CLINICAL EFFICACY OF A LARGE-FIELD-OF-VIEW SCINTILLATION CAMERA

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In evaluating the clinical application of a prototype large-field-of-view scintillation camera, a significant increase in the quality of static and dynamic images was observed. With parallel-hole collimation, imaging time for large areas was reduced by more than 50% and a marked enhancement in resolution and sensitivity of lung images occurred in relation to those obtained with diverging collimation on a conventional camera. Using converging collimation, the prototype camera produced images of brain and other organs with considerably better depth response than comparative studies performed with standard size cameras. These results demonstrate that further clinically relevant improvement in scintillation camera performance is possible.

Technologic advances in scintillation camera electronics and collimation have resulted in progressive improvement in gamma-imaging capabilities. In recent years, the intrinsic resolution has been developed to such an extent that one wonders whether efforts toward additional improvement might offer little return. Consequently, it has often been suggested that the potential for further enhancement of radionuclide images resides in the development of new devices based on tomography, coincidence detection of photons from positron emitters, coded aperture imaging, or other principles, and in the introduction of new and more specific short-lived radiopharmaceuticals of low particulate emission and high photon yield. During the clinical application of a prototype large-field-of-view scintillation camera (LFOV) (manufactured by Searle Radiographics)

TABLE 1. COLLIMATORS FOR LFOV

Collimator	FWHM (10 cm)	Relative sensitivity (10 cm)
High-resolution converging (HRC)	8.6 mm	0.95
Medium-resolution converging (MRC)	12.5 mm	2.6
High-efficiency converging (HEC)	15.1 mm	4.2
High-resolution parallel (HRP)	10.9 mm	0.63
Medium-resolution parallel (MRP)	12.0 mm	0.91
High-efficiency parallel (HEP)	15.0 mm	1.9

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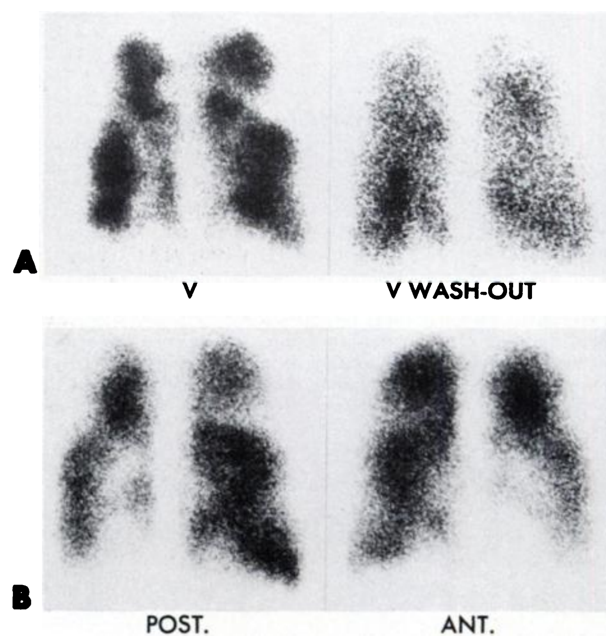

FIG. 1. LFOV images with high-efficiency parallel-hole (HEP) collimator from 60-year-old woman with chronic bronchitis and emphysema. (A) Posterior single-breath ventilation and washout following inhalation of 15 mCi of ^{133}Xe; (B) ^{99m}Tc-HAM perfusion images.

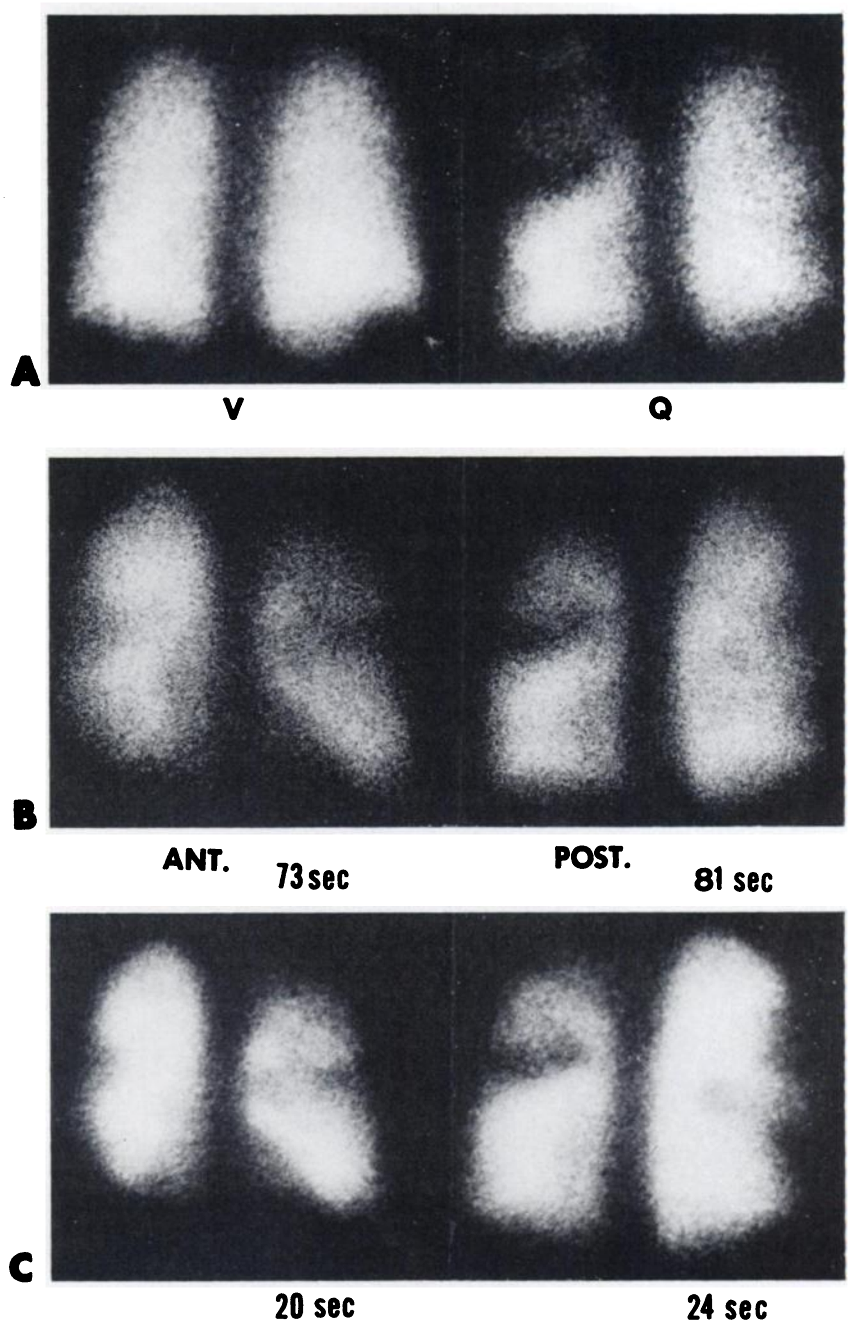

FIG. 2. Pulmonary thromboembolism in 48-year-old woman. Posterior ^{133}Xe images of ventilation V and perfusion Q with LFOV (A); ^{99m}Tc-MAA perfusion images with PG/IV (B); and LFOV (C). PG/IV images with low-energy diverging collimator and LFOV with HEP.

it became evident that it is possible to improve scintillation camera performance considerably more than anticipated. At a time when computerized transverse axial tomography has created an impetus for reevaluating radionuclide imaging, this report is submitted with the intention of providing a better perspective for the status of scintillation camera technology.

MATERIALS AND METHODS

The LFOV has 37 photomultiplier tubes with a useful field of view of 15.25 in. using parallel-hole collimation. Several low-energy collimators, both parallel and converging, were designed to accommodate the clinically relevant extremes between high efficiency and high spatial resolution (see Table 1 and Ref. *1*).

The general operational and performance characteristics of the system (i.e., relative resolution, sensitivity, count rate acceptance capabilities, and uniformity of response) were determined as described in the preceding paper. The present report concerns comparisons of practical performance between the new LFOV and two conventional cameras: the Searle Radiographics Pho/Gamma HP (PG/HP) and Pho/Gamma IV (PG/IV). The study covers

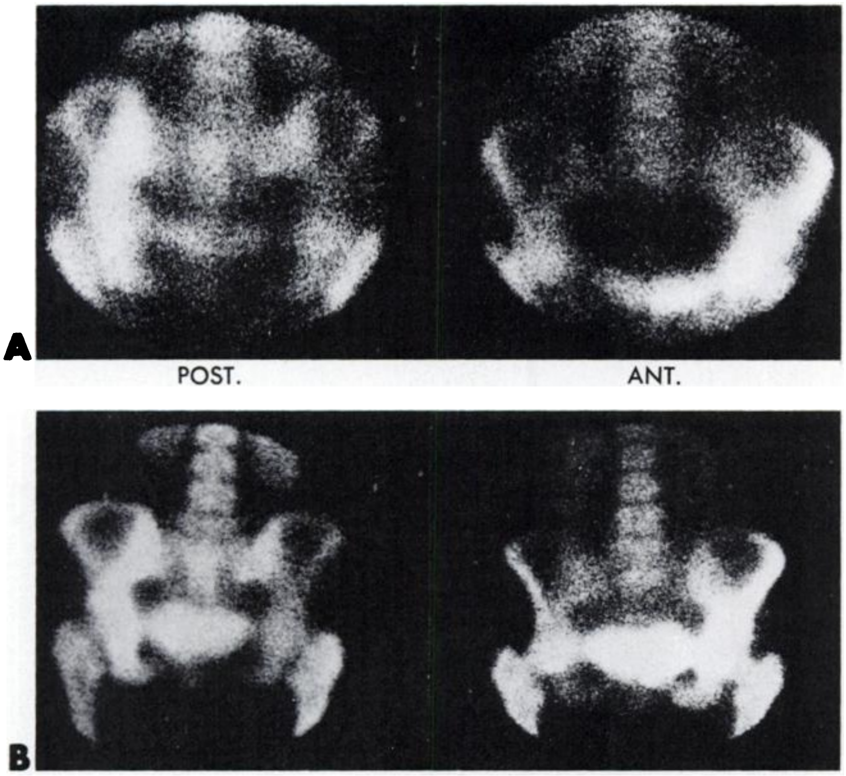

FIG. 3. Pelvic ^{99m}Tc-pyrophosphate images from 52-year-old woman with metastatic carcinoma of the breast. (A) PG/HP images with low-energy diverging collimator; (B) LFOV images with HEP collimator. Imaging time for LFOV is approximately one-third of that for PG/HP.

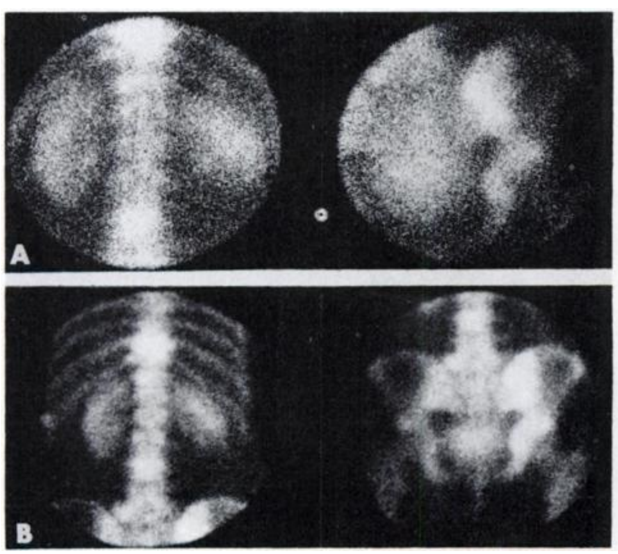

FIG. 4. Posterior ^{99m}Tc-pyrophosphate bone images from 61-year-old woman with metastatic carcinoma of breast. Medium-resolution collimation used for both PG/IV (A) and LFOV (B). The field size for LFOV is more than twice that of PG/IV.

more than 1,500 patients referred for clinical evaluation, static and/or rapid sequence scintiangiographic images of brain, liver/spleen, lung, bone, kidney, or heart.

RESULTS

In spite of the significant increase in detector size, the positioning of patients for all routine imaging procedures is no more difficult with the LFOV than with a standard camera. The hexagonal detector head is less bulky than a circular configuration and, for example, facilitates access above the patient's shoulder and thorax for recording lateral brain views. The placement of image-orientation controls on the detector assembly is a useful innovation, while the two-speed drive for yoke and detector rotation

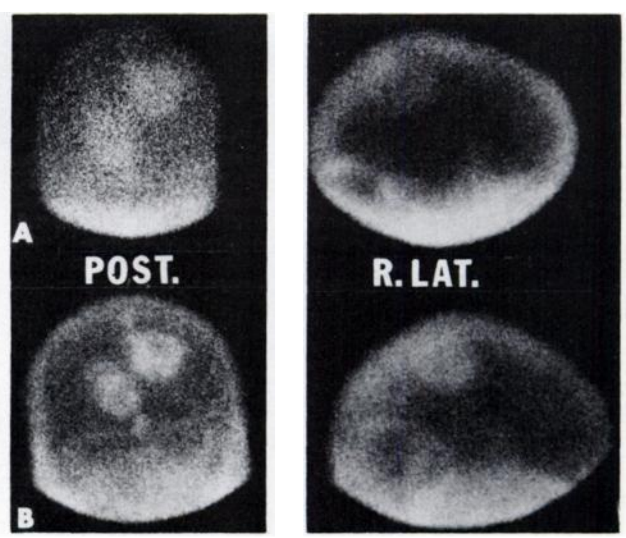

FIG. 5. Comparative brain images from 54-year-old man with metastatic carcinoma of lung with LFOV and converging collimation (B) and PG/HP with equivalent parallel-hole collimation (A).

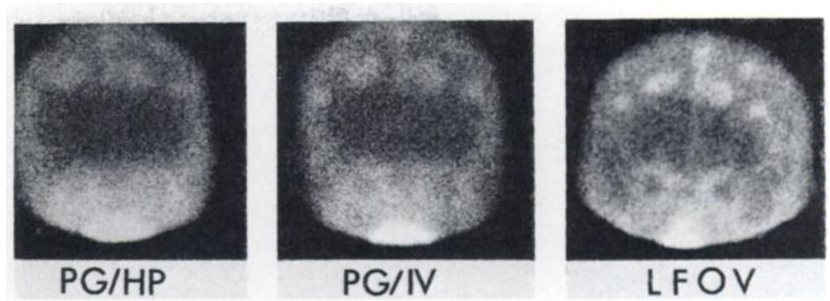

FIG. 6. Anterior brain images from 60-year-old woman with metastatic carcinoma of lung. High-resolution parallel-hole collimation for PG/HP and PG/IV; high-resolution converging collimation for LFOV.

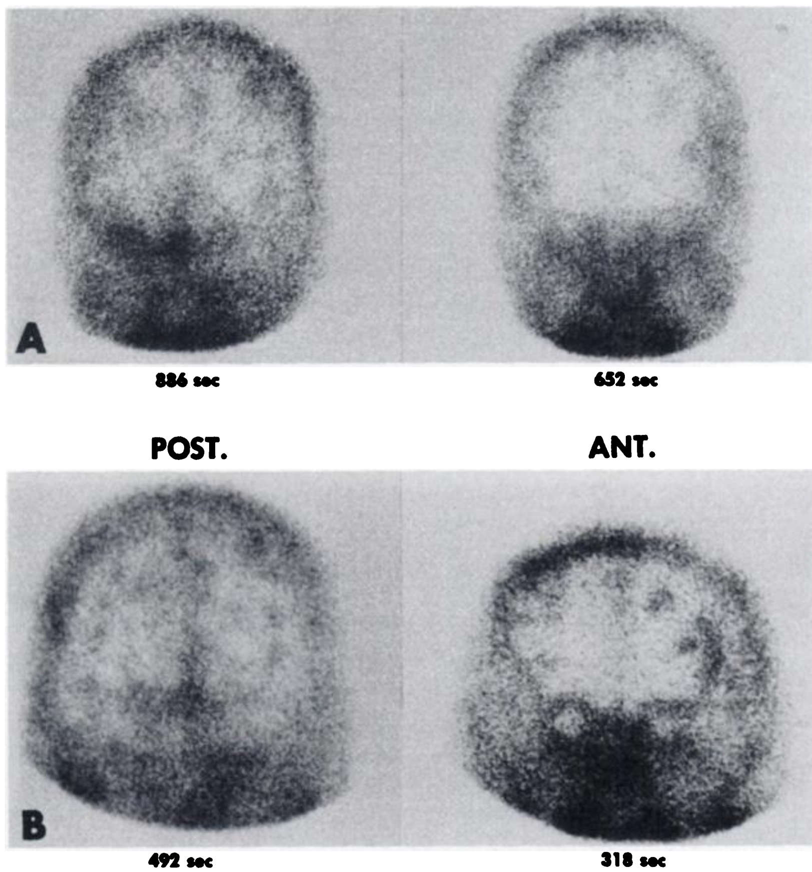

FIG. 7. Delayed ^{99m}Tc-pertechnetate images (400K counts) from 67-year-old woman with metastatic carcinoma of breast. PG/IV images with high-resolution parallel-hole collimator (A); LFOV images with HRC collimator (B).

decreases the time needed for patient setup and collimator changing.

The camera electronics are capable of scaling count rates up to 200,000 cps. An automatic peaking feature allows symmetric placement of the pulse-height analyzer window about the photopeak, thereby removing a potential subjective variable in camera setup over a period of time or between different operators. The uniformity of detector response is ±10% across the field of view when the photopeak is properly positioned, and flood-field images appear more uniform than those obtained with the standard size camera. With equivalent parallel-hole collimation the LFOV resolution is slightly less than that of the most recent model (PG/IV) of the standard camera (*1*). However, this difference was not observed in the clinical comparisons.

The field of view of the LFOV was sufficient to encompass both lungs of all 300 patients who had perfusion and ventilation studies. Static perfusion images using ^{99m}Tc-human albumin microspheres (HAM) or macroaggregated albumin (MAA) demonstrate better definition of pulmonary structures than those obtained with conventional low-energy diverging collimation, but a greater enhancement occurs in the photon-limited ^{133}Xe breath-holding images of ventilation and perfusion (Figs. 1 and 2). The three- to fourfold average increase in sensitivity, in comparison with standard diverging collimation, produces a level of resolution for ^{133}Xe in most patients ap-

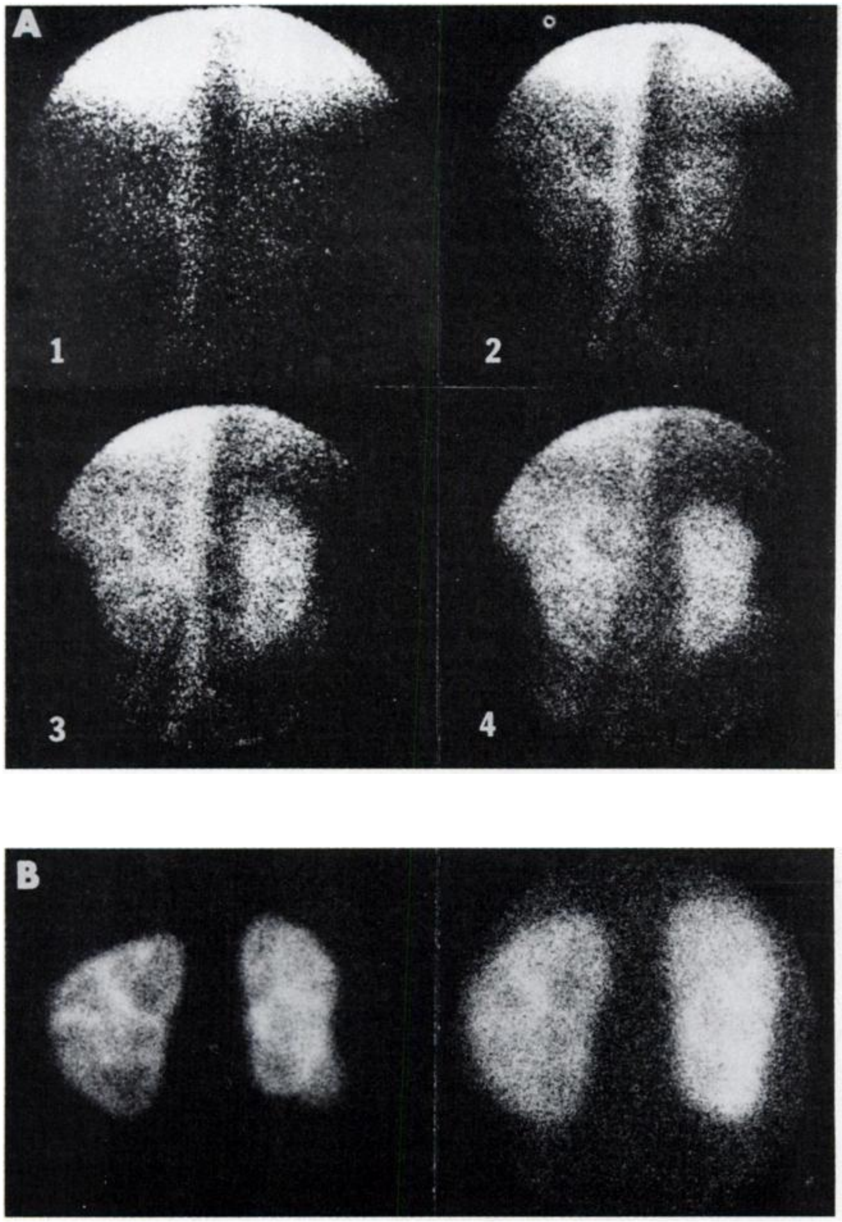

FIG. 8. Renal study using 10 mCi of ^{99m}Tc-DTPA in 25-year-old woman with obstructive uropathy. (A) Sequential 3-sec scintiangiographic images with LFOV and HEC collimator; (B) 400K-count images 3 hr postinjection. PG/HP with high-resolution parallel-hole collimator and LFOV with HRC collimator.

proaching that in static perfusion scintiphotos. In many cases a near-optimal information density can be collected during a single breath-holding interval, thus reducing motion artifact. The increase in sensitivity and field size also make it possible to accomplish total-body surveys in about one-third of the time usually required by the standard camera with equivalent collimation (Figs. 3 and 4).

With a field of view at 4 in. from the collimator surface, which is equivalent to that of the standard size camera with parallel-hole collimation, each of the LFOV converging collimators demonstrates better depth response than similar parallel-hole collimators. Static brain images reveal a marked improvement in resolution for deep structures, with the additional advantage of a 25% reduction in imaging time (Figs. 5–7). As expected, a similar enhancement of image quality is noted for the kidneys (Fig. 8) and for deep-seated lesions within the liver (Fig. 9). For dynamic studies the LFOV converging collimators produce much better images than those obtained with the standard camera, undoubtedly due to the combined effects of increased sensitivity and improved resolution at depth (Figs. 10 and 11).

DISCUSSION AND CONCLUSIONS

Historically, radionuclide images have been information limited due to the relatively low photon emis-

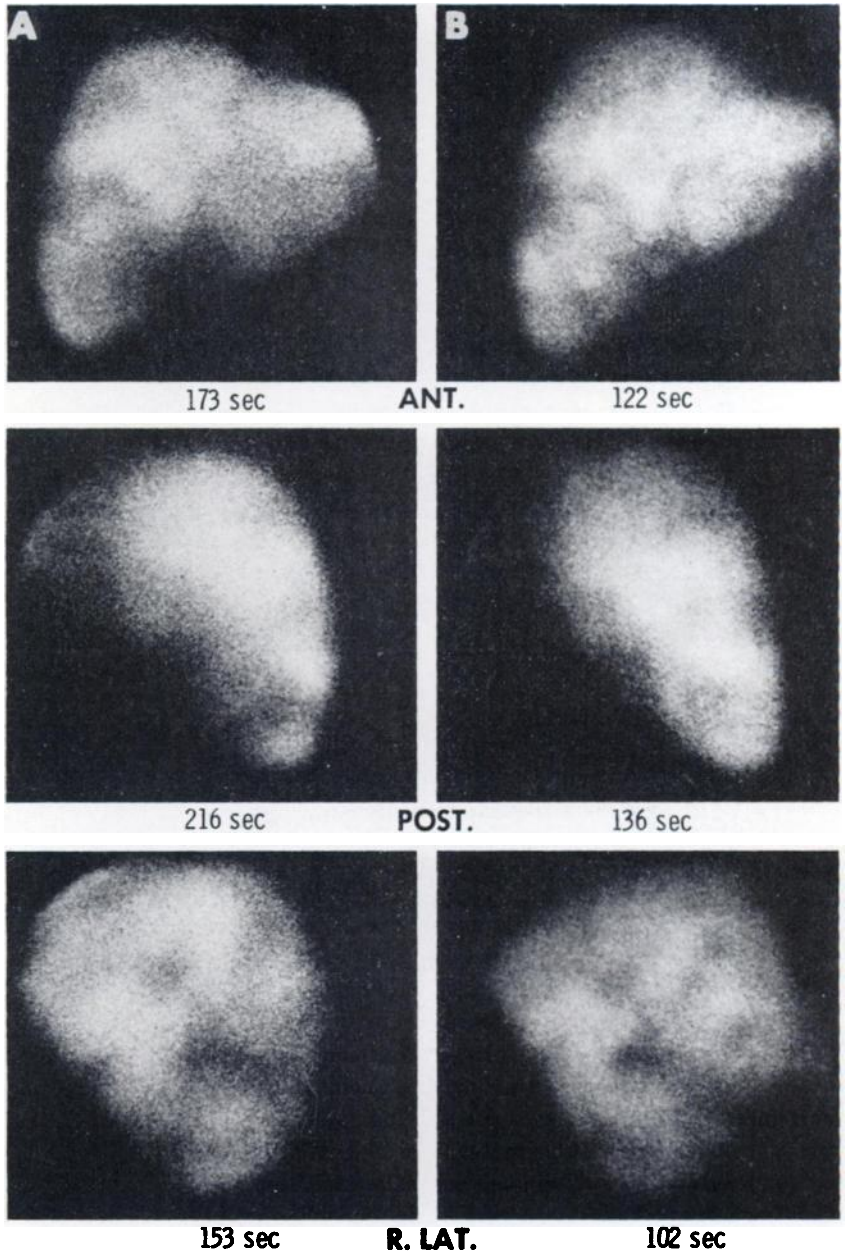

FIG. 9. Comparative ^{99m}Tc-sulfur colloid images (600K counts) in 68-year-old woman with metastatic carcinoma of bladder. PG/IV images with high-resolution parallel-hole collimator (A); LFOV images with HRC collimator (B). Imaging time for LFOV is approximately two-thirds that of the PG/IV.

sion rates from clinically acceptable levels of radiation dosage and the inherently poor efficiency of collimated detectors. In order to use a larger fraction of available photons for imaging, either the fraction of the object viewed at one time by the detector or the geometric detection efficiency for the object must be increased. A large-field-of-view camera with parallel or converging collimation increases photon utilization by both of these mechanisms. For large objects, such as the lungs, bone, and liver/spleen, increased count rates are obtained by viewing either the entire organ or a large fraction of it. For object dimensions smaller than the diameter of the detector, the use of converging rather than parallel-hole collimation results in higher count rates due to enlargement of the solid angle subtended by the irradiated detector.

The clinician is frequently presented with bar phantom resolution studies performed at the surface of a collimator as a basic criterion of camera performance. In reality his diagnostic information depends on the system resolution and sensitivity available at depth as diminished by certain patient variables including motion artifact. The rate of resolution loss with distance from the surface of parallel-hole collimators can be reduced by employing collimation which results in image magnification. The concept of image magnification in nuclear medicine has existed

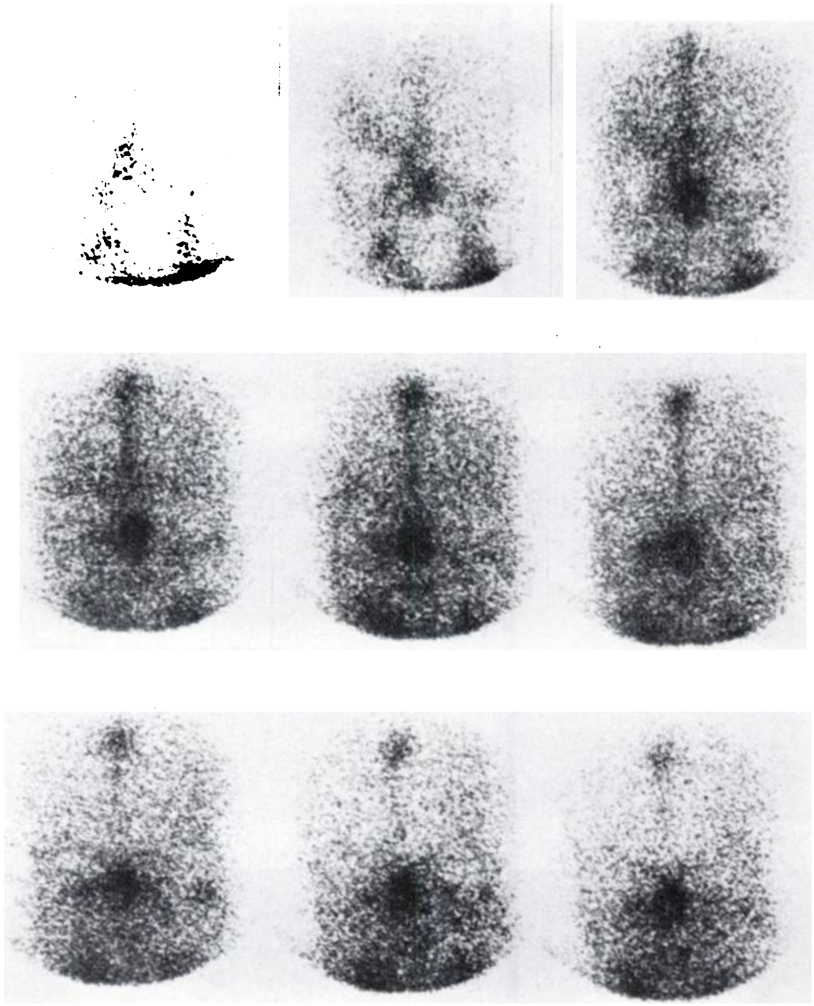

FIG. 10. Anterior cerebral scintiangiographic images (2 sec) after injection of 15 mCi of ^{99m}Tc-pertechnetate, with LFOV and HEC collimator, in 71-year-old man following acute cerebrovascular accident. In addition to decreased left middle cerebral perfusion and "flip-flop," note periorbital external carotid perfusion and "hot nose" sign. Due to increased efficiency, short collection intervals may be used with preservation of good image quality.

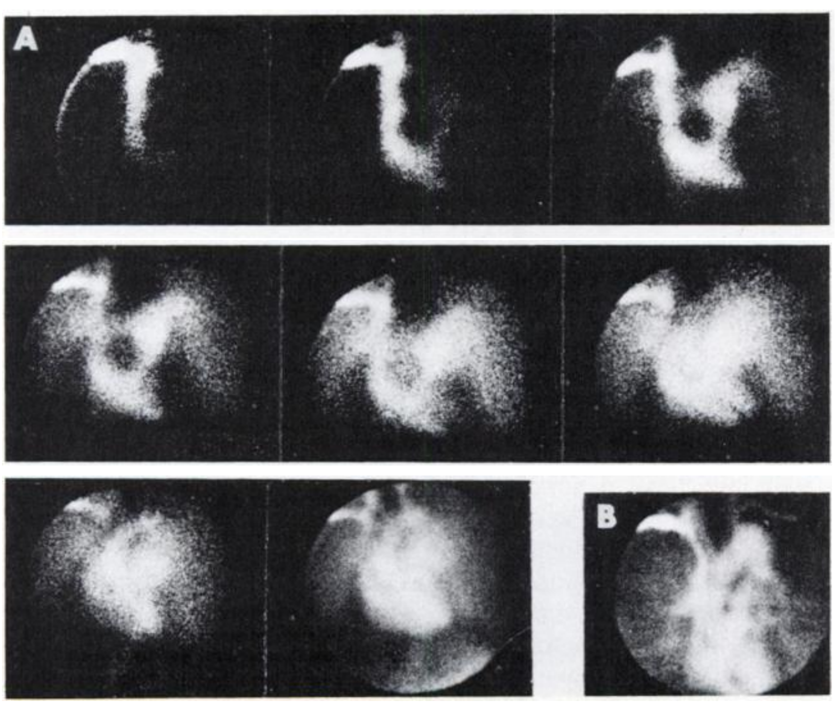

FIG. 11. (A) Cardiac scintiangiogram following injection of 10 mCi of ^{99m}Tc-pertechnetate in 59-year-old woman with pericardial effusion following aortic and mitral valve replacement. Collection intervals of 1 sec with LFOV and HEC collimator. Note vascular detail including interventricular septum. (B) 400K-count pool images with LFOV and HRC collimator.

since the introduction of the initial Anger device which employed pinhole collimation (*2*). Multihole converging collimators also produce image magnification but have the added advantage of increased sensitivity (*3–8*). Experience with an experimental converging collimator for the standard size camera, as reported earlier by this laboratory (*5,8*), suggested that such collimation might have routine clinical applicability when coupled with a larger detector. Since convergence results in a progressive diminution in the field of view with depth, the dimensions of the camera's detector must be sufficient to adequately visualize the object.

The unique characteristics of a large-field-of-view scintillation camera with converging and parallel-hole collimators render it a general-purpose imaging system by permitting maximal application of the large crystal to the regions of interest. With increased resolution and sensitivity, substantial improvement in static image quality for organs such as the brain occurs. In addition, better perception of anatomic structure is gained in radionuclide scintiangiograms, and visualization of the sequential vascular compartments (arterial, capillary, and venous) is facilitated because of shorter allowable collection intervals for each image. The influence of improved counting statistics as well as better resolution obtained with the LFOV high-efficiency parallel-hole collimator over that of the conventional low-energy diverging collimators produces a marked change in the appearance of breath-holding pulmonary ventilation and perfusion images. Also, imaging time is substantially decreased in all patients, thereby tending to reduce motion artifact. Although new approaches to imaging will undoubtedly play an increasing role in future instrumentation, the results of this study indicate that significant further refinement of scintillation camera imaging is possible.

ACKNOWLEDGMENTS

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