

Wrongs known as right in thyroid scintigraphy and uptake study

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ABSTRACT

Objectives: Thyroid scintigraphy using ^{99m}Tc -pertechnetate is commonly used to study function and structure of thyroid gland. Pin-hole collimator is generally preferred in thyroid scintigraphy and uptake studies. The purpose of the present study was to determine actual radiopharmaceutical uptake value in an experimental ^{99m}Tc -pertechnetate thyroid scintigraphy and uptake model.

Methods: Thyroid hyperactive and hypoactive nodule models were created using 4 mCi (148 MBq) ^{99m}Tc -pertechnetate. In the experimental model, 4 mm, 6 mm and 8 mm diameter pin-hole collimators, and 5 cm, 7 cm and 10 cm object-to-pin-hole distances were investigated.

Results: In thyroid hyperactive nodule model, despite the same activity value, uptake at 7 cm object-to-pin-hole distance was higher compared to 10 cm distance (122% and 103%, respectively). In the patient with Graves' disease, despite the same activity value, uptake at 5 cm object-to-pin-hole distance was higher compared to 10 cm distance (8% and 4%, respectively). In thyroid hypoactive nodule model, 4 mm, 6 mm and 8 mm diameters pin-hole collimators were imaged at 5 cm, 10 cm and 15 cm object-to-pin-hole distances. The resolution differences between the images were evaluated.

Conclusion: It was determined that imaging using 10 cm object-to-pin-hole distance and 4 mm diameter pin-hole collimator was best in terms of image resolution and optimum ^{99m}Tc -pertechnetate uptake level.

Keywords: ^{99m}Tc -pertechnetate, thyroid, scintigraphy, uptake

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Thyroid scintigraphy and uptake examination is a simple, non-invasive and safe method for evaluation of thyroid gland function and structure. For a standard estimation of thyroid hormone synthesis in clinical practice, radiopharmaceuticals (i.e., ^{131}I iodine, ^{123}I iodine, ^{99m}Tc Technetium) have been commonly quantified for thyroid gland uptake through determining the degree of trapping or organification in the thyroid gland for more than five decades [1, 2].

Use of ^{131}I iodine in thyroid scintigraphy and uptake

studies have major disadvantage of high radiation impact on gland (1-3 rad/mCi administered) due to longer half-life and beta particle emission of ^{131}I iodine [3]. ^{123}I iodine has major limitations of high cost and unavailability due to complex production in a cyclotron [4]. Thyroid scintigraphy and uptake studies also use ^{99m}Tc Technetium (^{99m}Tc), in the chemical form of pertechnetate [1, 2, 5]. ^{99m}Tc -pertechnetate is concentrated in thyroid gland, gastric mucous membrane, lachrymal and salivary glands [6]. Thyroid gland up-



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takes ^{99m}Tc -pertechnetate because of its volume and charge similarities with iodide. ^{99m}Tc -pertechnetate has been commonly used to evaluate thyroid function because it has shorter half-life (six hours) and shorter retention time in the gland and does not involve beta radiation. As a result, its dosimetry load on thyroid gland and on whole body is 10,000 times less than what is caused by ^{131}I iodine. It has gamma photon of 140 keV, which is ideal for imaging with scintillation cameras. Besides, it is costless and is easily available [7].

Thyroid scintigraphy and uptake studies generally employ a pin-hole or a parallel-hole collimator. It is used together with rotating gamma cameras which have large crystal areas to augment the sensitivity for emission and transmission computed tomography when used with small organs such as the thyroid, brain or heart [8]. For thyroid imaging, scintillation gamma cameras with pin-hole collimator are preferred [9, 10]. Thyroid gland has low absolute ^{99m}Tc -pertechnetate uptake, which ranges from 0.3 to 3.0% depending upon the method employed [11]. Because of semi-quantitative parameters used, higher inter- and intra-observer variability has been reported for ^{99m}Tc -pertechnetate uptake [12].

The aim of the present study was to determine actual radiopharmaceutical uptake value in an experimental ^{99m}Tc -pertechnetate thyroid scintigraphy and uptake model. Uptake value and image resolution effects were investigated using different pin-hole collimator diameters and object-to-pinhole distances.

METHODS

Study Design

Effects of 4, 6 and 8 mm diameter pin-hole collimators, and 5cm and 10cm object-to-pinhole distances were evaluated in the present study. Hyperactive and hypoactive thyroid nodule models were created using 4 mCi (148 MBq) ^{99m}Tc -pertechnetate. Scintigraphic hot areas represent hyperactive nodules, while cold areas represent hypoactive nodules. Width of the circular object field was determined by moving the source across the widest part of the field. Detector-to-pinhole and the object-to-pinhole distances were measured. Magnification factor was determined and verified by

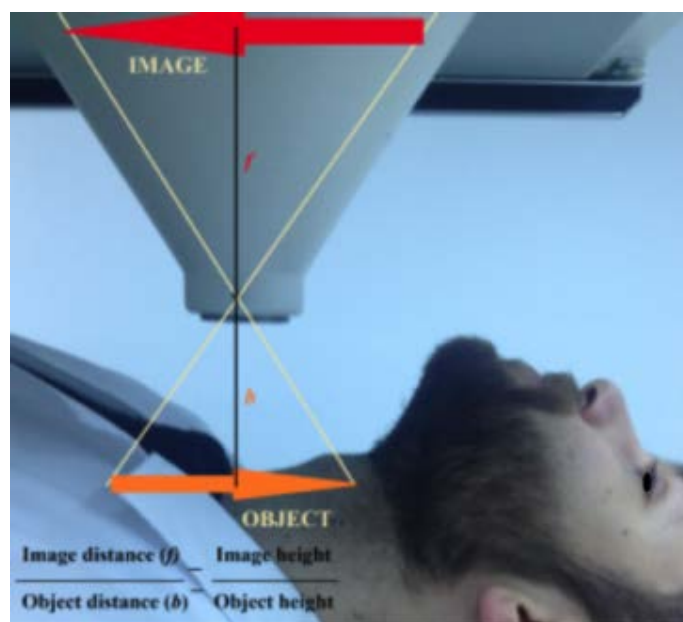


Figure 1. Geometry of the pin-hole collimator. The size of the image depends on the distance between object and image.

both using these field widths and using the camera and object distances to the pinhole. A scintillation gamma camera (Siemens E-CAM, Germany) equipped with a low-energy, pin-hole collimator was used. Images were obtained on a 128×128 matrix and at zoom 1. For uptake calculation, images of the injector were obtained before and after radiopharmaceutical injection. Images of the syringe were obtained for 1 minutes and of the anterior neck for 100,000 counts. Images were taken from the source directly under pin-hole collimator with a 140 keV and 20% energy window for 1 minutes at a distance of 5 cm, 7 cm and 10 cm. Peak counts were measured and full width was determined using half of the maximum distance. Operating principle of the pin-hole collimator is shown in Figure 1.

^{99m}Tc -pertechnetate thyroid uptake was calculated semi-quantitatively from regions of interest in thyroid tissue and background activity values as shown in Figure 2 using the formula: Thyroid Uptake (%): “T-BG/F-E” [Full (F) and empty injector (E), anterior neck region thyroid (T) and background (BG) activity values] [13].

RESULTS

For thyroid hyperactive nodule model, full and

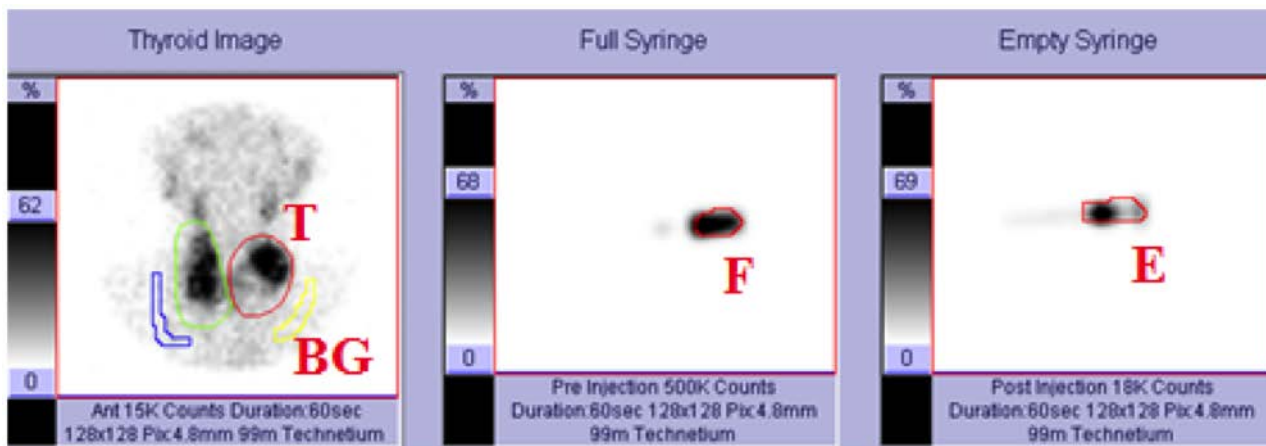


Figure 2. Parameters used in thyroid uptake study [Full (F) and empty injector (E), anterior neck region thyroid (T) and background (BG)].

empty injector counts were taken before and after injection of ^{99m}Tc-pertechnetate radioactivity. Radiopharmaceutical uptake measurements were performed at 7 cm and 10 cm object-to-pinhole distances using a 4 mm diameter pin-hole collimator. Although activity values were the same, uptake at 7 cm object-to-pinhole distance was higher than that of 10 cm (122% and 103%, respectively) (Figure 3). In diffusely increased uptake, thyroid uptake values in our patients for ^{99m}Tc-pertechnetate at 5 cm and 10 cm

object-to-pinhole distances were 8% and 4%, respectively (Figure 4).

In thyroid hypoactive nodule model, images were taken from 4 mm, 6 mm and 8 mm diameter pin-hole collimators at 5 cm, 10 cm and 15 cm object-to-pinhole distances. The resolution differences in images from different parameters were evaluated. It was found out that the best images were obtained from 10 cm object-to-pinhole distance and using 4 mm pin-hole collimator (Figure 5).

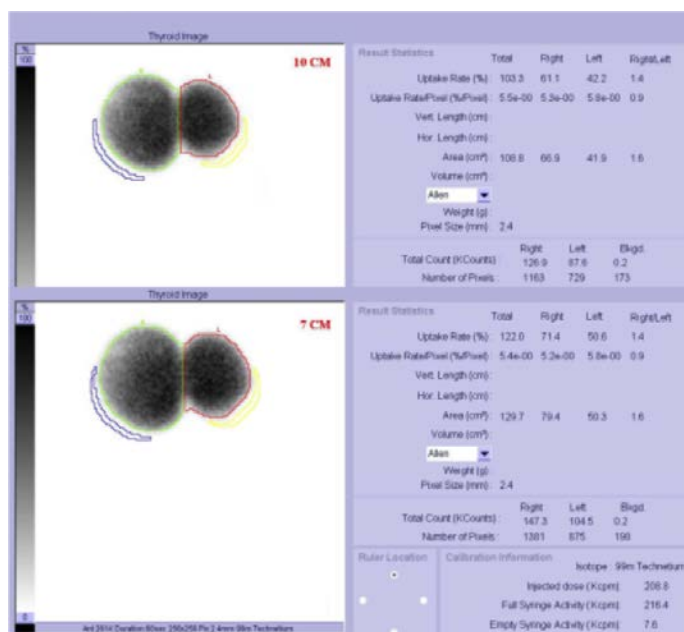


Figure 3. Different uptake values of the thyroid hyperactive nodule model at 7 cm and 10 cm object-to-pinhole distances.

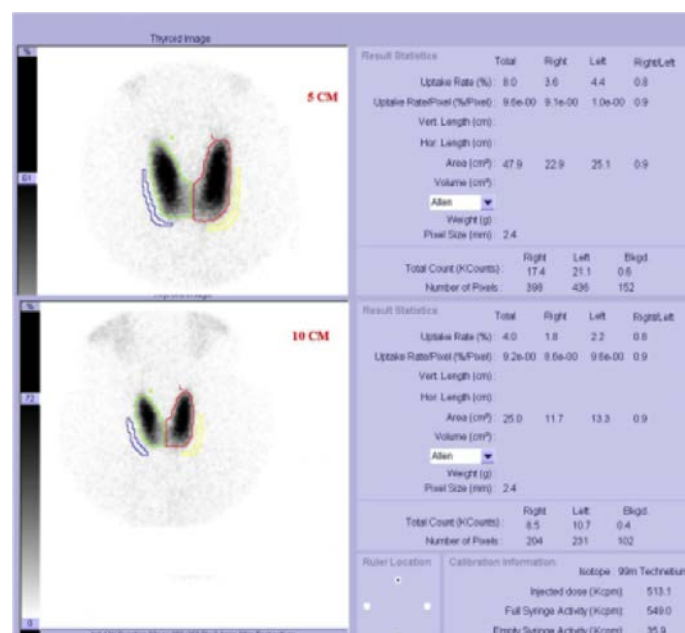


Figure 4. Different uptake values of patient with Graves' disease at 5 cm and 10 cm object-to-pinhole distances.

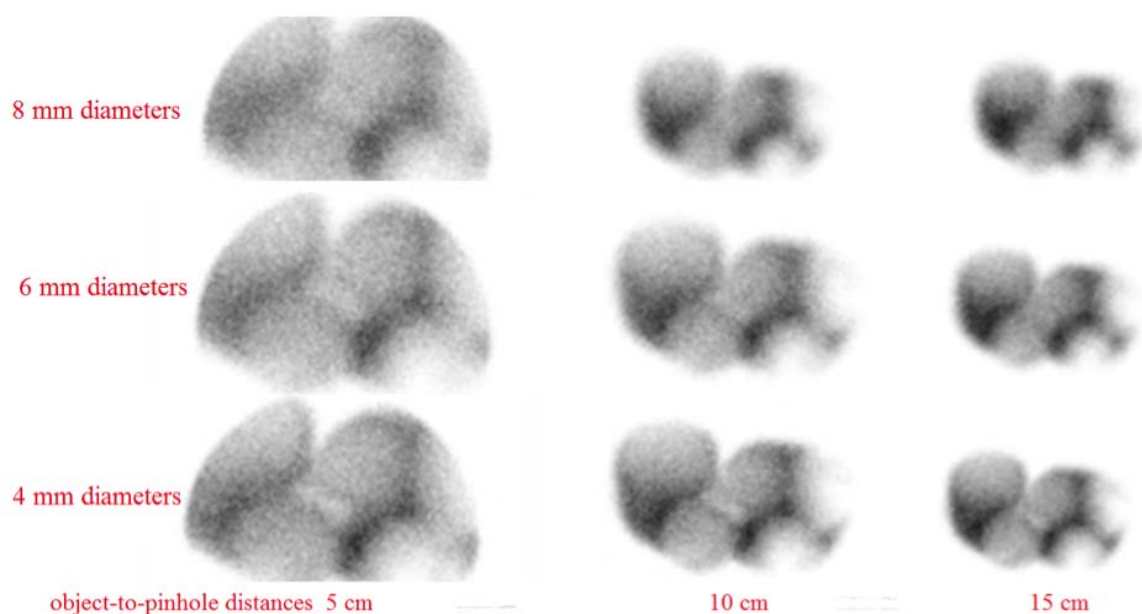


Figure 5. Image quality of the thyroid hypoactive nodule model at 5 cm, 10 cm and 15 cm object-to-pinhole distances using 4 mm, 6 mm and 8 mm diameter pin-hole collimators.

DISCUSSION

Thyroid uptake and scintigraphy scans have been commonly used in diagnosis and management of thyroid diseases [14-16]. They are an important practice in nuclear medicine [17, 18]. Similar to radioiodine, ^{99m}Tc -pertechnetate enters into thyroid follicular cells through a sodium-iodide symporter. Thus, uptake of ^{99m}Tc -pertechnetate in thyroid can be used to evaluate thyroid function [19, 20]. A pin-hole collimator is generally used in thyroid scintigraphy [21]. Thyroid uptake is calculated using gland images and syringe counts before and after radiopharmaceutical injection, and is simplified for use in routine nuclear medicine [5]. The mistakes made in the uptake operation are affecting the result. In our study, we investigated the parameters required for the uptake of the most accurate results. In the presents study, thyroid uptake of ^{99m}Tc -pertechnetate was evaluated using different object-to-pinhole distances and different pin-hole collimator diameters. Radioactive iodine uptake test is mainly used to determine the etymology of hyperthyroidism and to help decide appropriate ^{131}I rate for the treatment of hyperthyroidism [22, 23]. ^{131}I complexes with pharmaceutical substrates enable imaging other organs. However, it had a limited use, and its high

gamma energy and beta emission lowered the activity of radiopharmaceuticals used, which leads to long acquisition periods and lower quality images. ^{99m}Tc -pertechnetate, which emits only gamma radiation of 140 keV and has a half-life of only six hours, is a better radionuclide and can be used for imaging of numerous organs in the body. However, due to shorter half-life, ^{99m}Tc -pertechnetate delivered weekly by radiopharmaceutical companies [24, 25].

It has been reported that normal thyroid uptake of ^{99m}Tc -pertechnetate ranges from 0.3 to 3% in high iodine-consuming countries and from 1.2 to 7.0% in low iodine-consuming ones [2, 11]. On the other hand, thyroid uptake of radioiodine is much higher, ranging from 6 to 35% in 4-24 hours after radioiodine administration [6]. Due to absence of an organification mechanism for ^{99m}Tc -pertechnetate and its resulting leakage from thyroid, thyroid uptake of ^{99m}Tc -pertechnetate is usually measured at the plateau phase of 15 to 30 min after injection. One of the reasons why ^{99m}Tc -pertechnetate thyroid uptake test is considered unreliable compared to radioiodine test is this unstable retention. Heterogeneity of the ^{99m}Tc -pertechnetate thyroid uptake protocol constitutes another reason for its unreliability [26]. It was shown in the present study that smaller object to pinhole distance during thyroid uptake study results in higher ^{99m}Tc -pertechnetate

uptake values than it actually is.

^{99m}Tc-pertechnetate thyroid uptake test can be carried out using different parameters such as hardware (thyroid uptake system or planar gamma camera), software (thigh or mediastinum for background activity correction, syringe activity or separate standard source for injected dose determination), injection dose (37-370 MBq = 1-10 mCi) and measurement time and duration. Because of its suboptimal reliability, ^{99m}Tc-pertechnetate thyroid uptake test is useful only for differential diagnosis to distinguish conditions with extremely altered thyroid function, such as Grave's disease from destructive thyroiditis [27]. In the present study, it was shown that the results could be different depending upon object-to-pinhole distances during ^{99m}Tc-pertechnetate and thyroid uptake.

Limitations

The main limitation of the present study to demonstrate the reproducibility of ^{99m}Tc-pertechnetate and thyroid uptake is employment of a single model of thyroid probe device in a single institution. It could have been beneficial to evaluate the test in different institutions with different equipment, with use of isotope of iodine, and with different staffs, patient populations, and protocols. Nonetheless, the present study is the first attempt to measure the reproducibility of the test. This highlights the importance for each institution to measure their own practice-specific values. Significant deviation from norm should prompt a review of equipment and technique used including radioiodine dosage, probe characteristics, and technologists' expertise [12, 28].

CONCLUSION

In conclusion, thyroid uptake studies are frequently used in clinical practice. Use of ^{99m}Tc-pertechnetate to assess thyroid structure and function provides a simple, fast and efficient method which could easily become a part of the routine studies in nuclear medicine laboratories. However, ^{99m}Tc-pertechnetate thyroid uptake has an inter- and intra-observer variability, which must be standardized before its routine use. Optimum distance in pin-hole collimators deserve special attention for imaging

quality. Effects of patient's object-to-pinhole distance on collimation, image quality and uptake value were investigated in the present study. It was found out that 10 cm object-to-pinhole distance with 4 mm-diameter pin-hole collimator gave the best result for optimum imaging in ^{99m}Tc-pertechnetate thyroid uptake test.

Conflict of interest

The authors disclosed no conflict of interest during the preparation or publication of this manuscript.

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