Assessment of Camera Uniformity Using a Dynamic Line Phantom

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A commercially available dynamic line phantom has been investigated for its suitability as a quality control tool for assessing scintillation camera uniformity. A nonuniformity was found to be introduced due to count rate losses. These losses were caused by the variation in the length of the line source exposed to a circular detector as the source was scanned across the camera face. Although the handling of the line source reduced the radiation hazard to which personnel would be exposed, the uniformity flood images produced by the phantom were unacceptable and could certainly not be used for uniformity correction in single-photon emission computed tomography (SPECT) imaging. The dynamic line phantom can also be programmed to produce several different line source resolution and contrast patterns. Under the test conditions some of these resolution patterns were too fine to be useful but could perhaps be of more value with more modern cameras.

A comprehensive quality control program for scintillation cameras requires a multiplicity of phantoms ranging from flood field phantoms to resolution bar phantoms. The increasing application of SPECT has resulted in greater use of flood phantoms to obtain uniformity correction matrices. In 1983, LaFontaine et al. (*1*) reported on the radiation doses received by personnel using flood phantoms and suggested steps to be taken to reduce this dose. They recommended the use of cobalt-57 (^{57}Co) sheet source phantoms, but, besides being expensive, the uniformity may not be adequate for SPECT quality control. The dynamic line phantom—a line source of activity which is moved at a constant speed across the face of the camera—has also been suggested.

MATERIALS AND METHODS

The Dynamic Line Phantom DLP-101 is a commercially available system* designed according to the descriptions of Deconinck and Verzelen (*2, 3*). Briefly, the DLP-101 phantom consists of a line source on a movable carriage mounted on a base. The carriage movement is regulated by a microprocessor-controlled stepping motor with 100:1 variable speed range. The line source of activity (0.1 mm diameter) mounted on the carriage can be made to scan across the face of the scintillation camera at either a constant or variable speed. By appropriate programing of the microprocessor, several resolution and contrast bar phantoms can be simulated. With the addition of a lead shield with regularly spaced holes, additional test patterns can be produced. Forward scattering conditions can be created by using a scatter block placed on top of the line source.

A total of eighteen functions are possible, of which two remain available for future development. The sixteen presently available functions are: resolution hot lines; resolution cold lines; positioning; center line; variable contrast LFOV and SFOV; dynamic range LFOV and SFOV; homogeneous field (low counts) LFOV and SFOV; homogeneous field (high counts) LFOV and SFOV; MTF; BRH; PLES; and Hine-Duley.

To assess the utility of this phantom, the DLP-101 was compared to a ^{57}Co sheet source phantom and a standard technetium-99m (^{99m}Tc) intrinsic flood phantom using a point source of activity. Two LFOV cameras were employed, each equipped with a low-energy, all-purpose collimator.†‡ According to specifications, the 0.4-ml line source is to be loaded with 1.08 mCi (40 MBq) of activity for a low-count rate flood. This is usually accomplished with the aid of the filling attachments that are subsequently replaced by tube sealing plugs. It is easy to ensure that the activity is evenly distributed along the length of the tube and this can be checked by taking a profile of the counts along the line source. However, this level of activity fails to provide sufficient counts for statistical validity even if the high count flood mode is used. Since the speed of the scanning motion cannot be reduced, we employed a 10.8 mCi (400 MBq) activity of ^{99m}Tc which gave ~30K cps in the center of the field of view using a 20% energy window and a general purpose low-energy collimator.

Under microprocessor control, the line source scanned the field of view in approximately 5 min, resulting in ~5 million counts for the low count homogeneous field function. The high count scan was obtained by making six passes of the line

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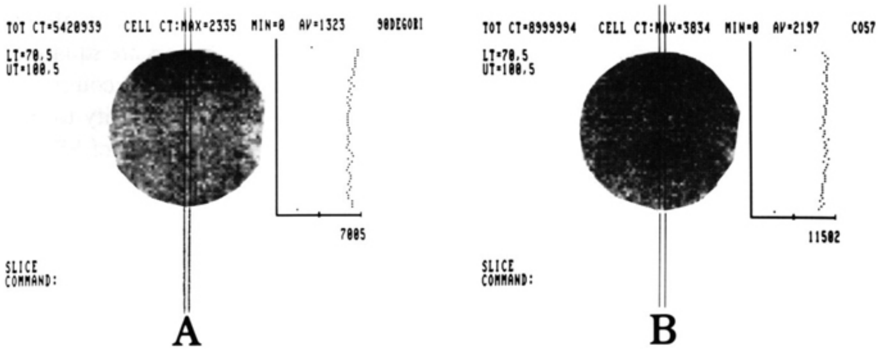

FIG. 1. (A) Uniformity flood field obtained using dynamic line phantom and GE-400AT camera. Count profile demonstrates loss of counts in central part of scan which was from top to bottom. (B) Uniformity flood from same camera obtained with ^{57}Co sheet source. Similar count rate profile shows flatter response.

source in front of the detector at the same speed used for the low-count scan. Intrinsic and extrinsic uniformity flood images were obtained using a point source of ^{99m}Tc and a sheet source of ^{57}Co, respectively. The cameras were tuned for the appropriate radionuclide. Images were also obtained for each of the contrast and resolution bar patterns using camera 1† and a low-energy high-resolution collimator.

RESULTS

Representative flood images for camera 1 are presented in Figure 1. Figure 1A gives the high count scan using the line source, whereas Figure 1B is the flood field image produced using a ^{57}Co sheet source. The results for camera 1 and all three flood sources are presented in Table 1 which lists the uniformity assessed using the NEMA algorithms for integral and differential uniformity (*5*).

DISCUSSION

Some difficulties were encountered as a direct result of the finite size of the line source. As the line source is scanned across the face of the camera the length of the line exposed to the detector varies as a chord of the circle (2Rsinθ). The count rate, therefore, changes from essentially zero, where there is no count rate loss, to ~30K cps when the line source is across the diameter where, even with the newer camera (camera 1), the count rate losses begin to become significant. Because of the significant count rate losses, the normal uniformity pattern of the camera has a further nonuniformity superimposed upon it (Fig. 2). Camera 2‡ had inherent nonuniformity with considerable edge effects such that the added nonuniformity was not immediately observable. However, in the case of camera 1, the high count scan indicated considerable nonuniformity when compared to a flood image using a ^{57}Co sheet source (Fig. 1). Referring to Table 1, the differences in uniformity between phantoms are very evident. Hughes and Sharp (*4*) have reported that a sensitive index of change in uniformity is the coefficient of variation which takes into account global nonuniformity. This is demonstrated in Table 1. This index is larger in the case of the DLP-101 than for either the ^{99m}Tc intrinsic flood or the ^{57}Co sheet source.

Contrast test patterns are usually used in an intrinsic mode without a collimator, but the design of the dynamic line phantom requires that a collimator be in place. Most of the contrast test patterns generated in the parallel line test mode gave reasonably acceptable results. However, the PLES and BRH patterns tended to be too fine for the resolution of the cameras and collimators used in this assessment. In several instances the line patterns created Moirè interference patterns with the configuration of the collimator holes. This would make the phantom unsuitable for monitoring changes in the spatial resolution. This may reflect on the collimators and performance of the two cameras used in this assessment, but it does suggest that the dynamic line phantom would be best used in conjunction with cameras of superior spatial resolution. It might be more appropriate if the resolution bar phantoms could be specific to each individual camera. Since the dynamic line phantom operates under the control of a microprocessor it might therefore be possible to program the unit to create line patterns with line separations appropriate for the camera to be tested. This, of course, would imply that for a department with several cameras of varying vintages and, therefore, various spatial resolutions, different programs would be needed for generating the test patterns. Therefore, the microprocessor would probably have to be more versatile, thus increasing the cost.

In summary, the dynamic line phantom was easily loaded and stored so that it presented a significantly reduced radiation hazard when compared to the extrinsic flood phantoms. The variety of test patterns available makes this an attractive all-purpose phantom for quality control. Despite the wide variety of test patterns available, as the microprocessor is presently programmed, these patterns are probably best suited for camera/collimator combinations offering high resolution and for cameras of recent manufacture. The major drawback when used with circular or hexagonal cameras is that the

TABLE 1. Integral and Differential Uniformities and Coefficients of Variation and Various Flood Sources with the Same Camera

	UFOV (%)		CFOV (%)		Coeff. of
	Integral	Diff.	Integral	Diff.	Var. (%)
Tc-point	6.66	4.35	4.89	3.43	1.93
Co-sheet	6.07	3.99	5.93	3.00	1.89
DLP-101	8.29	4.05	6.13	2.94	2.98

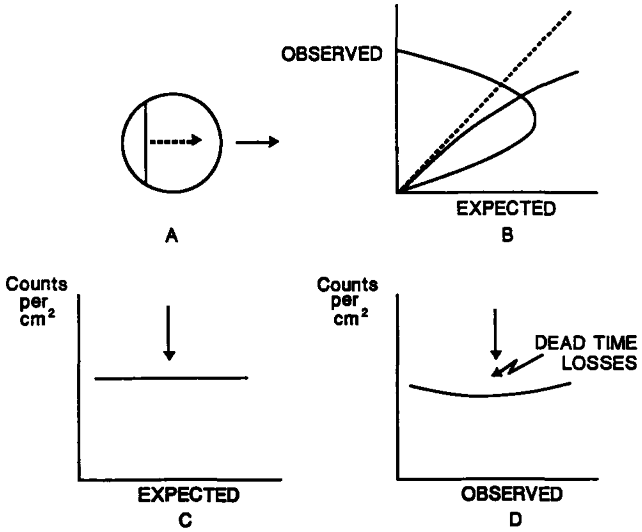

FIG. 2. As the line source scans across camera face, counts vary sinusoidally and move into regions of significant count rate losses causing loss of counts in center of field of view compared to case of no loss.

varying length of the line source exposed to the camera results in a varying count rate loss. This produces sufficient variation of count rate losses to introduce a further nonuniformity to the flood. This problem could be avoided if a slower scan speed and a reduced amount of activity could be used. It would not be as severe in the cameras of rectangular design for which the filling and handling of normal flood phantoms would present an even greater radiation protection hazard.

Uniformity flood correction is particularly important for performing accurate SPECT studies. It would be most advantageous if this device could be used to acquire flood images suitable for uniformity correction in SPECT. It might be possible to use it in this manner if the detectors are square or rectangular. In the case of circular detectors the count rate losses will create sufficient additional nonuniformity to preclude the use of the DLP-101 for quality control of SPECT cameras.

NOTES

* Veenstra Instrumentation, Eext, The Netherlands and Nuclear Associates, Carle Place, NY
† GE 400 AT, GE Medical Systems, Milwaukee, WI
‡ LFOV Siemens Medical Systems, Schaumburg, IL

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REFERENCES

1. LaFontaine R, Graham LS, Behrendt D, et al. Personnel exposure from flood phantoms and point sources during quality assurance procedures. *J Nucl Med* 1983;24:629–632.
2. Deconinck F, Verzelen J. The dynamic line phantom: A new approach to quality control of gamma imaging systems. *J Nucl Med* 1982;23:P93.
3. Deconinck F, Verzelen J. A dynamic line phantom for quality control of gamma camera. *Nucl Med Comm* 1982;3:13–22.
4. Hughes A, Sharp PF. The sensitivity of objective indices to changes in gamma camera non-uniformity. *Phys Med Biol* 1983;34:885–893.
5. *A guide to revised standards for performance measurements of scintillation cameras.* Washington DC: NEMA; 1986.