Parathyroid Imaging: An Approach to Protocol Evaluation

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A review of the literature demonstrates that even though the basic subtraction approach to parathyroid imaging remains the same, there are a number of technical variables that can be adjusted to optimize the parathyroid procedure. The volume of parathyroid studies is not sufficient to allow a comparison of technical parameters with separate groups of patients. Also, this type of study cannot be repeated with different parameters without reinjecting the patient. We proposed the use of a phantom, which would simulate realistic imaging situations, to help in protocol evaluation. We examined this approach with collimator selection because collimator parameters can be measured. Two collimators were evaluated for both sensitivity and resolution. We then compared these conclusions with those derived from our phantom measurements. There was basic agreement with both phantom and collimator parameter measurements. We concluded that this type of phantom could be useful in analysis of parathyroid imaging parameters.

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Since its introduction in 1964, the technique for imaging parathyroids has undergone many changes. In 1982, Ferlin described a simple double tracer technique utilizing thallium-201 (^{201}Tl) and technetium pertechnetate (^{99m}TcO_4), which forms the basis for the current method of parathyroid imaging (*1*). This technique relies on the unique distribution characteristics of the two isotopes: one isotope localizes in the thyroid and the other localizes in both the thyroid and the parathyroids. Further image enhancement and computer-assisted subtraction improve the sensitivity for detecting the parathyroid lesions. Even the recent development of the substitution of ^{99m}Tc-sestamibi (MIBI) for thallium (*2*) relies on the same basic double tracer subtraction technique described by Ferlin.

There is still no clear consensus on what constitutes the optimal imaging protocol for parathyroid studies. In fact, several investigators have stated that the differences in reported sensitivities for parathyroid imaging can be attributed in part to the differences in imaging protocols (*2,3*). A review of the literature demonstrates that even though the basic subtraction approach to parathyroid imaging remains the same, there are a number of technical variables that can be adjusted to optimize the procedure (*1–9*). Selection of a collimator and adjustment of patient dose are two common variables. Time or count acquisition parameters vary but are limited by the amount of time a patient can remain immobile (~30 min).

There are also numerous processing techniques. Each one is concerned with the subtraction of the correct number of thyroid and background counts without the oversubtraction of counts from the parathyroids. The volume of parathyroid studies at most institutions is not sufficient to allow a comparison of technical parameters with separate groups of patients. Since imaging during sequential injections is involved, this type of study cannot be repeated with different parameters without reinjecting the patient.

Therefore, we thought it necessary to develop a phantom technique, which would simulate realistic imaging situations, to help in these evaluations. We chose to examine how this approach would work with the selection of collimators for our parathyroid imaging. Since collimator parameters can be readily measured, we can evaluate if the phantom images predict collimator performance.

MATERIALS AND METHODS

The two collimators available for us to test were the high-resolution parallel-hole collimator, used with a hardware zoom, and a 6-mm pinhole collimator. The collimators were evaluated for both sensitivity and resolution. Sensitivity measurements were performed with a small (1 ml) spherical source of ^{99m}Tc. To simulate the effects of attenuation and scatter, the source was immersed in water. The cylinder of water was placed 6 cm from the face of the collimator, the approximate distance of a patient's neck from the collimator. Sensitivity measurements were obtained every 2 cm for a distance of 6.5 cm to 16.5 cm from the collimators and are expressed as counts/second/μCi. To obtain counts, regions of interest were drawn around the source image to simulate areas that would be circumscribed for small adenomas. The sensitivity results are shown in Figure 1. Resolution measurements were performed with capillary line sources in air (*10,11*). Two line sources, 2 cm apart, were imaged to obtain a calibration of pixel width. The resolution measurements

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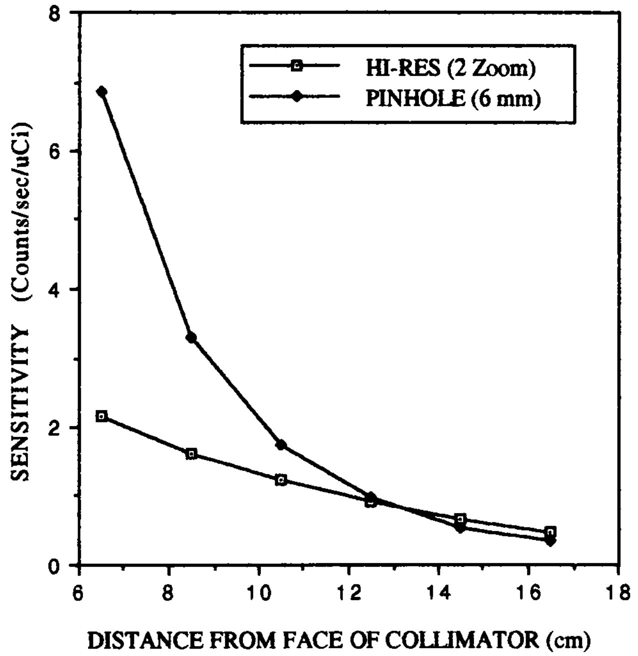

FIG. 1. Source sensitivity of collimators studied for 140 keV gamma rays of technetium-99m in a scatter medium starting at 6 cm.

are shown in Figure 2 and are expressed in mm FWHM (full width half maximum).

We next developed our phantom, shown in Figure 3, which consisted of a polymethyl methacrylate hollow shell molded from a cadaver thyroid and mounted in an 11-cm diameter chamber to simulate the neck. Three small plastic cylinders, simulating adenomas with adjustable volumes of up to 2 ml, were mounted on plastic rods. The rods were

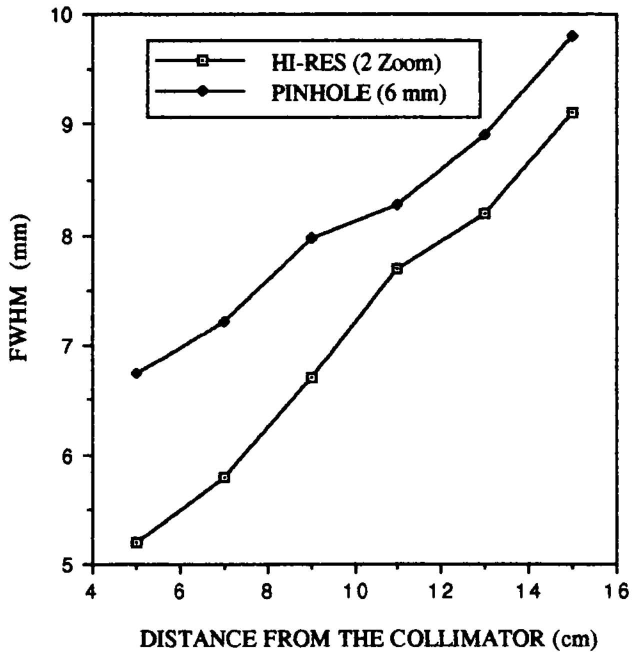

FIG. 2. Resolution of collimators studied for 140 keV gamma rays of technetium-99m in air.

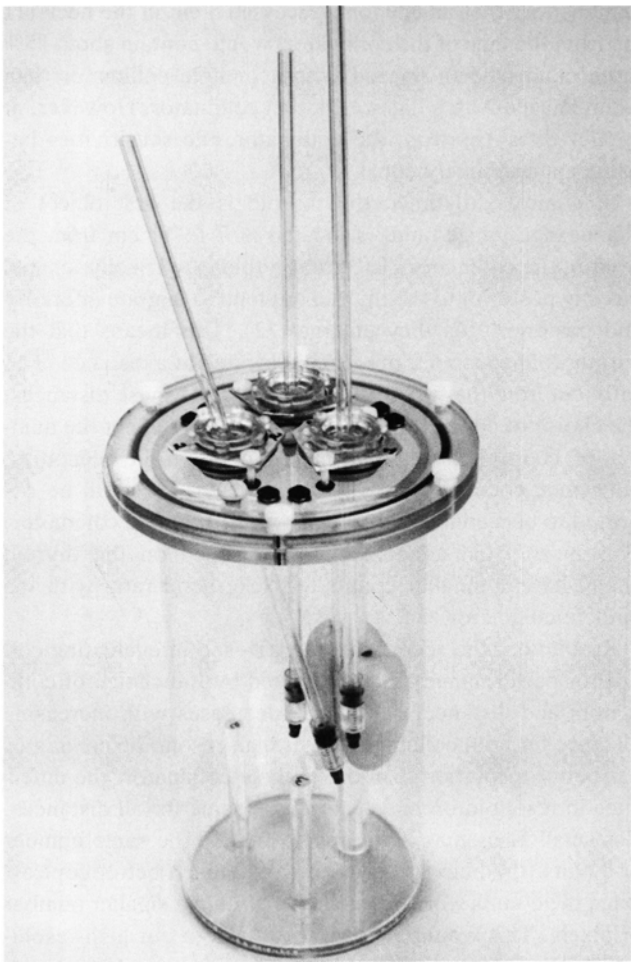

FIG. 3. Parathyroid imaging phantom. Polymethyl methacrylate hollow shell molded from a cadaver thyroid and mounted in an 11-cm diameter chamber to simulate the neck. Three small plastic cylinders, simulating adenomas with adjustable volumes, were mounted on plastic rods. The rods were inserted through the top of the phantom, in such a way that the adenomas could be positioned at different locations behind the thyroid.

inserted through the top of the phantom in such a way that the adenomas, filled with radioactive material, could be positioned at different locations behind the thyroid. Repositioning of the adenomas could take place during the study without moving the phantom. The phantom was imaged for equal times with both collimators. Two to three million counts were acquired to ensure that equipment characteristics were not masked by noise. We imaged three adenomas. The first was directly behind the right thyroid lobe, the second was 2 cm behind the left lobe, and the third was beside the right lobe, at the same distance from the front of the phantom as the first.

RESULTS AND DISCUSSION

Collimator sensitivity directly affects the intensity and, therefore, the visibility of parathyroids in the image. Figure 1 shows that source sensitivity depends on both the choice of collimator and the distance to the object imaged. Our results demonstrate that an adenoma recessed 5 cm in the neck (11 cm from the face of the collimator) would contain about 25% more counts when imaged with a pinhole collimator than when imaged with a high-resolution collimator. However, at greater distances from the collimator, the sensitivities become approximately equal.

In clinical situations, the thyroid is the first object of significance imaged and is located at 7 to 11 cm from the front of the collimator. The parathyroids are usually located directly posterior to the thyroid but tend to migrate inferiorly and posteriorly as they enlarge (*12*). This means that the parathyroid adenomas are usually located at a distance of 11 to 16 cm from the face of the collimator. At these distances, the choice of collimator will not significantly affect the number of counts extracted from the parathyroid adenomas. However, counts obtained from the thyroid would be expected to be significantly higher with the pinhole collimator. This means that adenomas superimposed on the thyroid would have a smaller counts-to-background ratio with the pinhole collimator.

Resolution, the second parameter used in evaluating collimator performance, is also affected by the choice of collimators and distance. Resolution decreases with increasing distance for both collimators. Our high-resolution collimator has better resolution than our pinhole collimator: the difference in resolution remains about the same for all distances. For small adenomas, with approximately the same number of counts, the better resolution would mean better contrast since the counts would be collected within a smaller number of pixels. This would give an advantage to our high-resolution collimator.

We then compared these conclusions to those derived from our phantom measurements. After subtraction of the images without the adenomas, counts were found to be 20% higher for the first adenoma imaged with the pinhole. However, the counts were equal with the two collimators for the second and third adenomas. This was expected because these two adenomas were more distant from the pinhole aperture. Total counts for the thyroid were found to be 30% higher with the pinhole than with the high-resolution collimator. These results for both the thyroid and adenomas at the given distances from the collimators are consistent with our collimator sensitivity measurements, which are shown in Figure 1.

Detection sensitivity of small adenomas is not only dependent on total adenoma counts but also on the adenoma-to-background contrast ratio. During processing, thyroid counts are subtracted to produce the parathyroid image. This subtraction process produces statistical errors manifested as background noise (or nonzero pixel values). Hence, the final parathyroid image contains adenoma counts superimposed on noise remaining from the thyroid subtraction. The more counts in the thyroid, the higher the pixel count values due to subtraction errors. An analysis of the phantom subtraction images showed the ratio of adenoma counts to background more than 50% higher with the high-resolution collimator than with the pinhole collimator. This is consistent with what would be expected from the higher pinhole sensitivity and the higher pinhole thyroid counts. A consequence of this would be that the chances of seeing smaller adenomas in the subtracted image should be better with the high-resolution collimator than with the pinhole collimator.

CONCLUSION

We were able to demonstrate that our high-resolution collimator should be superior in the imaging of parathyroids, even though the differences were not that large. There was basic agreement with both phantom and collimator parameter measurements. This leads us to believe that this type of phantom could be useful in the analysis of the technical parameters of parathyroid imaging.

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