B and D. Point C is reconstructed by computer from data seen by Channels 8 and 14 while Point F is reconstructed from Channels 15 and 7. Field of view may be enlarged to include Points A and B using float-top table shifted in direction of collimator angulation. Thus in Position 1, D becomes D<sub>1</sub> and is seen in Channel 1, and in Position 2, D becomes D<sub>2</sub> and is seen in Channel 3.

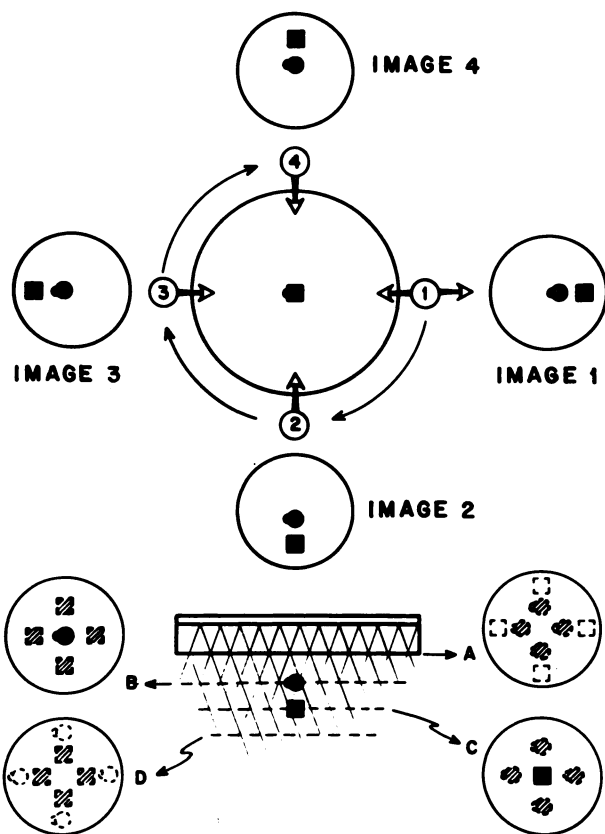


12 cm and 12,091 for the lesion at 6 cm) are shown in Frame 1. Using the upper half of the 50/50 (Memory 2) planes were reconstructed at 4, 6, 8, 10, 12, 14, 16 and 18 cm. Note that single images of the lesions appear at 6 and 12 cm surrounded by four "ghost" images of the other lesion. The "ghost" images are useful in indicating the presence of another lesion at a different level. Beyond a depth of 16 cm both lesions appear as "ghost" images.

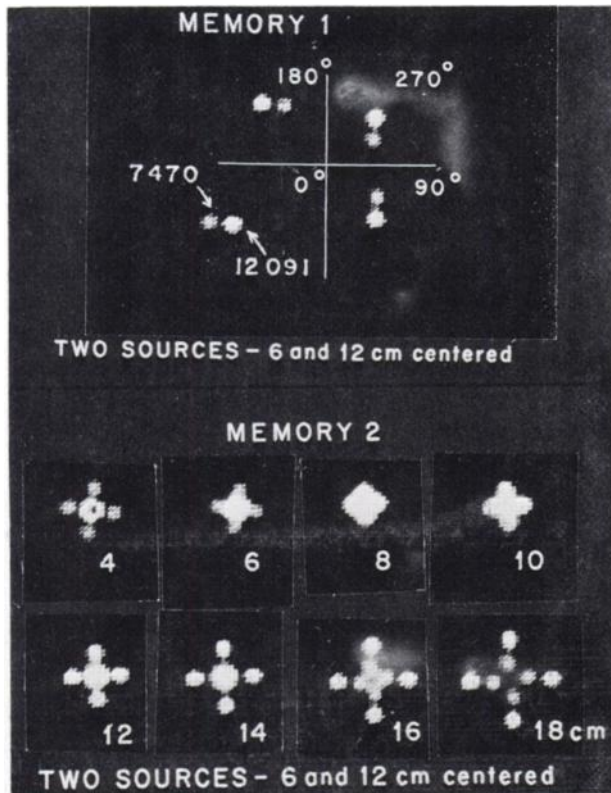
#### IMPROVEMENTS

Having proven the basic concept, improvements to the image can be made by increasing the number of positions from which images will be obtained from 4 to 8 or 12. Thus, each ghost image would have 1/8th or 1/12th the activity establishing a much more favorable signal-to-noise ratio. Further image improvements can be achieved by increasing the collimator thickness and increasing the number of holes from 32 along the diameter to 64. This modification, matches the computer memory of a 64 x 64 array. Each image from each of the 8 or 12 viewing positions would be stored as a separate 64 x 64 digital image on magnetic tape. On replay these images would be transferred to Memory 1, then used to reconstruct the desired section in Memory 2.

The principal disadvantage to this system is that the cross-section area of the tissue diminishes with depth. Although enlarging the crystal diameter would contribute to the elimination of the problem, further enlargements beyond a 13.5-in. dia appear unlikely in the near future. Longitudinal camera-head motion such as described by McAfee and Anger are possible solutions to this problem. A less expensive approach



**FIG. 2.** In lower diagram round and square lesions are seen in profile below rotatable angled collimator. Upper half shows top view of lesion surrounded by satellite views illustrating how these lesions would appear to collimator angled in direction of arrow at Positions 1, 2, 3 and 4. These four images can be appropriately combined by computer to construct images at Planes A, B, C and D. In Plane B circular lesion is reconstructed with square "ghost" images and in Plane C square lesion is reconstructed with circular "ghost" images.



**FIG. 3.** Images of two circular lesions positioned 6 and 12 cm below center of face of crystal are shown in memory as seen at 0, 90, 180 and 270 deg. Four views are recombined in Memory 2, and sections at depths 4, 6, 8, 10, 12, 14, 16 and 18 cm are displayed on the oscilloscope. Note lesions are shown at 6 and 12 cm surrounded by "ghost" images of other lesion. Beyond 16 cm both lesions appear as "ghost" images.

would be to move the patient on a float-top table so that the patient remains within the area viewed by the angled collimator field (Fig. 1). By moving the table top in the direction of angulation, Point A becomes A<sub>1</sub>, C becomes C<sub>1</sub> and B becomes B<sub>1</sub> during Position 1; during Position 2, A becomes A<sub>2</sub>, C becomes C<sub>2</sub> and B becomes B<sub>2</sub>. This would actually increase the area viewed because the distance from the collimator is increased and would include Points A and B otherwise excluded. The amount of the table movement could just equal the shift normally made in the computer so that the points in Plane P from the different views could simply be added together.

$$\text{Plane P} = \Sigma [(A_1 + 0) + (A_2 - 0) + (B_1 + 0) (B_2 - 0) \dots (N_i \pm 0)].$$

When going through multiple positions, the table would move a fixed increment (2 in. in Fig. 1) along the radius at that position.

A further advantage of this concept is the theoretical possibility of reconstructing the data to provide transverse tomographic sections in addition to the longitudinal sections already described. All points in the desired transverse (z-axis) section would be transferred to an x,y-array in Memory 2. This would require a somewhat more complex computer program. Other programs can be written to correct for increased tissue absorption with increasing depth.

**SUMMARY**

A system for gamma camera longitudinal and transverse tomography is proposed which uses a standard gamma camera, a special collimator and a digital computer. The system will permit the reconstruction of images in a layer-by-layer tomographic manner and display the results on an oscilloscope.

**ADDENDUM**

A commercial prototype tomographic unit based on principles described by G. Muehlehner was presented at the July 1970 meeting of the Society of Nuclear Medicine (6). It embodied some of the principles described herein using an analog method for longitudinal tomography.

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