INSTRUMENTATION

Misalignment of Multiple Photopeak Analyzer Outputs: Effects on Imaging. Concise Communication

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With the increased use of gallium-67 citrate and cameras with multiple pulse-height analyzers, the spatially linear response of the camera with respect to simultaneous use of multiple pulse-height analyzers is essential. Nonlinear response will result in spatial distortion and loss of resolution and image contrast. It is not acceptable under these circumstances to pay for increased count density with decreased resolution.

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The introduction of gallium-67 citrate for tumor and abscess imaging has brought about changes in nuclear medicine's primary imaging device, the Anger camera. With the growing acceptance of gallium-67 as a valuable diagnostic tracer, most major manufacturers of gamma cameras are now designing their systems with two or three independent pulse-height analyzers to take advantage of the 93-, 184-, and 296-keV photopeaks of this radionuclide (*1*). Resolution, window widths, count densities, and relative imaging times have been evaluated (*2*). With the use of multiple analyzers and properly designed collimators, the new generation of Anger cameras has established its place in gallium imaging by producing good-quality clinical images with acceptable count densities and resolution (*1–4*).

In our institution we are currently using three Anger cameras that have two or three separate pulse-height analyzers. Each of these cameras is from a different manufacturer. In the course of daily quality control we have noticed that two of these cameras demonstrate multiple edge-packing on intrinsic gallium-67 flood fields (Fig. 1A). This paper will show that under these circumstances the camera's response is spatially distorted when using multiple photopeak analyzers, due to the superposition of misaligned images where each image corresponds to the output from a separate analyzer. Under these circumstances, the images obtained using multiple photopeak analyzers are not equivalent to those obtained by a linear combination of the images corresponding to the three photopeaks of Ga-67, generated one at a time through a single analyzer (Figs. 1–3). This paper studies the effects of multiple misaligned images on spatial distortion, spatial resolution, and image con-

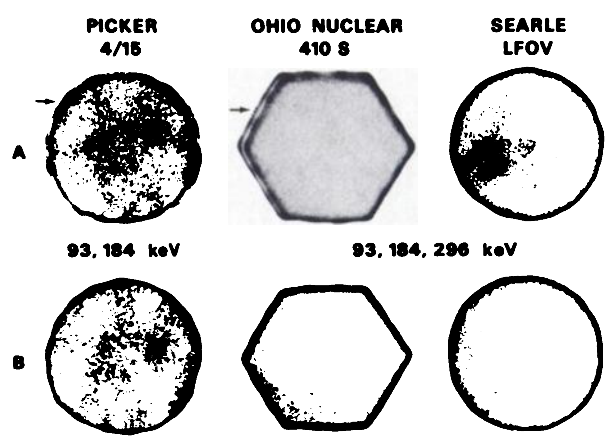

FIG. 1. Ga-67 intrinsic floods. Row A: Simultaneous output of multiple pulse-height analyzers set for Ga-67 photopeak energies listed below camera name. Note multiple misaligned edge packing (arrows). Row B: Same photopeaks of Ga-67 summed one at a time using same pulse-height analyzer, simulating images with perfect alignment.

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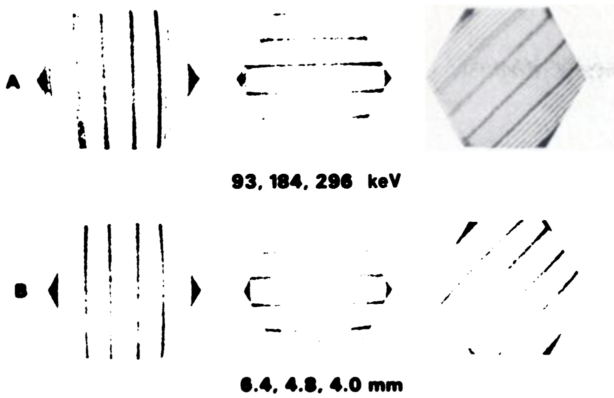

FIG. 2. Intrinsic Hine–Duley bar patterns with Ohio Nuclear 410S. Row A: 93-, 184-, 296-keV photopeaks of Ga-67 imaged simultaneously through three different pulse-height analyzers. Row B: same Ga-67 photopeaks summed one at a time through same pulse-height analyzer, simulating perfectly aligned images. Note spatial distortion and loss of resolution and contrast in Row A when compared with Row B.

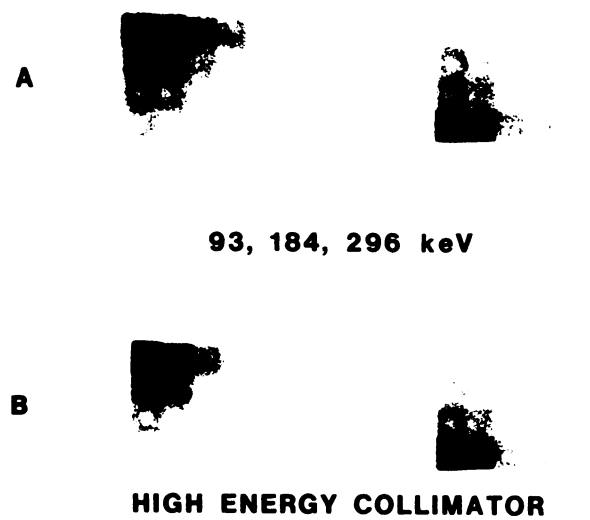

FIG. 3. Ga-67 Rollo phantom with Ohio Nuclear 410S. Row A: 93-, 184-, 296-keV photopeaks of Ga-67 imaged simultaneously through three different pulse-height analyzers. Row B: Same Ga-67 photopeaks summed one at a time through same pulse-height analyzer to simulate images with perfect alignment. Note the loss of contrast in Row A when compared with Row B. Right-hand images were acquired with respect to left-hand images after vertically inverting phantom to illustrate spatial variance in Row A not seen in Row B. (Arrow in upper left corner has no significance.)

trast. This was done by evaluation of (a) the FWHM and FWTM obtained from LSF measurements taken at the surface of the collimator at different positions in the field; (b) intrinsic images of a Hine–Duley bar pattern rotated at different angles; and (c) different images of the Rollo phantom.

MATERIALS AND METHODS

The three Anger cameras illustrated are the Picker 4/15, the Searle LFOV, and Ohio Nuclear 410S. The Picker 4/15 has two pulse-height analyzers. The Searle LFOV and Ohio Nuclear 410S both have three pulse-height analyzers. All cameras are interfaced to a nuclear medicine minicomputer system.

Analog intrinsic flood images were made on each machine using a 100-μCi gallium-67 point source without a shadow shield, to illustrate the absence or presence of nonlinear camera response when using multiple pulse-height analyzers (Fig. 1A). Floods were obtained for 2 million-count images using the multiple pulse-height analyzers simultaneously, and the time of acquisition was recorded. In order to simulate perfectly aligned images, the floods were then repeated by superimposing images of each photopeak energy made with the same pulse-height analyzer (Fig. 1B). The superimposed floods were given the same time as the initial multiple-peak floods, thereby keeping the contribution from each photopeak approximately the same as during the imaging with multiple photopeaks. The Hine–Duley bar pattern images were acquired intrinsically using a shadow shield for 2 million counts each. The Rollo phantom, containing 1.4 mCi of Ga-67, was imaged extrinsically for 1.25 million counts. The bar-pattern and Rollo images were acquired using the same method described for the intrinsic floods. The simulated images done by superimposition illustrate the appearance an image should have if the camera response is spatially invariant (Figs. 1B, 2B, 3B).

Line spread functions were obtained at the surface of the collimator by imaging surgical tubing, 25 cm long and 0.8 mm i.d., containing 15 μCi/cm of gallium-67. The line-source images were acquired in a 128 × 128 matrix using the computer, with a ×2 zoom to achieve an effective 256 × 256 matrix. Initially two line sources spaced 10 cm apart were acquired for 400,000 counts to determine a scaling factor (cm/pixel) for use in evaluation of the FWHM and FWTM values (Table 1).

A single line source (LSF_{123}) was then imaged using all of the pulse-height analyzers simultaneously for 200,000 preset counts, and the image time was recorded (T_{123}). The source was imaged at the center of the collimator and at 5 cm to the left and right of center. The shift of the line source from center was toward the edges of the field that shows maximum and minimum edge-packing misalignment (Fig. 1).

Simulated images of the line source (LSF'_{123}) were obtained by repeating measurements at the same positions, with 200,000 counts for each of the three major photopeaks of gallium, one at a time, using the same pulse-height analyzer. The imaging times T_1, T_2, and T_3 were recorded corresponding to the 93- (LSF_1), 184- (LSF_2), and 296-keV (LSF_3) photopeaks, respectively.

Assuming a linear camera response (*2*):

$$LSF_{123}(x,y) = LSF'_{123}(x,y) = \sum_{i=1}^{3} \frac{T_{123}}{T_i} LSF_i(x,y)$$

TABLE 1. FWHM and FWTM RESULTS*

	Toward misalignment X = −5 cm		Crystal Center X = 0		Away from misalignment X = +5 cm	
	FWHM (cm)	FWTM	FWHM (cm)	FWTM	FWHM (cm)	FWTM
Simultaneous output of three analyzers	1.4	2.2	1.1	1.8	0.9	1.6
Summed output of three photopeaks using same analyzer	0.9	1.5	0.9	1.5	0.9	1.5

* All values quoted in table are for the Ohio Nuclear 410S (see Fig. 1A).

The FWHM and FWTM were evaluated for each LSF_{123} generated by simultaneous output of multiple pulse-height analyzers and for each simulated LSF'_{123} generated by a linear combination, as expressed mathematically above, of the three individual photopeaks imaged with the same analyzer.

RESULTS

It is clear that the gallium-67 point-source floods of two of the three cameras (Fig. 1A) demonstrate multiple edge packing. Using one of these cameras (ON 410S) to illustrate the effects of misaligned images from multiple pulse-height analyzers, we have shown spatial distortion, with loss of contrast and resolution relative to simulated images obtained assuming perfect alignment of the output from each pulse-height analyzer. The results are as follows:

1. Loss of resolution indicated by the degradation of the FWHM (Table 1) and the Hine–Duley bar pattern (Fig. 2).
2. Loss of contrast indicated by the degradation of the FWTM (Table 1) and the Hine–Duley bar pattern and the Rollo phantom (Fig. 3).

Note also that the degree of degradation is spatially variant (x-y-dependent) as demonstrated by these results.

DISCUSSION

The purpose of this paper was not to compare the resolution characteristics of three cameras for gallium-67, but to demonstrate the effects of nonlinear camera response with respect to each analyzer. Accordingly, quantitative results (Table 1) are given for only one of the three cameras. The loss of system resolution, image contrast, and the extent of spatial distortion will depend on the varying degrees of superimpositional relation of the images from the individual analyzers.

We feel that with increasing use of multiple-analyzer gamma cameras for such radionuclides as In-111, Tl-201, and Ga-67, it is important to check periodically the linearity of camera response with respect to the analyzers (*1*). This is easily done with a point-source flood image without the use of a shadow shield. Furthermore, the use of a misaligned system is not acceptable, since the increased count density does not compensate for image degradation.

REFERENCES

1. HENKIN RE: The good, the quick, and the inexpensive. *J Nucl Med* 18:1131–1133, 1977
2. GARCIA EV, KILANOWSKI G, MIALE A: Gallium-67 imaging performance for scintillation-camera systems. *Appl Radiol* 7:125-128, 1978
3. HOFFER PB, SCHOR R, ASHBY D, et al: Comparison of Ga-67 citrate images obtained with rectilinear scanner and large field Anger camera. *J Nucl Med* 18:538–541, 1977
4. SIEMSEN JK, GREBE SF, WAXMAN AD: The use of gallium-67 in pulmonary disorders. *Semin Nucl Med* 8:235–249, 1978