Articles

Importance of Correct Photopeak Setting in Nuclear Medicine Imaging Procedures

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Most scintillation camera systems currently use an analog display for photopeak selection. A systematic evaluation of this peak setting procedure was undertaken to investigate its accuracy and effect upon the resultant image. The scintillation camera we selected provided both an analog and a multichannel analyzer (MCA) display of the spectrum. For each data collection, the investigator set the Co-57 peak symmetrically using the MCA. Polaroid images were taken of the resultant field flood. Several technologists were then asked to set the Co-57 peak using the analog display; additional Polaroid images were obtained of the ensuing field floods. The field flood images thus obtained were given to a panel for evaluation. The panel ranked as "best" those field flood images taken with the peak symmetrically aligned. In addition, a series of patient images was obtained at various peak settings. When this series was evaluated by the panel, the patient images obtained with the peak set too high were judged to be of unacceptable diagnostic quality. The accuracy needed for a diagnostically useful image is often not achieved by using an analog display for photopeak setting. The use of an MCA enables an accurate and objective method of selecting the peak.

The diagnostic quality of an image strongly depends on how well details are distinguished in the image. In the field of radionuclide imaging, the one-to-one mapping of a distribution of radioactivity is of primary concern. Scattered radiation does not contribute to one-to-one mapping and hence distorts the image.

The most commonly used radionuclide in nuclear medicine today is Tc-99m, which emits 140-keV photons. The scattering cross-section for photons of this energy is not negligible in tissue; minimizing this effect is essential to preserve image fidelity. Since the NaI (Tl) crystals used in scintillation cameras have an energy resolution of about 15% in the 140-keV region, the elimination of scattered photons is not realizable in practice if the efficiency of the system is to remain reasonably high.

Thus, a trade-off is made between "efficiency" and "quality" in a scintillation camera system. In fact, one may speak of an optimal window that will result in the best image under the conditions for a given scattering situation. Studies have shown that for optimum quality of the image, both the window width and the photopeak setting should be carefully chosen (*1, 2*).

An objective method of correct photopeak setting in daily nuclear medicine practice will eliminate factors that lead to technically unsatisfactory image studies because of the effect of scattered photons. We systematically evaluated the accuracy and effect of the photopeak (hereafter referred to as peak) setting procedure as it is performed most frequently in clinical nuclear medicine practice. This procedure involves visual inspection of an analog display; the technologist subjectively adjusts the spectrum so that the peak falls within a preselected window. We assumed that there were no problems with uniformity inherent in the camera electronics as peak position was varied.

Materials and Methods

We selected an Ohio-Nuclear Series 100 scintillation camera for this study because of its capability to provide both analog and MCA displays of the spectrum. The high sensitivity parallel-hole collimator was attached to the camera, and a 3-mCi Co-57 solid disk flood source

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obtained from Amersham-Searle Corp. was used in data collection. To simulate tissue-equivalent scattering, a 2-in thick piece of Masonite was used to cover the useful field of view of the camera. Scattering material was added because technologists at the University of Cincinnati Medical Center generally used the patient as a source to set the peak at the time of our study.

For data collection, the camera head was rotated upward and the tissue-equivalent scattering material positioned directly on top of the high sensitivity collimator; the Co-57 disk source was placed on top of the scattering material. A window width of 20% was selected, and symmetric centering of the Co-57 peak in the window was obtained using the MCA. The photopeak centerline setting was recorded and retained for Polaroid images of this spectrum, the analog display, and a 500,000-count field flood (Fig. 1). This peak setting was termed the "master" setting for that day's observations.

Several staff technologists with clinical experience ranging from 1 to 14 years were asked to set the Co-57 peak using only the analog display. Without changing any technologist's setting, a spectrum was obtained using the MCA. Polaroid images of the spectrum, the analog display, and a 500,000-count field flood were then obtained. The technologist's setting was recorded for later comparison with the master setting. This procedure was followed on ten separate days by seven staff technologists. Each technologist was not able to participate on each occasion but a total of 63 observations was made.

The variability of peak setting was defined in the following manner:

Percent shift =

$$\frac{\text{master setting} - \text{technologist setting}}{\text{master setting}} \times 100.$$

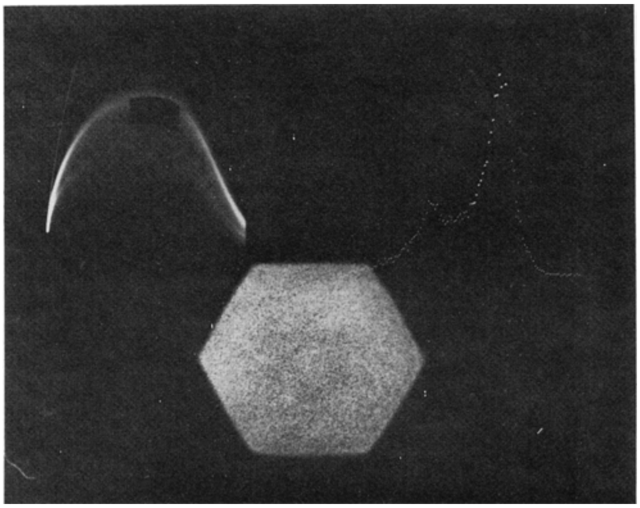

FIG. 2. Images illustrate negative percent shift (−1.2%).

A negative percent shift indicates that a technologist's setting was higher than that of the master. This has the effect of placing the photopeak higher in the window and consequently more scatter photons contribute to the image. The analog display, MCA spectrum, and field flood resulting from such a shift are shown in Fig. 2. A positive percent shift results when a technologist selected a lower setting than that of the master. Corresponding images are shown in Fig. 3. The mean and standard deviation of the percent shift values were calculated for each technologist's results.

To evaluate the field flood quality as a function of peak setting, a 500,000-count field flood image was obtained at each technologist's peak setting and at the master setting for two separate days. Both sets of eight images each were circulated to a panel consisting of five nuclear medicine physicians and six nuclear medicine scientists.

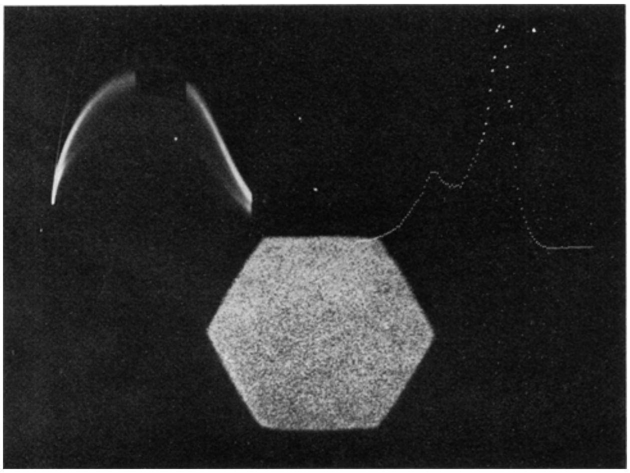

FIG. 1. Images of analog display, MCA spectrum, and 500,000-count field flood taken at master photopeak setting.

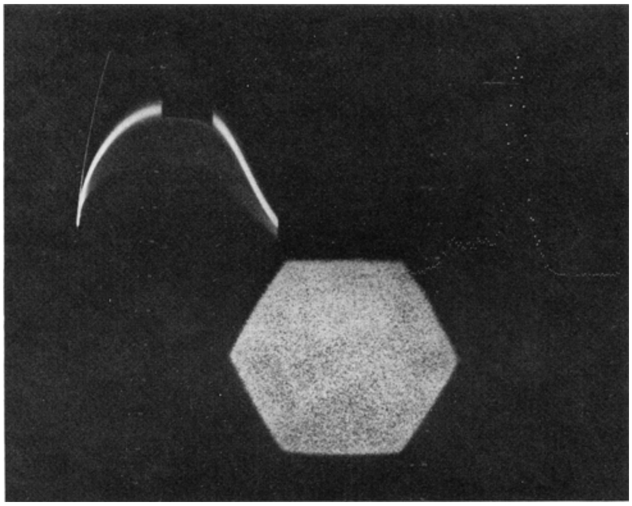

FIG. 3. Images illustrate positive percent shift (+1.2%).

Each member of the panel was asked to rank the field flood images in order of preference with No. 1 being "best" and No. 8 being "worst". This permitted a total possible score of 11 for the best field flood image with a possible score of 88 for the worst image. The readers were also asked to indicate whether any field flood images were equal in quality.

In order to evaluate the reproducibility of field flood quality, a third set of four field flood images taken consecutively at the master peak setting was obtained. This set was circulated to a nuclear medicine physician and four nuclear medicine scientists. In this case, the best possible score was 5 and the worst possible score 20. Again, the readers were asked to indicate if they judged any images as equal.

An additional series of images was obtained to investigate further the importance of correct peaking in the true clinical situation. These images were obtained from four patients who were already in the laboratory for brain, liver, bone, and lung imaging procedures. Without moving the patients, images were taken at the correct peak setting and at both the −1.5% and +1.5% shift settings. These four sets, of three images each, were given to five nuclear medicine physicians, who were told that each set contained a presumably normal study and were asked to rank the images according to clarity of anatomical structures and reflection of a normal study. A score of one was given to the best image in the set and a score of three was given to the worst. The total possible score for the best images was 20, and the worst images had a total possible score of 60.

Results and Discussion

The calculated percent shift values for each technologist's settings are shown in Table 1. The mean and standard deviation for each technologist are indicated on the table. Note that the individual percent shift values range from −1.5% to 2.2%, and the mean percent shift values range from 0.1% to 1.4%. The majority of the observations favored a positive percent shift, indicating a tendency to set the peak too low when using only the analog display.

The analog displays shown in Figs. 1, 2, and 3 illustrate the difficulty in setting the peak accurately when using this type of display. Indeed, there is little difference in the analog displays seen in these three figures. The poor quality field flood images, which result from incorrect peak setting, are shown in Figs. 2 and 3.

When the two sets of field flood images were ranked by the 11-member panel, the image obtained at the master peak setting was rated as best in both sets. In each set the image obtained at the greatest shift, whether positive or negative, was rated the worst. The scores of all images in both sets are listed in Table 2. Scoring indicates that images obtained with a too low peak setting were judged to be poorer visually than those obtained with a too high setting. The exception is image I in set 2 (Table 2) in which the technologist's peak setting was very much greater than the master setting.

Note image M in set 1 (Table 2). The field flood image was obtained at the same peak setting as the master image. However, none of the panel rated it first or even second; it ranked fourth in the overall scoring. This situation prompted the circulation of the third set of four supposedly identical, field flood images to a five-member panel. Only one person rated all four images equally. Two persons rated three of the images as equal, and the other two persons rated all four images differently. Our close inspection of these images revealed some slight but discernible differences. This nonreproducibility of supposedly identical field flood images may explain why case M in set 1 (Table 2) received a mediocre ranking.

TABLE 1. Percent Shift Values for Seven Technologists' Observations

1	2	3	4	5	6	7
1.5	−1.2	1.4	0.3	0.2	1.2	0.0
2.2	1.2	1.7	0.2	−0.2	1.5	0.7
1.8	−0.2	1.5	0.5	0.0	0.9	0.3
1.7	0.5	1.4	0.6	−0.2	1.2	0.2
1.3	−0.3	1.2	1.0	0.5	−0.8	0.0
1.4	0.0	1.7	1.2	1.2	−0.2	−0.1
0.8	0.4	0.7	0.7	−0.4	−1.5	−0.2
1.5	0.0	1.0	0.8	-	1.2	0.7
1.2	0.4	1.3	0.7	-	-	0.6
1.0	-	-	0.4	-	-	0.2
$\bar{X}$ = 1.4	0.1	1.3	0.6	0.2	0.4	0.2
1 s.d. = 0.40	0.66	0.32	0.31	0.55	1.12	0.33

$\bar{X}$ = mean; "-" = no observation.

TABLE 2. Scoring of Field Flood Images

Set	Image	Percent Shift	Total Score
1	A	Master	13
	K	−0.8	24
	O	−0.3	33
	M	0	40
	N	0.5	58
	L	1.0	62
	J	1.2	80
	P	1.3	84
2	B	Master	13
	D	−0.2	22
	H	−0.4	41
	C	0.8	42
	F	0.4	46
	E	0.7	66
	C	0.7	73
	I	−1.5	88

The means and two standard deviations of all observers' scores for each field flood image are shown (Fig. 4). The solid curve represents a least-squares parabolic fit to this data. Assuming that the calculated means of these scores represent samplings of a normal distribution for each percent shift, then at the 95% confidence level for an absolute percent shift ≥ 1.0, significant differences in field flood quality might be expected.

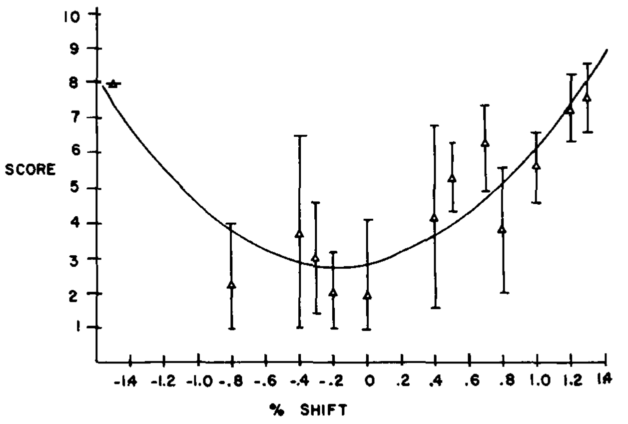

FIG. 4. Graph of means and 2 s.d. of observers' scores for each percent shift value of field flood images. Zero percent shift equals master photopeak setting.

When the clinical images were ranked by the five-member physician panel, the total scores were 36 for images obtained at the correct peak setting, 34 for those obtained with a +1.5% shift, and 51 for the −1.5% shift images. This indicates that in the clinician's judgment, there is no apparent difference between clinical images obtained at the correct peak setting and at a +1.5% shift. However, the images obtained at a −1.5% shift were judged to be of unacceptable diagnostic quality.

A negative percent shift results in more scatter photons contributing to the image (Fig. 2). This in turn produces blurring of anatomical structures, which may explain the low ranking of these images. On the other hand, images obtained with a positive percent shift do not have increased scatter with resultant blurring, so it is feasible that these clinical images could be ranked as being as good as those obtained at the correct peak setting.

The effect of incorrect peaking on a field flood differs from its effect on a clinical image. The effect of scatter on a field flood image is not so noticeable because there are no structural outlines to become blurred. This may explain why a negative percent shift is of greater consequence on the clinical images than on the field flood images.

Summary and Conclusion

While the majority of today's scintillation cameras use an analog display for radionuclide peak setting, we have shown that it is difficult, if not impossible, to peak accurately using this type of display. This in turn contributes to inter- and intra-technologist variability. Even a small change in peak setting makes a visual difference on the field flood and such changes can also affect the clinical situation.

As we used only one scintillation camera, one should not assume that a similar degradation of uniformity occurs in all other cameras. This may not be true or, indeed, others may be worse. In either case, these results should not be directly extrapolated to cameras of different types.

We conclude that peak setting using the analog display often results in sufficient window misalignment that produces noticeably inferior floods. The more extreme window misalignments appear to have a noticeable effect on clinical image quality. Therefore, a more objective and accurate method of peak setting is required. Both objectivity and accuracy can be achieved through the use of a multichannel analyzer.

References

1. Rollo FD, Schulz AG: Effect of pulse-height selection on lesion detection performance. *J Nucl Med* 12: 690–696, 1971

2. Sanders TP, Sanders TD, Kuhl DE: Optimizing the window of an Anger camera for ^{99m}Tc. *J Nucl Med* 12: 703–706, 1971

ERRATUM

In the article entitled "Technical Aspects of I-125 Fibrinogen Testing for Detection of Deep Venous Thrombosis" by Vincent L. Sgroi and Kenneth M. Moser (*J Nucl Med Tech* 6:65-68, 1978), the first sentence of the second paragraph under the heading Method (p 65) should read as follows:

Blockade of the Thyroid. The estimated absorbed radiation dose to the unblocked thyroid of an average patient (70 kg) from an intravenous injection of 100 μCi of I-125 is 1.3 rad (*2*).