Comparison of Ga-67 Citrate Images Obtained with Rectilinear Scanner and Large-Field Anger Camera

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Two methods for Ga-67 citrate imaging were compared on 20 patients. Scans were performed using approximately equal procedure time with two instruments: (A) a dual 5-in. rectilinear scanner with medium-energy collimator, with a single window spanning both the 93-keV and the 185-keV spectral peaks; and (B) a large-field (15-in. diam) Anger camera equipped with moving table, medium-energy collimator, and three windows covering the 93-keV, 185-keV, and 300-keV peaks separately. Sixteen abnormal sites and 24 normal sites were selected for comparison. Each site was evaluated by four physicians experienced in interpreting Ga-67 citrate images. The observers performed significantly better using the images obtained with the large-field camera (three windows) than with the dual 5-in. scanner (single window).

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Gallium-67 was first introduced as a tumor-imaging agent by Edwards and Hayes in 1969 (*1*). It has subsequently gained wide popularity for the evaluation of specific tumors, and more recently for the detection of inflammatory lesions. A major limitation in the clinical application of this radionuclide is the relatively poor quality of the images produced using available imaging devices. Recently, Anger cameras with 15-in.-diam fields have become commercially available, and they can be equipped with three separate energy windows, a medium-energy collimator, and a moving-table attachment. Such instruments should be well suited for the imaging of Ga-67.

The purpose of our study was to compare the diagnostic quality of images obtained at approximately equal procedure time using a conventional Ga-67 citrate imaging instrument and a large-field camera to determine whether the improved quality of the images results in more accurate diagnosis.

MATERIALS AND METHODS

Twenty-four patients underwent clinically indicated Ga-67 citrate scans. Three to five millicuries of Ga-67 citrate were administered intravenously 24 to 96 hr before imaging. (The majority of the images —twelve—were obtained at 72 hr.) Bowel preparation, consisting of a cleansing enema, was given before the imaging procedure.

Each patient had studies performed using (A) a dual-detector 5-in. scanner* with 35M collimator and single wide window covering the 93-keV and 185-keV peaks and (B) an Anger camera† with large field of view, a medium energy collimator, moving table, and three individual 20% windows set over the 93-keV, 185-keV, and 300-keV peaks of Ga-67. The two studies on each patient were performed within 1 hr of each other. The rectilinear scans were set up to provide a count density of approximately 300 counts/cm² over the liver; they required an average of 50 min imaging time for total-body, anterior, and posterior views. The images were

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produced on radiographic film at 1:5 minification. The large-field camera images were obtained with the table moving at its slowest speed, 12 cm/min; two passes, 30-cm wide, were usually required. The posterior views were taken in the supine position; the anterior views were usually prone, with the camera head beneath the table. Each view took an average of 17 min with an average total count of 570,000 per view and a count density of approximately 1,000 counts/cm^2. The change from the prone to supine positions and the resetting of the moving table and camera required about 10 min per patient. Since the change in position was not required for the rectilinear scans, the times required for each instrument were about equal. The camera images were recorded on radiographic sheet film.‡

Twenty of the 24 patients had sufficiently well-documented evaluation of specific anatomic regions by nonscanning criteria to warrant a definite diagnosis of normality or abnormality. The indications for performing the scans on these 20 patients included eleven suspected abscesses, seven staging studies for Hodgkin's disease or other lymphoma, and two suspected hepatic tumors. Forty sites in these 40 studies (20 patients) were selected for observer evaluation: 16 confirmed abnormal sites and 24 normal sites. All abnormal sites were confirmed by either pathologic examination (nine sites), direct surgical observation (two sites), or radiographs (five sites). Eight lesions were inflammatory, seven were tumors, and one was a vascular abnormality. Sixteen of the normal sites were confirmed by similar direct evidence, and eight sites were confirmed as normal by clinical and laboratory followup. Four experienced observers were asked to evaluate each on a scale of certainty from 0 to 5, a zero rating indicating definitely normal and a 5 rating indicating definitely abnormal. The scans were presented to each observer by a monitor who provided the observer with the primary clinical indication for the scan and the site or sites to be evaluated, e.g., "suspected abscess, evaluate the lumbar spine." The images were presented in such a way that the same patients' studies were never presented in sequence.

The data were analyzed in the following manner. Each observer's interpretations with the large-field camera and the dual 5-in. scanner were compared for each site. The response that correlated best with the confirmatory information was recorded as the "superior" response, e.g., if a normal site was rated 1+ on the scanner image and 2+ on the camera image, it was rated as "dual 5-in. scan superior"; an abnormal site rated 3+ on the scanner image and 4+ on the camera image was rated as "large-field camera superior"; equal scorings were rated as "same." The results of this comparison were tabulated for abnormal, normal, and total sites and are listed in Table 1. The results were tested for significance by the chi-square test for paired samples using the Yate's correction (*2*).

TABLE 1. DIAGNOSIS WITH LARGE-FIELD ANGER CAMERA COMPARED WITH A DUAL-HEAD RECTILINEAR SCANNER

	Dual 5-in. rectilinear scanner (single window) superior	Same	Large-field camera with moving table (triple window) superior
Abnormal sites	3	31	30
Normal sites	18	47	31
Total	21	78	61

Performances of four observers examining 24 normal and 16 abnormal sites.

The distribution of counts as a function of energy-window setting was determined in eight patients with the large-field camera centered over the abdomen.

RESULTS

All observers performed better on the images obtained with the large-field camera and moving table than with the dual 5-in. scanner. The results were especially impressive in the detection of positive sites; here the large-field camera was superior in 30 observations compared with three for the scanner. These results were significant at the $p < 0.001$ level. At the normal sites, however, an apparent difference (31 compared with 18 in favor of the camera) was not statistically significant ($0.1 > p > 0.05$). Overall, including both normal and abnormal sites, the observers performed significantly better with the large-field camera than with the dual 5-in. scanner ($p < 0.001$). No case revealed any of the observers performing better with the dual 5-in. scanner images than with the large-field camera images.

The distribution of photons actually detected in the three energy windows of the large-field camera agreed well with expectations based on the physical properties of the radionuclide and the detector and disregarding the effects of scattered radiation. The distribution is shown in Table 2.

DISCUSSION

Instrument sensitivity has been a major factor limitating the quality of Ga-67 scans produced with conventional single-window dual 5-in. scanners and Anger cameras with 10-in.-diam fields of view. One method of circumventing this limitation has been the use of a very wide window on the 5-in. rectilinear

TABLE 2. RELATIVE DETECTION EFFICIENCIES FOR THE 93-, 185-, AND 300-keV EMISSIONS OF Ga-67 USING THE LARGE-FIELD ANGER CAMERA

Energy (keV)	Photons/100 disintegrations	Photons detectable per 100 disintegrations by 0.5-in.-thick NaI crystal	% contribution of each peak to total activity detected from peaks (theoretical)	% contribution of each peak to total activity detected, as measured in 8 patient studies
93	41	41	64	63
185	23	16	25	28
300	18	7	11	9

scanner to include the 93-keV, 185-keV, and occasionally even the 300-keV Ga-67 peaks. However, Bell (P. R. Bell, oral presentation at the Southeastern Chapter Meeting, Society of Nuclear Medicine, Cincinnati, Ohio, 1970) and Harris (C. C. Harris, personal communication) have shown that when such wide windows are used, the inclusion of a significant scatter fraction degrades the image to an extent equal to or greater than the apparent improvement due to higher counting rates. A better but less popular approach involves the incorporation of additional single-channel analysers into the rectilinear scanning device (*3*).

An 80- to 210-keV window bracketing the two peaks at 93 and 185 keV was used with the dual 5-in. rectilinear scanner in this study based on the Performance Index (*4*) criterion, which indicates that this is the preferred window when only one pulse-height analyser per detector is available. (Rollo, F. D., personal communication)

The recent commercial introduction of 15-in., large-field-of-view Anger cameras offers a major improvement in instrument sensitivity for studies involving Ga-67 imaging. At least one manufacturer offers the large-field camera with three individual pulse-height analyzers, a medium-energy collimator, and a moving table. The unit in this configuration has a three- to fourfold advantage in sensitivity over the dual 5-in. rectilinear scanner.

In spite of the obvious theoretical advantages of a high-sensitivity device for Ga-67 imaging, it is still important to prove that the new device is superior to previous instruments. The absence of direct comparisons of new and old techniques has raised controversy, for example, concerning the relative improvement in liver imaging with the Anger camera versus the rectilinear scanner (*5*). Moreover, a major change in instrumentation involves potential differences in many factors, including not only overall sensitivity but specific photopeak sensitivity, scatter rejection, and collimation. Turner (*6*) recommends the use of the receiver operator characteristic curve for such comparisons (*7–11*). Unfortunately, the number of confirmed abnormal lesions in our study was small and there was considerable difference in performance among observers. Those factors hamper the analysis of performance by the ROC curve method. Our data were suitable, however, for evaluation by conventional paired-sample comparison. A highly significant difference in observer performance with images from the two instruments was shown by this method. Between the two systems, the major differences that could be responsible for the differences in observer performance include the difference in the type and resolution of collimator, the selection of energy peaks, and the sensitivities of the two instruments.

Collimation. The dual 5-in. scanner was equipped with 35M collimators. This collimator is designed to have acceptably small septal penetration even at the 394-keV energy of Ga-67. It has a plane of best focus at 10 cm from the collimator face, with 14-mm FWHM resolution in air at that plane. The resolution characteristics for the middle-energy collimator used with the large-field camera are given in Table 3.

Although the composite resolution (triple window) of this collimator is 9 mm (FWHM) at the collimator face, it was quite similar to the focused collimator (namely 16 mm FWHM in air) at 10 cm from the collimator face. In view of the relative similarity of resolution characteristics at depth, and of the fact that the instrument with worse resolution at 10 cm provided the best diagnostic quality in the images, it is doubtful that differences in collimator resolution played a major role in the observed differences in performance.

TABLE 3. SPATIAL RESOLUTION VS. DISTANCE FROM COLLIMATOR FACE FOR Ga-67 IMAGED WITH LARGE-FIELD CAMERA, MEDIUM-ENERGY COLLIMATOR, AND INDIVIDUAL, 20% WINDOWS FOR 93-, 185-, AND 300-keV PEAKS

Distance from collimator face (cm)	FWHM (mm) in air	FWTM* (mm) in air
0	9.0	16.5
5	11.7	23.9
10	15.3	26.6
15	19.2	32.0

* Full width at 1/10 maximum.

Peak selection. The rectilinear scanner was operated with a single wide window covering the 185-keV and 93-keV peaks. The 2-in.-thick crystal will stop virtually all photons at both energies. Therefore, 65% of the detected events should come from the 93-keV spectral region and 35% from the 185-keV region. Included in this window is a substantial amount of scatter. The large-field camera had separate 20% windows bracketing each of the lower three energies of Ga-67. However, the 0.5-in.-thick crystal detects only about 70% of the 185-keV photons as total-absorption events and 36% of the 300-keV photons. It is virtually 100% efficient for the 93-keV photons. When the relative numbers of photons emitted are multiplied by the detection probability, the relative detection efficiency can be determined. Surprisingly, the resulting percent contribution from the 93-keV photon is about 60–65% with both instruments. In the case of the large-field camera, the actual peak ratios were measured and were in close agreement with those estimated (Table 2). Therefore, the relative contributions of the various spectral peaks probably did not have a major effect on the observation differences. However, the increased scatter acceptance by the single wide window of the dual 5-in. scanner did have a degrading effect, no doubt, on these images.

Sensitivity. There are major differences in the sensitivities of the two instruments. The detection area of the large-field crystal is almost five times the combined surface area of the two 5-in. crystals of the scanner. The thicker 5-in. crystals (2 in. versus 0.5 in. for the large-field camera) would improve the relative efficiency for the higher-energy photons but the single-window limitation of the scanner vitiates this potential advantage. Using a sheet source of Ga-67 citrate and the window configurations described in this study, the large-field camera with the medium-energy collimator was four times as sensitive as the two 5-inch detectors with the 35M collimators. Thus, in spite of the fact that the actual imaging time for the large-field camera was 30% less than the rectilinear scan time (34 compared with 50 min), the count density was three times as high.

The finding that the difference in performance was more significant for the abnormal sites than for the normal sites agrees well with the conclusion that the main differences between the two methods result from the greater sensitivity and inclusion of less scatter in the camera images. Scatter diminishes contrast, and a noisy image makes an experienced observer more hesitant to call a lesion. Both conditions would tend to obscure abnormalities to a greater extent than to make a normal region seem abnormal to an experienced observer.

CONCLUSIONS

A significant difference was observed in the ability of experienced observers to diagnose lesions in Ga-67 citrate images when obtained with a large-field camera and triple-window technique compared with the single-channel rectilinear-scan images. The major reasons for this difference appear to be the better photon density of the camera images combined with the smaller amount of scatter accepted by three individual energy windows.

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FOOTNOTES

* Ohio Nuclear 84D, Solon, Ohio.

† LFOV, Searle Radiographics, Des Plaines, Ill.

‡ Searle MicroDot Imager, Des Plaines, Ill.

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