Quality Control for Artifacts Seen on Pinhole Thyroid Images and Caused by a Collimator Shielding Defect

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Objective: The purpose of this study was to investigate artifacts seen on several pinhole thyroid imaging studies at one of our institutions and to determine their cause.

Methods: The pinhole collimator was tested using radioactive point sources and a thyroid phantom to determine the presence and location of a suspected shielding defect and to confirm its subsequent repair. A 14-mo retrospective review of $^{99m}$Tc and $^{123}$I pinhole thyroid imaging studies was performed.

Results: The point source and thyroid phantom studies confirmed the defect, its location and repair. The patient review revealed extra thyroidal activity in 38% of the studies. The artifacts evoked several misinterpretations, but none were of clinical significance.

Conclusion: Artifacts seen during patient studies were caused by a collimator shielding defect. Due to the lack of standardized quality control for pinhole collimators, point source testing is recommended for all new and existing pinhole collimators and after any suspected damage.

Key Words: thyroid imaging; quality control


During a routine review of the day's clinical studies at one of our institutions, a pinhole thyroid imaging study using $^{123}$I sodium iodide revealed tracer activity outside the thyroid bed (Fig. 1) which was highly suggestive of an artifact. Technetium-99 pertechnetate thyroid phantom studies were performed varying several imaging parameters (i.e., orientation, isotope channels, analog versus computer images). The use of another small field-of-view scintillation camera failed to reproduce the artifact. During the next pinhole thyroid imaging study the artifact was seen again. A repeat anterior view was performed and the artifact was no longer seen (Fig. 2). The only difference between the two anterior images was the patient's orientation (rotated 180°) when compared to the collimator. This observation prompted another phantom study that revealed the artifact when the phantom was not centered in the field of view (Fig. 3), suggesting that a collimator shielding defect was responsible for the artifact. We conducted our study to test the pinhole collimator for a shielding defect and to determine the frequency and significance of the imaging artifact.

MATERIALS AND METHODS

Point Source Studies

To determine the location of the suspected collimator shielding defect, both $^{99m}$Tc and $^{123}$I point sources were used in conjunction with three lead sheets (1.6 mm thick) with varying centered apertures of 2.4, 4.9 and 6.8 cm. The lead sheets were placed directly onto the pinhole collimator to shield various sections of the collimator to determine the suspected defect's location (Fig. 4). For the $^{99m}$Tc point source...
testing, approximately 307 MBq (83 mCi) of $^{99m}$Tc in 1.5 ml was placed in a 5-ml syringe and sealed with a syringe cap. A single $^{123}$I capsule containing approximately 12.6 MBq (340 μCi) was used for the $^{123}$I point source. Each point source was separately placed approximately five fields of view above the crystal face and centered over the pinhole collimator. Computer images were obtained using a $128 \times 128$ matrix for similar times compensated to correct for radioactive decay (approximately 300 and 1500 sec for $^{99m}$Tc and $^{123}$I, respectively). These images were obtained with and without the varying aperture lead sheets using a 20% energy window centered over the appropriate photopeak. The raw unshielded image had approximately 62K ($^{99m}$Tc) and 26K ($^{123}$I) counts. Background computer images were also obtained for both radioisotopes.

**Thyroid Phantom Studies**

To simulate patient studies, radionuclide images were obtained using a commercially available thyroid gland phantom and the varying aperture lead sheets. The thyroid phantom was filled with either 8.5 MBq (230 μCi) of $^{99m}$Tc or 2.2 MBq (60 μCi) of $^{123}$I. The $^{99m}$Tc phantom activity was 2.9% of our normal administered dosage, which is within the normal per-technetate uptake range of 0.2% to 3.5% (1). The $^{123}$I activity was 53% of our maximum dosage (based on 24-hr decay) which is higher than our institution’s normal 24-hr uptake range of 9% to 31%. One set of computer images was obtained using a $128 \times 128$ matrix for similar times compensated to correct for radioactive decay (approximately 300 sec). These images were obtained with and without the varying aperture lead sheets using a 20% energy window over the appropriate photopeak and a phantom to pinhole insert distance of 7.6 cm (3 in). The raw unshielded image had approximately 178K ($^{99m}$Tc) and 32K ($^{123}$I) counts. A second set of phantom studies was acquired using the same imaging parameters with the phantom to pinhole insert distance increased to 12.5 cm (4.9 in) and acquisition times of approximately 600 and 480 sec for $^{99m}$Tc and $^{123}$I, respectively, with each time compensated to correct for radioactive decay. The raw unshielded image had approximately 156K ($^{99m}$Tc) and 30K ($^{123}$I) counts. Background computer images were also obtained for both sets of phantom studies and for both radioisotopes.

**Patient Review**

One author retrospectively reviewed 14 mo of pinhole thyroid imaging studies. These studies were classified according to the presence or absence of tracer activity residing outside the thyroid bed on any of the acquired views; if present, its location was noted. Subsequently, the original image interpretations were reviewed. Depending on the clinical indication for the study, either 296 MBq (8 mCi) of $^{99m}$Tc or 7.4 to 14.8 MBq (200 to 400 μCi) of $^{123}$I was used for each study. Patients were imaged either 20 min after intravenous injection of $^{99m}$Tc or 24 hr after oral administration of $^{123}$I. Analog images were obtained using a standard small field-of-view scintillation camera and a low-energy pinhole collimator with a 5-mm insert. Standard anterior, and right and left anterior oblique (RAO, LAO) views...
were obtained for approximately 200K counts ($^{99m}$Tc) or 20K counts ($^{123}$I), not to exceed 10 min using a 20%-energy window over the appropriate photopeak. The images were obtained at a fixed distance of 7.6 cm (3 in) between the anterior surface of the patient’s neck and the pinhole insert.

**RESULTS**

**Point Source Studies**

In review of the raw data images (Fig. 5), the artifact was clearly evident on the unshielded point source images and the 6.8-cm aperture lead sheet images of both radioisotopes. The point source images acquired with the 2.4-cm and 4.9-cm aperture lead sheets did not demonstrate the artifact. From these images, the cause of the artifact was isolated to a defect in the collimator shielding. It was located in the small collar between the pinhole insert and the pinhole cone (Fig. 4). A radiograph of the pinhole collimator confirmed the location and appearance of the defect (Fig. 6). Based on this information, the pinhole collimator was repaired with a lead insert placed in the area of the defect. A subsequent radiograph and unshielded $^{99m}$Tc point source image confirmed that the repair properly shielded the defect and eliminated the artifact.

Quantitative analysis of the point source data was performed. A region of interest was placed around the center of each image to include only the counts that would normally pass through the pinhole aperture as a point source. The percentage of true net counts from the point source for each image is summarized in Table 1. Since the 2.4-cm aperture lead sheet shielded the defect and made the image artifact-free, the artifact was quantitatively expressed as a percentage of the net counts within the entire unshielded image (Table 2) by using the following equation:

$$\left(\frac{\text{net cts unshielded image} - \text{net cts 2.4-cm aperture image}}{\text{net cts unshielded image}}\right) \times 100$$

**Thyroid Phantom Studies**

Similar to the point source images, the unshielded thyroid phantom images and the 6.8-cm aperture lead sheet images of both radioisotopes demonstrated the artifact (Fig. 7). The artifact appeared as extra-thyroidal activity similar to some of the patient studies when the thyroid phantom was 12.5 cm from the pinhole. With the phantom at a distance of 7.6 cm from the pinhole, the artifact was overlying the upper pole of the left thyroid lobe. Given the size and position of the thyroid image in the field of view, and the orientation of the phantom or patient in relationship to the defect, the artifact will be seen as extra thyroidal activity or activity overlying the thyroid gland that may not be appreciated as seen in Figure 2. The artifact seen in the thyroid phantom studies was quantified in Table 2 similar to the point source data.

**Patient Review**

The 14-mo review of pinhole thyroid imaging studies consisted of 42 studies; 28 with $^{99m}$Tc and 14 with $^{123}$I. The artifact was seen on one or more views in 16 of the 42 cases (38%); $^{99m}$Tc: 9 of 28 (32%) and $^{123}$I: 7 of 14 (50%). The artifact was...
In most of the cases, the artifact was unappreciated or ignored as evidenced by no comment on the original dictated report. In no cases prior to the two mentioned index cases was the abnormality reported as an artifact. In one case the artifact was described as residual tissue within the thyroid bed of a previously removed lobe of the thyroid gland (Fig. 8A). In three cases, the artifact was incorrectly described as the pyramidal lobe of the thyroid gland (Fig. 8B). Figure 9 demonstrates the normal change in pyramidal lobe location relative to the thyroid lobes with oblique images. In another case, the artifact made the left lobe appear larger than its true size (Fig. 8C).

**DISCUSSION**

The use of the pinhole collimator is preferred for thyroid imaging due to its magnifying ability without loss of resolution. Pinhole collimator imaging does have potential problems. Parallax errors (2,3), edge distortion (4), accurate thyroid sizing (5) and collimator masking of large field-of-view scintillation cameras (6) may lead to difficulties and errors in image interpretation. Artifacts or unusual tracer presentations are occasionally seen in radionuclide imaging and can be separated into three major groups: camera dependent, radiopharmaceutical dependent and patient-related artifacts (7). In most cases they can be explained by performing or reviewing quality control on the camera or radiopharmaceutical (8–10), reviewing the raw data, reviewing the acquisition/processing parameters and injection techniques (11–15), or examining the patient and reviewing the patient's medical history (16–18). The unexplained artifacts in our pinhole thyroid imaging stimulated our study of radionuclide thyroid images and the pinhole collimator.

![FIGURE 7. Technetium-99m thyroid phantom images. Top row: 7.6-cm distance from phantom to pinhole. Bottom row: 12.5-cm distance from phantom to pinhole. Similar to Figure 5, the unshielded images (left) demonstrated the artifact. Top: overlying the upper pole of the left lobe (closed arrow). Bottom: similar to extra thyroidal activity (open arrow). The 2.4-cm aperture lead sheet images (right) were artifact-free. The 123I phantom images revealed similar information.](image)

primarily seen as a curvilinear tracer activity residing outside of the thyroid bed. In the 16 studies with an artifact, it was seen on one view in five cases, two views in eight, and on three views in three cases. The artifact was equally seen on all views (10 anterior, 9 RAO and 11 LAO views) and was usually (67%) located in relation to the upper pole of the left thyroid lobe.

![FIGURE 8. Three cases from the retrospective patient study review: artifact (arrows) interpreted as residual thyroid tissue post right lobectomy (A), pyramidal lobe (B), left lobe appearing larger than true size (C).](image)

![FIGURE 9. This case demonstrates a true pyramidal lobe with appropriate change in position in relationship to the thyroid gland associated with its anterior position. Note that the artifact is superimposed on the true pyramidal lobe (arrow) in the RAO view.](image)
In a careful review of patient studies, the artifact was seen in only 38% of the cases. Due to the location of the collimator defect, the artifact, in most cases, was superimposed onto the thyroid gland and, therefore, could not be distinguished as an artifact. This was demonstrated in the thyroid phantom study when the phantom was imaged at a distance of 7.6 cm from the pinhole insert. The artifact was overlying the upper pole of the left thyroid lobe and was only seen when the shielded images were compared to the unshielded image. This is the distance that we use clinically, though the phantom size is slightly larger than normal thyroid glands. By increasing the distance to 12.5 cm, the phantom image size was reduced and the artifact was seen outside the thyroid bed as it was seen in some of the clinical studies. Depending on the size of the thyroid, its location in the field-of-view, and the patient’s orientation to the collimator defect, the artifact may or may not be clearly evident on a clinical study. When present, it was either not noticed or ignored in 11 of 16 cases. In 5 patient studies, the artifact was mistaken for thyroid tissue. Although the inaccurate interpretations were of no clinical significance in these cases, the collimator defect producing the artifact provides the potential for serious misdiagnosis.

Since the visual inspection of the pinhole collimator showed no evident outward shielding defect, the defect was probably formed internally during the original casting of the collimator. Using the point source images with the lead sheets of varying centered apertures, we clearly demonstrated the artifact and determined its location. This aided in its subsequent repair to shield the defect and eliminate the artifact.

In review of all the data involving the point source, phantom and patient studies, the artifact was more prevalent when using $^{123}$I. This is because the pinhole collimator was manufactured for use of $^{99m}$Tc and its 140-keV gamma energy. Though $^{123}$I has only a slightly higher gamma energy of 159 keV, it does have a higher penetrating rate of the collimator shielding when compared to $^{99m}$Tc (Table 1). The percentage of total net counts contributed by the point source passing through the pinhole aperture is lower for $^{123}$I when compared to $^{99m}$Tc, indicating that a higher percentage of $^{123}$I counts penetrate the collimator shielding.

Quality control on various collimators has been described in the literature (19–25), though due to the lack of standardized quality control for pinhole collimators, we recommend that point source testing be performed on all new and existing pinhole collimators on a one-time basis and after any suspected damage. The procedure is simple and not time-consuming. A point source of the radioisotope(s) used for thyroid imaging should be centered over the pinhole collimator at least five fields of view from the crystal. A 5- to 10-min computer acquisition is performed. The data is visually reviewed for potential shielding defect artifacts by continually lowering the upper threshold. If an artifact is discovered, then further testing as we have described should be done to isolate the defect.

CONCLUSION

The artifacts that were seen in the pinhole thyroid studies were caused by a collimator shielding defect that was not evident on a visual inspection. The use of point source and phantom studies reproduced the artifact and were used to determine the defect location that led to a successful repair of the collimator. Radionuclide point source testing should be performed on all new and existing pinhole collimators to exclude any shielding defect which may lead to image misinterpretation.

REFERENCES