A Low-Contrast Phantom for Daily Quality Control

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A simple phantom is proposed to provide a low-contrast test object for daily quality assurance. The phantom consists of four quarters and five dimes taped to a Plexiglas plate. For daily quality control, the phantom is used with 5 cm of Plexiglas as scattering material and a flood source. Examples of images are presented for several gamma cameras, illustrating some of the information that can be obtained. In particular, we present examples of cameras providing improper imaging performance with the coin phantom but with "normal" floods and bar-phantom images. The major conclusion is that daily quality-control images should include significant amounts of scattering material and low-contrast objects.

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A major goal of daily quality assurance (QA) procedures in clinical nuclear medicine laboratories should be to detect subtle changes in gamma camera performance before such changes significantly degrade image quality. In most laboratories typical procedures consist of obtaining images of a flood source and of a bar phantom placed on the collimator surface. These images are not very sensitive indicators of the quality of clinical images, since few clinical images have the uniformity of the flood image or the high contrast of the bar phantom.

To simulate more closely clinical images, we have begun to include low contrast phantom images as part of the daily quality control images at our hospital. The use of low-contrast phantoms for camera testing is not new (*1–5*). For example, the Rollo phantom provides for 16 different defects of various sizes and contrasts, but is difficult to construct and cumbersome to use for evaluating different portions of the field of view.

Our low-contrast phantom consists of nine coins (four quarters and five dimes) with a flood source behind them. It is inexpensive, light-weight and easy to use.

The coins attenuate 140 keV gamma rays by approximately 25%, resulting in relatively small count density differences between the coins and the surrounding areas in the image. The ability to see these coins is an excellent test of the resolution, uniformity, and scatter rejection of the gamma camera and appears to be considerably more sensitive to defects in these parameters than the currently used testing techniques.

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METHODS

Four U.S. quarters and five dimes are placed in a square array with the quarters at the corners and the dimes at midpoints of lines drawn between the quarters. The side of the square is 94 mm to

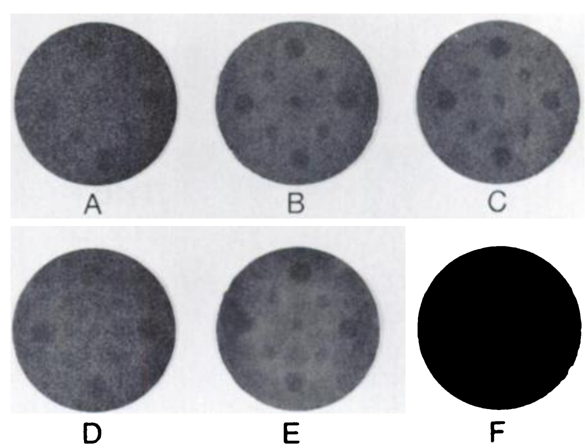

FIG. 1. Example of use of coin phantom to test performance of uniformity correction system in G.E. Porta IIC gamma camera. All images were acquired with coin phantom directly on high-resolution collimator with flood source above it. Images A and D are 1-million-count images with symmetric energy window with and without uniformity correction, respectively. Images B and E are 5-million-count images but otherwise like A and D. Images C and F are 5-million-count images and energy window shifted high with and without uniformity correction, respectively.

accommodate both large- and small-field cameras. The coins are taped to a 405 × 405 mm Plexiglas plate (3 mm thick). For the daily quality control tests, the phantom is placed, coins down, on top of 50 mm of Plexiglas as scattering material, and a standard technetium-filled flood source is placed on top of the phantom. The high-resolution, parallel-hole, low-energy collimator is used. Once a month, additional images are acquired, one with no scatter and one with 100 mm of Plexiglas.

In order to demonstrate the usefulness of the technique, several comparisons of cameras within the University system were made. For each camera the following four sets of images were obtained: (a) a two-million-count flood image with a Tc-99m flood source; (b) a two-million-count image with the coins on the face of the high-resolution collimator, with the flood source directly above the coins; (c) a two-million-count image with 100 mm of Plexiglas as scattering material between the coins and the collimator, with the flood source immediately above the coins; and (d) a two-million-count bar phantom image with 3/16, 1/4, 5/16, and 1/2 in. bars lying on the collimator, with the flood source directly above it.

The images presented here were acquired from a 1978 General Electric Porta IIC (Camera 1), a 1979 Picker DC4/15 with Micro-Z (Camera 2), a 1975 Picker DC4/15 (Camera 3), a 1979 Ohio Nuclear Sigma 410 (Camera 4), and a 1978 Ohio Nuclear Sigma 410 (Camera 5). Several additional images were acquired with Camera 1 with the uniformity-correction computer on and off and with the energy window (a) centered on the photopeak, and (b) shifted high such that the count rate fell by 10%. The window was set at full width at half maximum (FWHM) and the reference flood for the uniformity correction was acquired immediately before each set of images, using the same window setting.

Image contrast was also measured quantitatively. The expected contrast for the coins was measured using a fixed-point source of Tc-99m placed 1.5 m below a gamma camera with a high-resolution collimator in place. Count rates were determined with and without the coins placed immediately over the point source. The expected contrast is then the change in count rate divided by the unattenuated count rate. The contrast from the coin phantom images was measured from images acquired on a computer by producing a count profile across the center of a coin image. The contrast measured is the difference between the minimum and surrounding count rates divided by the surrounding count rate.

RESULTS

Figure 1 shows the effects of uniformity correction and information density on the visual detectability of the coins on Camera 1. In each pair of images, the coins are more clearly seen when the uniformity-correction system is in operation. In addition, it is apparent that the coins are much more easily seen in the high-information density (5 million count) images.

Figure 2 shows a series of quality assurance images from five of the cameras at our institution. As expected, the oldest instrument (Camera 3) has the worst uniformity and has poor low-contrast detectability. Camera 1 shows good low-contrast detection with scatter as well as on the collimator. Camera 2 has excellent

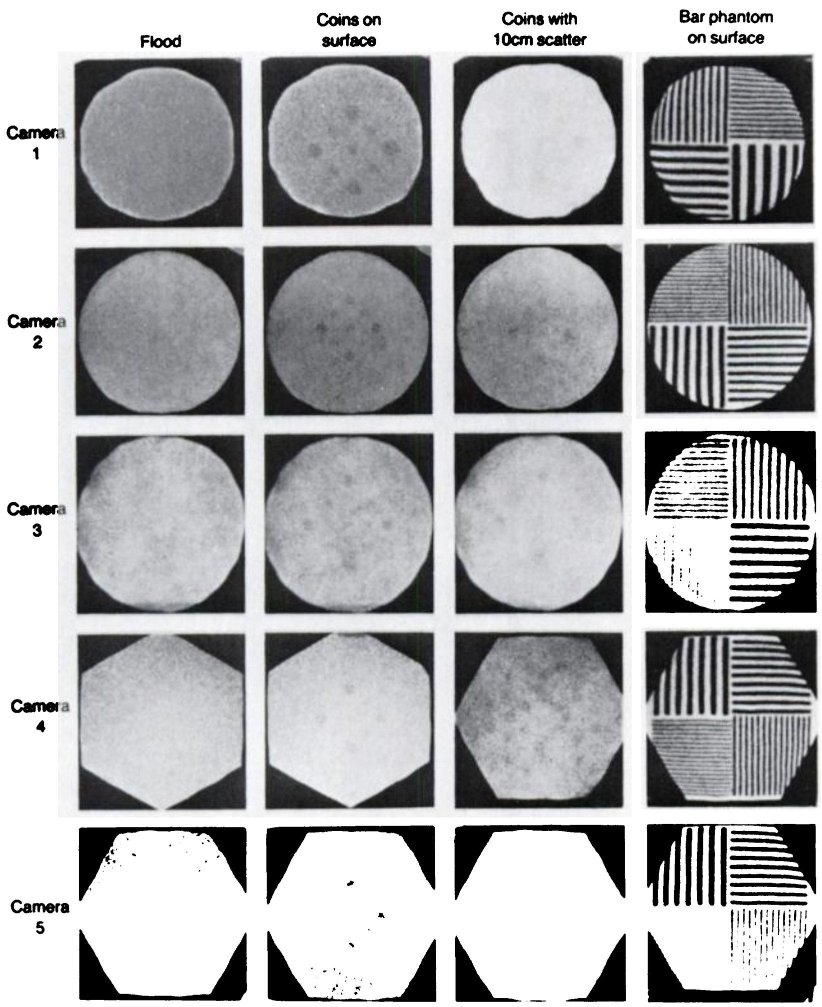

FIG. 2. Examples of daily quality assurance images from five gamma cameras. Columns present, left to right, two-million-count flood source on collimator surface, two-million-count coin phantom image on collimator surface, two-million-count coin phantom image with 10 cm of Plexiglas, and two-million-count bar phantom on collimator surface. Rows represent data for Cameras 1–5 as listed in text.

TABLE 1. IMAGE CONTRAST

	Contrast* on collimator surface			Contrast* with 10 cm Scattering Material		
Camera	Quarter #4	Dime #1	Quarter #2	Quarter #4	Dime #1	Quarter #2
1	0.23	0.14	0.19	0.18	0.07	0.14
2	0.23	0.15	0.21	0.15	0.05	0.12
3	0.21	0.08	0.22	—	—	—
4	0.18	0.09	0.15	0.13	0.06	0.16
5	0.22	0.12	0.22	0.15	0.07	0.20

* Measurement conditions are for a flood source of Tc-99m placed immediately above the coins. Contrast = $(C_0 - C_c)/C_0$, where C_0 = count rate per unit area near the coin image and C_c = count rate per unit area in the center of the coin image.

visual uniformity and reasonable low-contrast detectability, although the visual impression is that the contrast resolution is not the same at different areas in the field. Camera 4 shows normal flood response on the collimator surface, but develops artifacts when scattering material is added—in fact, the coins are not visible. Camera 5 shows reasonable response, although low-contrast detectability is lower than in Camera 2, another large-field-of-view system installed at about the same time.

Table 1 summarizes the quantitative measurements of contrast of quarters and dimes for the various cameras whose images are seen in Fig. 2. The expected contrasts for quarters and dimes are 0.25 and 0.20, respectively.

DISCUSSION

The study of gamma-camera image performance and quality assurance has resulted in a proliferation of phantoms, techniques, and definitions of parameters. As is often the case with complex systems, no single parameter or image can be used to describe camera performance completely. Many parameters should be investigated both quantitatively and qualitatively when one is considering a camera purchase or operating a quality-control program.

Many groups, including ours, have been developing quantitative techniques for measuring gamma-camera performance (*6–10*). Parameters measured include energy resolution, uniformity, linearity, and intrinsic and extrinsic line spread functions. The comparison of quantitative data and qualitative evaluations of images of various phantoms to predict clinical performance has proven to be somewhat difficult. Figure-of-merit approaches (*6, 7*) and quantitative assessment of low contrast (*8, 9*) have been partially successful, but the problem of predicting the more subtle differences observed clinically remains to be adequately solved.

The majority of the techniques currently in use stress parameters associated with high-contrast detectability. Examples are images of bar phantoms and measurements of full width half maximum (FWHM) of line spread functions. Although these parameters are important in that they indicate the limiting resolution of a system, the actual in vivo image quality is probably more a function of low-contrast object detectability. In terms of quantitative parameters, low-contrast detectability is strongly dependent on the tails of the line spread function and local contrast (*6*), parameters not routinely quoted by manufacturers or easily measured in a typical nuclear medicine clinic.

The use of a simple low-contrast phantom, such as the coin phantom, can provide considerable information about the imaging systems in a clinic. For example, the images obtained from Camera 1 show the importance of uniform visual response in the detection of low-contrast defects. (Figure 1 shows the low-contrast images with the uniformity-correction system on and off.) The comparisons among several of the cameras in our institution clearly indicate the importance of low-contrast tests for routine quality control (Fig. 2). In all cases the coin images demonstrate more significant differences between the cameras than do the bar-phantom images.

One of the most impressive results obtained was the difference in Camera 4 between the normal QA flood (on the collimator surface) and the coin image with scatter. This demonstrates that with modern gamma cameras—especially those with renormalization types of uniformity "correction" systems—quality assurance tests should be done with scatter present. In the case of Camera 4, the problem was an inoperative auto-track peaking circuit, which resulted in considerable texture in the image from this camera when scatter was present.

A more subtle defect is demonstrated by Camera 2. In this case, the flood with scatter appeared normal. The coin images with scatter showed a marked asymmetry in the detectability: Some dimes are seen more clearly than others. This sort of variation is often a result of too much renormalization, indicating that the camera should be retuned or checked out for more subtle problems.

The data in Table 1 represent a first attempt to derive some quantitative results from images of the coin phantom. As expected, the absolute contrast is reduced when scattering material is introduced. Whether the values of contrast can be used as a criteria for determining the quality of camera service remains to be seen. One approach being investigated at our institution is the tabulation of the differences in contrast between coins in the same image and with changes in the contrast in serial images. Since the human eye is more sensitive to changes in contrast than absolute differences in contrast, some sort of edge response will probably be necessary if quantitative data from the coin images are to be used as a stringent QA test procedure.

CONCLUSION

The coin phantom described here provides a simple and inexpensive way to test a gamma camera's ability to detect low-contrast objects. The technique can incorporate easily into quality-assurance procedures, is probably more sensitive than flood fields, and is certainly more sensitive than bar-phantom tests in detecting subtle changes in camera performance. The use of scattering material in daily quality-control procedures is important, especially if the camera has a uniformity "correction" system.

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