NMT Gadgetry

Equally Spaced Parallel-Bar Phantom for Performance Monitoring of Scintillation Cameras

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A series of transmission phantoms with equally spaced parallel bars has been designed and evaluated as performance monitors of the linearity and resolving power of scintillation cameras. Each phantom in the series has bars of equal width and spacing. The series has a range of bar widths from 3 to 7 mm in 1-mm increments. The concept is to use that one phantom with bar specifications which are best suited to assess the resolving power of a given camera. The results show that improved quality assurance monitoring is accomplished using this technique as compared to using existing phantoms. It is recommended that scintillation cameras be equipped with this type of phantom at time of purchase.

Bar phantoms have been demonstrated to be useful in monitoring the performance of scintillation cameras *(1-3)*. Most available phantoms are designed with bars, wedges, holes, etc., with multiple widths and spacings in order to be generally useful for cameras within a range of performance limits. However, this multiplicity of widths and spacings limits the effectiveness of these phantoms for any particular camera.

In the present work, a series of equally spaced parallel-bar phantoms has been designed to offer the simplest and most accurate means of monitoring changes in the resolving power and linearity of scintillation cameras. A single phantom of the series is chosen to best match the performance of a given camera.

Principle

It is generally recognized that the best method of observing the linearity of the camera is to image a row of straight edges traversing the entire viewing area. However, many of the phantoms available commercially are divided into quadrants and do not provide the continuity of a straight edge over the entire viewing area. Furthermore, these devices have the disadvantage that their only useful area is that portion with dimensions commensurate with the resolving power of the individual camera.

The underlying design philosophy of the majority of transmission bar phantoms has been to develop a single phantom that is useful for several scintillation cameras. The shadow images of three common designs are shown in Figs. 1, 2, and 3. All of these images were obtained with the bar phantom on the collimator surface. One million counts were collected using a ^{57}Co flood source. The dark lines represent bars of some highly absorptive material such as lead or tungsten. The image in Fig. 1(A) was obtained from a scintillation camera with 37 photomultiplier tubes; that in Fig. 1(B) from one with 19 photomultiplier tubes. In this phantom, four sets of lead bars, with equal width and spacing per set, are arranged in quadrant fashion; the widths and spacings vary from 4.8 to 12.7 mm. It is apparent from Fig. 1(A) that even the finest bar width and spacing of the phantom can be well resolved by the camera, whereas in Fig. 1(B) the most sensitive test of resolving power occurs in the lower right quadrant, i.e., the images of the bars are just distinguishable but would disappear when resolving power degrades. It can be concluded from these images that this phantom is not useful for testing the camera in Fig. 1(A) and is useful in critically monitoring the resolving power of only one-fourth the viewing area of the camera in Fig. 1(B). It is known from experience with the camera used to obtain Fig. 1(A) that barrel distortion is a problem. However, it is not obvious that distortion exists by observing this image.

Shown in Fig. 2 are images from the same two cameras using another version of the quadrant phantom. This particular phantom is made of tungsten bars with variable widths and spacings of smaller dimensions than the phantom used in Fig. 1. It can be seen that this phantom is useful for critically monitoring the changes of resolving power in only one quadrant of the camera, the lower left quadrant in Fig. 2(A) and the upper right quadrant in Fig. 2(B). As in the case with the previous

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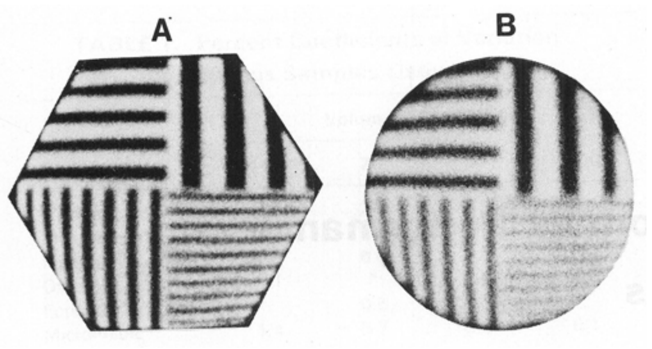

FIG. 1. Transmission images of quadrant phantom from scintillation camera. (A) 37 PM tube type; (B) 19 PM tube type.

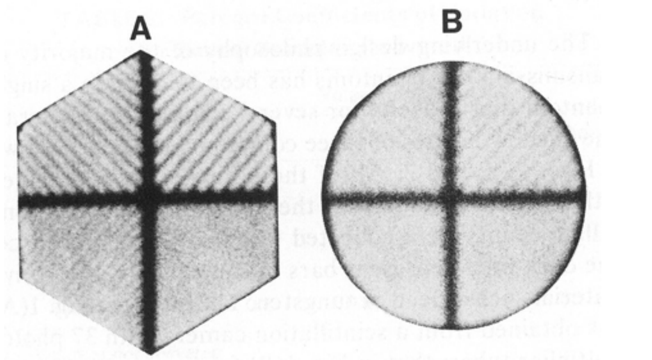

FIG. 2. Transmission images of quadrant phantom from scintillation camera. (A) 37 PM tube type; (B) 19 PM tube type.

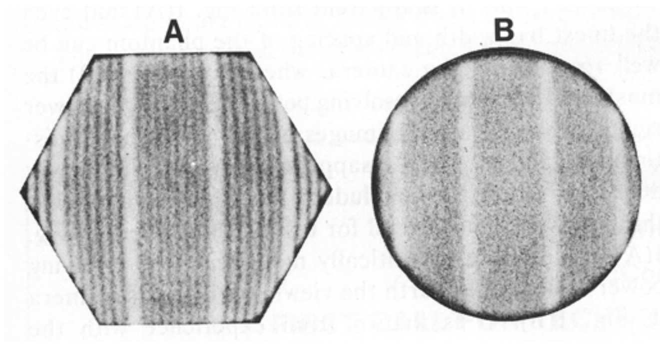

FIG. 3. Transmission images of parallel-bar phantom from scintillation camera. (A) 37 PM tube type; (B) 19 PM tube type.

phantom, it is difficult to judge the linearity of either camera using these images. Resolving power near the center of the field of view is also difficult to judge.

The images in Fig. 3 were obtained from the same two cameras using a phantom with lead bars which traverse the entire viewing area. Each adjacent set of bars has different widths and spacings. It is obvious that the camera image in Fig. 3(A) shows barrel distortion not readily seen on the images of the quadrant phantoms shown in Figs. 1 and 2, obtained immediately prior to these results. The size and spacing of the bars in the center cluster are useful to evaluate the resolving power of the camera in Fig. 3(A), but the bar pattern is too fine to be of use with the camera in Fig. 3(B).

It appears that none of the phantoms shown in Figs. 1, 2, and 3 is optimum for critically evaluating the resolving power and linearity of a scintillation camera over its entire sensitive area. The observations suggest that a better phantom might be one with parallel bars traversing the entire field of view and with a single width and spacing coinciding with the camera's resolving power. A pattern of such a phantom with equally spaced parallel bars is shown in Fig. 4.

Materials and Methods

Five phantoms of the design shown in Fig. 4 were constructed with identical bar widths and spacings of either 3, 4, 5, 6, or 7 mm. The phantoms were fabricated by bonding a 1.6-mm-thick lead sheet to a 3.2-mm-thick Lucite foundation, milling out the appropriate spaces from the lead, and covering the lead with another sheet of 3.2-mm-thick Lucite. The 1.6-mm thickness of the lead sheet adequately attenuates the photon intensity from ^{57}Co and ^{99m}Tc sources to yield a distinct shadow image, but is thin enough to be easily machinable. A border of approximately 3 cm of lead is left for ruggedness. The phantoms fabricated for this study were grooved on an automated milling machine requiring 10–20 min per phantom, depending upon the bar size.

The production cost of each phantom is estimated to be approximately $80.

During the past three years, seven different scintillation cameras, representing four manufacturers, were monitored routinely, using an equally spaced parallel-bar phantom. The width and spacing of the bars for each camera were determined by imaging the entire series of five phantoms and choosing the one phantom that most closely matched the resolving power of that particular camera *(4)*. The specific bar phantoms chosen for seven

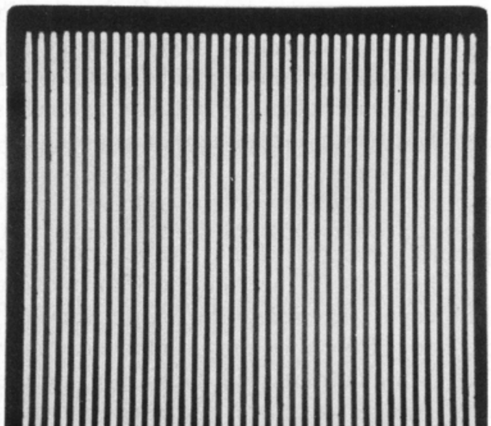

FIG. 4. Design of equally spaced parallel-bar phantom.

scintillation cameras used in surrounding collaborative hospitals are listed in Table 1.

The images shown in Fig. 5 are of the chosen transmission bar phantoms for the two scintillation cameras used for the previous illustrations. The images were obtained using a phantom with bar widths and spacings of 4 mm in Fig. 5(A) and 5 mm in Fig. 5(B). Both images are sensitive indices of resolving power and linearity changes of each camera. In order to monitor changes in resolving power in both the X and Y directions, the phantom is alternately imaged parallel to each axis. These bar phantoms were more valuable in observing changes in camera performance than were other types of phantoms.

Discussion and Conclusion

The technical evaluation has shown that it is desirable to use a phantom with a specific bar width and spacing over the entire field of view. The phantom's specifications should coincide with the resolving power of the scintillation camera. Furthermore, bars traversing the entire field of view allow the optimal observation of linearity. Routine imaging of this phantom, alternating its X and Y orientation, is recommended as the most sensitive method for monitoring changes in resolving power and linearity. At our institution these images are obtained daily because experience has shown that significant changes in these parameters can occur from day to day without corresponding changes in uniformity. The construction of these phantoms is simple and the cost of production should be similar to those presently available commercially. Alternate methods of construction have been published elsewhere *(5, 6)*.

The major problem facing the camera user is to determine the specific bar and space dimensions best suited for the resolving power of a particular scintillation camera. While this choice also exists when purchasing a general-purpose phantom, it is not as critical as the choice of the equally spaced parallel-bar type. Assuming a series of phantoms is not available, one way of selecting the proper dimensions is to use a general-purpose phantom to determine the bar width most appropriate for a camera in question. Another method is to consult the literature of manufacturer's specifications concerning the resolution capability of the type of scintillation camera being considered. Also, the data given in Table 1 may be helpful to guide in the selection of phantoms for similar cameras. Of course, these data were obtained on only one camera of each type and do not necessarily represent other cameras of the same type. However, use of this table may aid in narrowing the choice of possible phantoms for specific camera types.

In the case of a new instrument purchase, it is the view of the authors that the purchaser should request that the appropriate phantom be supplied by the manufacturer at the time of purchase.

TABLE 1. Specific Bar Phantoms Selected for Scintillation Cameras Used in Study*

Manufacturer	Type	Collimator	Bar size (mm)
Baird-Atomic	System 77	1½ in.	3
Ohio-Nuclear	Series 100	High sensitivity	4
Picker Nuclear	Dynacamera 2C	Technetium dynamic	7
Picker Nuclear	Dynacamera 4	Technetium dynamic	6
Searle Radiographics	Pho/Gamma 3	250 keV	7
Searle Radiographics	Pho/Gamma HP	High sensitivity	6
Searle Radiographics	Pho/Gamma 4	High sensitivity	5

**These bar specifications were obtained for only one camera of each type and do not necessarily represent other cameras of the same type.*

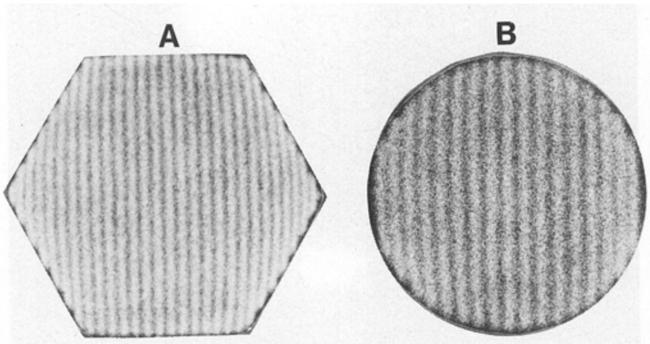

FIG. 5. Transmission images of equally spaced parallel-bar phantom from scintillation camera. (A) 37 PM tube type, 4-mm bars; (B) 19 PM tube type, 5-mm bars.

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References

1. Hayes M: Techniques of evaluation of nuclear medicine instrumentation. *CRC Crit Rev Clin Radiol Nucl Med* 6: 31–55, 1975

2. Van Tuinen RJ: Phantom evaluation of instrument performance. In *Proceedings of Symposium on Standardization, Performance and Quality Control in Nuclear Medicine*, Gaithersburg, MD, June 1975, to be published.

3. Powell MR: Clinical applications of the scintillation camera. In *Nuclear Medicine*, 2nd ed, Blahd WH, ed, New York, McGraw-Hill, 1971, pp 533–574

4. Grossman LW, Van Tuinen RJ, Hoops RG, et al.: A rationale for choosing a bar phantom for routine performance monitoring of Anger cameras. *J Nucl Med* 16: 531, 1975

5. *Workshop Manual for Quality Control of Scintillation Cameras in Nuclear Medicine*, Washington, DHEW, FDA 76-8039, 1976

6. Aoxi CT: Simple construction of a lead-bar phantom. *J Nucl Med* 16: 441, 1975