The Effect of Photon Energy on Tests of Field Uniformity in Scintillation Cameras: Concise Communication

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Although Co-57 is generally used for testing the field uniformity of scintillation cameras, the various photon energies of other radionuclides require uniform response throughout the entire range of energies to which a scintillation camera can respond. The use of Co-57, however, may not adequately demonstrate the field response, which may be uniform at 122 keV but not at other energies. Two scintillation camera systems were investigated in this regard by storing field-flood images, obtained at several photon energies, in a minicomputer. The stored data were analyzed using the Kolmogorov-Smirnov test, revealing that field uniformity may change with photon energy. One of the scintillation cameras showed a variation in field response with photon energy, whereas the other camera did not. These results, however, should not be extrapolated to other cameras of the same type. If a particular scintillation camera is to be used routinely with several energies, its performance should be tested with each one to provide assurance that valid information is being obtained. The effects of dynamic uniformity field correction remain to be evaluated.

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For the testing of scintillation cameras for field uniformity, a source of Co-57 is generally used because its main photon energy is near that of Tc-99m, and its 271-day half-life allows long usage. However, although many clinical studies are obtained with Tc-99m, others may be performed using radionuclides of various energies. Since the value of clinical studies to the patient depends upon the validity of information presented to the physician for interpretation, it is important to determine the effect of photon energy on a camera's field uniformity. Although commercially available data systems now provide a means of field uniformity correction, this practice can occasionally produce clinically significant artifacts (*1*). Hence, an inherently uniform response of the camera field is essential.

In 1974, Hannan and Bessent reported that relatively small changes in photon energy resulted in large changes in uniformity (*2*). When they used a Nuclear Enterprises Scinticamera IV, a change from Co-57 to Tc-99m resulted in a 16% change in uniformity of detector response. Jansson and Parker in 1975 tested the energy dependence of detector uniformity using a Searle Radiographics Pho-Gamma HP scintillation camera (*3*). They reported a change in uniformity when energy is varied over a *wide* range, but did not observe significant changes in uniformity between Co-57 and Tc-99m. Recently, Hasman and Groothedde reported no significant energy dependence in a Picker Dynacamera 2C detector (*4*). However, they also stated that no general conclusion can be drawn from the available data, and each nuclear medicine center should check the factors affecting uniformity for that center's particular scintillation cameras.

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MATERIALS AND METHODS

We investigated the effect of photon energy in testing field uniformity using two cameras of types not previously reported in the literature. They will be referred to as Camera A and Camera B. Both camera systems are interfaced with a Medical Data Systems minicomputer. Uncollimated field-flood images were obtained with radioactive point sources of approximately 2 mCi each, having energies ranging from 81 to 662 keV. This range more than encompasses the photon energies of radionuclides currently used in scintillation camera imaging. The point sources were placed 5 ft from the detector; the detector was in the horizontal position, and no scattering material was used. Images of 5 million counts at the 20% window setting were obtained in each case and stored in the minicomputer for later comparison with the Co-57 image, which was used as the "standard." These images were obtained at approximately 250,000 cpm. This method of data collection was repeated 15 times for Camera A and 17 times for Camera B for each energy.

The count distribution data over the field of view of the stored images were analyzed by applying the Kolmogorov-Smirnov test, which compares the cumulative distribution functions of two samples (*5,6*). The field-flood area for analysis was first defined by superimposing a mask that eliminated counts resulting from edge packing. Within this defined area, the error on each cell was ±5%. Work published by Cohen et al. in 1976 indicates that the level of visual detectability of nonuniformity is 10–12% (*7*). The count distributions were then compared in 9-cell squares, a size that corresponds to a 1.5 cm^2 area.

The Kolmogorov-Smirnov approach tests the hypothesis that two independent samples have been drawn from the same population—or from populations with the same distribution. This is done by examining the maximum difference in the cumulative distribution functions of the two samples. The maximum difference is then compared with the critical value that is calculated for the desired level of significance. If the maximum difference is greater than the critical value, the hypothesis is rejected. But if this difference is less than the critical value, the hypothesis is accepted, and the population distributions are considered identical. This test is completely distribution-free for any continuous common population distribution. That is, no assumptions are made regarding the homogeneity of variance among the individual cells. All of our data were tested at both the 0.05 and 0.01 levels of significance. The Kolmogorov-Smirnov two-sample test is represented mathematically in Table 1.

TABLE 1. KOLMOGOROV-SMIRNOV TWO-SAMPLE TEST

Null hypothesis

$$H_0: F_1(x) = F_2(x)$$

Test statistic

$$D_{n_1 n_2} = \max|F_{n_1}(x) - F_{n_2}(x)|$$

Critical value

$$\alpha = 0.05: 1.36\sqrt{\frac{n_1 + n_2}{n_1 n_2}}$$

$$\alpha = 0.01: 1.63\sqrt{\frac{n_1 + n_2}{n_1 n_2}}$$

The application of the Kolmogorov-Smirnov test tells us whether or not the count distribution of a field-flood image is the same as that obtained under identical conditions with the Co-57 standard. It does *not* tell us anything about the absolute uniformity of detector response. In other words, although the images obtained with the various radionuclides could be the same as that of Co-57, they *could* all be consistently nonuniform. It was necessary, therefore, first to determine the uniformity of the Co-57 field-flood image obtained at each data collection. To do this, we applied the Medical Data Systems "QUAL" program to the Co-57 image stored in the minicomputer. This program provides a simple and precise method of monitoring the field-uniformity performance of a scintillation camera. The method of calculation used in the program has been described by Keyes (*8*). In the program, the operator designates the acceptable limits of ±5%. At each data collection, this procedure was used to verify the acceptable uniformity of the Co-57 field-flood image before proceeding to image collection with the other radionuclides. With both Camera A and Camera B, the uniformity of detector response was within acceptable limits at each data collection.

Having first ascertained the detector uniformity with Co-57, the Kolmogorov-Smirnov test was applied to determine the similarity of the count distributions obtained with the various radionuclides. A field-flood image obtained with a particular radionuclide is said to "pass" the test when the hypothesis is accepted, that is, when the count distribution of that radionuclide's field-flood image is the same as that obtained with the Co-57 standard at the same level of significance.

RESULTS

Fifteen data collections were obtained on Camera A on three separate days, and the test results for

TABLE 2. NUMBER OF "PASSES"* RELATIVE TO Co-57 STANDARD

Photon energy (keV)	Radio-nuclide	Level of significance	Camera A (N = 15)	Camera B (N = 17)
122	Co-57	.05	15	17
	(standard)	.01	15	17
81	Xe-133	.05	0	17
		.01	0	17
140	Tc-99m	.05	10	15
		.01	10	17
279	Hg-203	.05	10	17
		.01	10	17
392	Sn-113–	.05	5	17
	In-113m	.01	5	17
514	Sr-85	.05	0	10
		.01	0	17
662	Cs-137	.05	5	17
		.01	10	17

* "PASS" = Count distributions of field-flood images are the same (hypothesis is accepted).

the individual radionuclides are listed in Table 2. Note that the count distributions of the field-flood images obtained with the various radionuclides often differed from that obtained with the Co-57 standard. In addition, the Kolmogorov-Smirnov test was applied to consecutive Co-57 images obtained on three separate occasions. The count distributions of these *standard* images were always the same as each other at both levels of significance. This fact underscores the validity of the test results obtained with the other radionuclides.

For Camera B, 17 data collections were obtained on four separate days. The Kolmogorov-Smirnov test was applied to the consecutive Co-57 images obtained on Camera B, again indicating that the count distributions of these standard images were the same. When the field-flood images obtained with the other radionuclides were tested relative to the Co-57 standard, the results indicated that the count distributions were nearly always the same regardless of photon energy. The individual test results for Camera B are listed in Table 2.

DISCUSSION

The results of this investigation indicate that these two scintillation cameras have different characteristics with respect to variation in uniformity with photon energy. It appears that the use of a Co-57 source to check the field uniformity of Camera B *is* valid. That is, once uniformity has been ascertained using Co-57, one can be reasonably confident that clinical studies obtained with radionuclides of other photon energies have been obtained on a uniform field, and valid information is being presented to the physician for interpretation. Camera A's test results, on the other hand, indicate that for this camera a change in photon energy results in some change in uniformity, and the use of a Co-57 source is not suitable for testing field uniformity in response to other radionuclides. Furthermore, in order to be assured that valid information is being obtained on this scintillation camera, the radionuclide used to test uniformity should be the same as that used in the clinical study.

CONCLUSION

Quality assurance testing for scintillation cameras as practiced in nuclear medicine today uses the field-flood image as a basis for judging the validity of clinical data. Common practice among manufacturers is to tune a scintillation camera for uniformity at 140 keV. Maintenance of field uniformity at different energies after such tuning is an extremely important property of a scintillation camera. This investigation reveals that field uniformity response does differ with photon energy for the two cameras evaluated. Since we examined only one scintillation camera of each type, no conclusions should be made about other cameras of the same type. This factor should be confirmed for each scintillation camera, regardless of type or manufacturer.

Related questions are arising with the advent of dynamic uniformity field-correction capabilities. Since most manufacturers use the 140 keV of Tc-99m to tune for field uniformity, can a Co-57 flood at 122 keV be used validly to field-correct clinical studies obtained at 140 keV? Even if the flood used for field correction is obtained with the same radionuclide as that used for tuning, can one be assured that field correction of clinical studies obtained at widely different photon energies—e.g., the 81 keV of Xe-133 and the 364 keV of I-131—is indeed valid? The dynamic uniformity field-correction capability was not available on either scintillation camera evaluated in this study, and the authors are not prepared to answer these questions at this time. This very important area of investigation remains to be explored.

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