CLINICAL APPRAISAL OF AN EXPERIMENTAL CONVERGING COLLIMATOR

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A description and clinical evaluation of an experimental multihole converging collimator for the scintillation camera is presented. MTFs, relative sensitivities, phantom and clinical images were compared with those from other appropriate collimators. The collimator was judged to provide superior resolution in imaging small objects.

Image magnification with the scintillation camera can result in improvement in the inherent resolution of the system if the magnification is accomplished before incidence of the gamma photons on the scintillation crystal. One means of accomplishing this end is to use a multihole converging collimator (*1,2*). We have recently completed a clinical evaluation of an experimental low-energy converging collimator for the scintillation camera*.

To evaluate the degree to which the anticipated improvement in resolution was achieved, comparisons of modulation transfer functions, phantom images, and clinical images between other appropriate collimators were studied.

PHYSICAL CHARACTERISTICS

The collimator, designed for 140-keV gamma rays, consists of about 6,000 holes focused at a distance of 34 cm from the exterior surface. The useful field of view varies from about 20 cm at the surface to 15 cm at 10 cm depth. This results in magnification factors, compared with a straight-hole collimator, which increase linearly from 1.2 at the collimator surface to 3.2 at 20 cm.

FUNCTIONAL CHARACTERISTICS

Modulation transfer functions (MTF) were obtained from the Fourier transform of a measured line source response function for ^{99m}Tc in air. The MTFs were calculated for object distances at 0, 10, and 20 cm for the experimental collimator, the Div/Con converging collimator, and the High Resolution collimator* (Fig. 1). At all three distances, the experimental converging collimator exhibits higher values for the MTF than the other two collimators.

The improvement in resolution predicted by the MTF is supported by phantom images, as shown in Fig. 2, for the standard bar phantom imaged at 10 cm from the collimator surface.

The relative plane-source sensitivities normalized to unit area of field of view (mean point-source sensitivities), are higher for the experimental converging collimator than the high-resolution collimator at

* Collimator designed and constructed by Searle Radiographics for the Pho/Gamma HP scintillation camera.

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* Searle Radiographics' collimators, Models Nos. 8217424 and 822017.

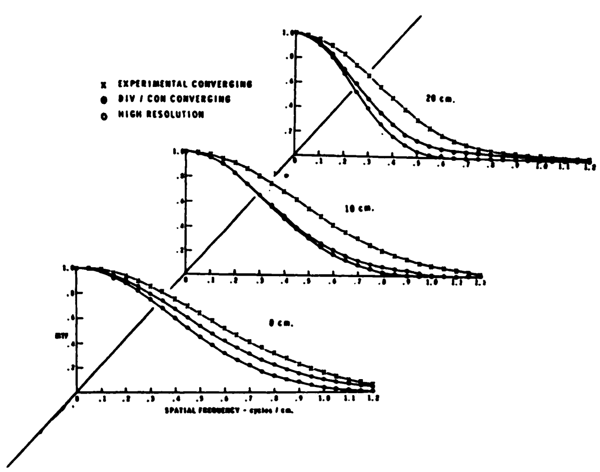

FIG. 1. Modulation transfer functions at 0, 10, and 20 cm from high-resolution, experimental, and Div/Con converging collimators. MTFs were obtained from Fourier transform of line-source response function for ^{99m}Tc in air.

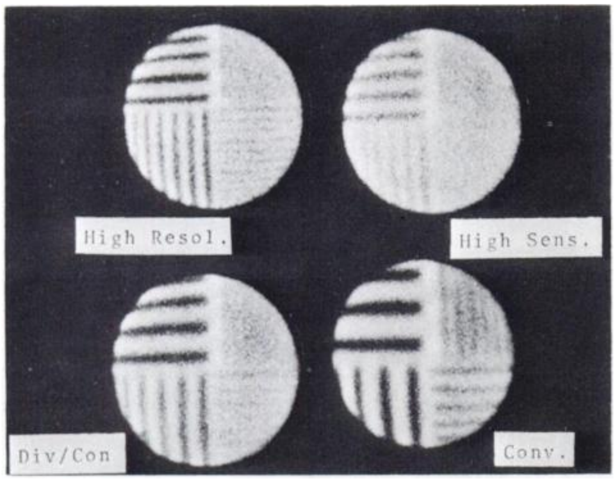

FIG. 2. Bar phantom images with ^{99m}Tc at 10 cm from exterior surface of collimators. Bar phantom consists of 3/16, 1/4, 3/8, and 1/2-in. bars and spacings.

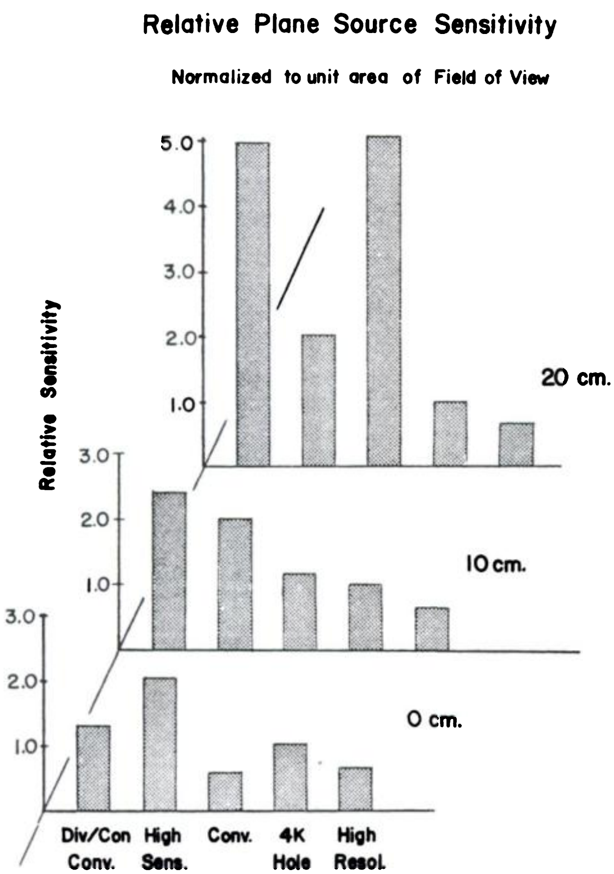

FIG. 3. Relative plane-source sensitivities normalized to unit area of field of view at 0, 10, and 20 cm from collimator surface. Normalized to value of 1.0 for 4K-hole (250-keV) collimator.

all clinically useful distances. In particular, at 10-cm object distance, it is intermediate between that of the high-resolution and high-sensitivity collimators (Fig. 3).

Examples of clinical images demonstrating the usefulness of the experimental collimator are shown in Figs. 4 and 5. The improved resolution obtained through magnification while maintaining relatively good sensitivity often results in superior images for both static distributions and flow studies particularly of small organs.

DISCUSSION

For a fixed-diameter NaI(Tl) crystal, the useful field of view of a system with a converging collimator will decrease as the magnification increases. Because of this field-of-view limitation with currently available scintillation crystals, we have elected to apply the collimator primarily to a pediatric population where the definition of structure in the organs of small children is often not adequate with currently available systems.

The resolution obtained with the experimental converging collimator is greater than that of all other Searle Radiographic multihole collimators at all clinically useful distances. This is quantitatively displayed by the modulation transfer functions and qualitatively supported by phantom and clinical images. The rate at which resolution degrades with distance from the experimental converging collimator is less than that of the Div/Con converging collimator because the magnification factor increases more rapidly. The decrease in resolution with distance of the Div/Con converging collimator is quite rapid (*3*), such that at distances greater than about 10 cm the resolution of the high-resolution collimator is superior (Fig. 1). However, the resolution of the experimental converging collimator exceeds that of the high-resolution collimator at all clinically useful distances. This improvement in the modulation transfer functions of both the experimental and the Div-Con converging collimators over the high-resolution collimator is primarily a consequence of an apparent decrease in the spatial frequencies of an object at the image plane.

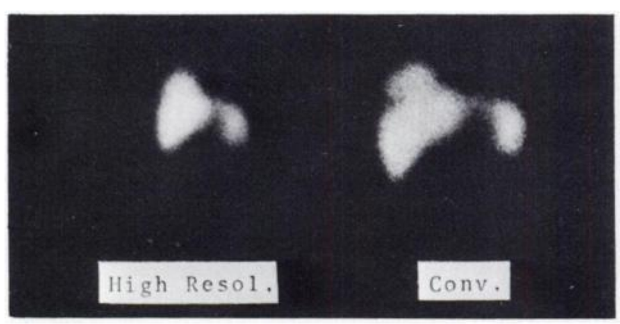

FIG. 4. Anterior liver scintiphotos obtained with high-resolution and experimental converging collimator in 2-week-old female. Patient presented with x-ray finding of right lower thoracic mass. High-resolution image demonstrated upward projection of right lobe with some irregularity of uptake in this region. Corresponding view with experimental collimator revealing ringlike defect in upper portion of right lobe produced by eventration of diaphragm.

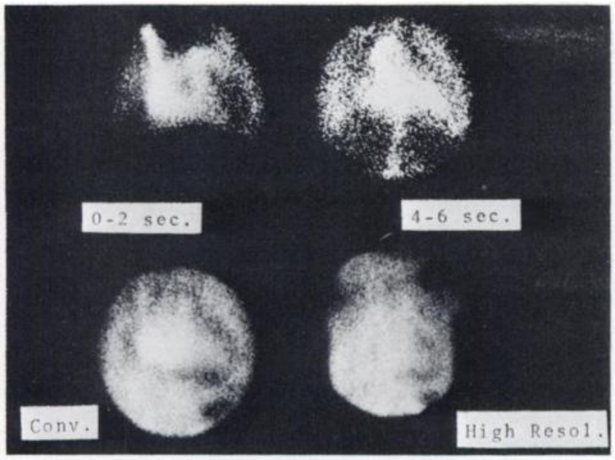

FIG. 5. Cardiac flow and blood pool images with converging collimator of 14-month-old child with suspected pericardial effusion. Definition of blood pool structures in flow images (above) is considerably better than usually obtained in child of this small size. The contrast produced by partially loculated pericardial effusion in static images (below) is superior to that obtained with high-resolution collimator.

A unique feature of a converging collimator is the increase in the point-source sensitivity and an increase in the radius of the image of a point source with increasing distance from the collimator surface. Initially, one might expect this to result in disturbing artifacts in clinical images of thick objects. In clinical studies to date we have not found this to be a problem, possibly because the increased sensitivity with depth is at least partially cancelled by the increased photon absorption in overlying tissues.

We conclude that the experimental converging collimator could be a valuable addition to the nuclear medicine laboratory for selective applications. It has been most useful for dynamic and static imaging in pediatric patients, in particular infants, and for taking a "second look" at questionable areas in any scan.

ACKNOWLEDGMENTS

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