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Evaluation of Thyroid Uptake of ^{99m}Tc Pertechnetate Using Gamma Camera and Dose Calibrator Methods in the Sudanese Population

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Abstract

Background: Estimation of the thyroid gland volume is generally considered important in several pathologic situations. The main objective of this study was to evaluate the thyroid uptake (TU) of ^{99m}TcO4$^-$ in Sudanese people, using gamma camera and dose calibrator methods and comparing the results with international TU levels.

Methods and Results: The study was conducted in 2020 at the National Cancer Institute (Wad Madani state, University of Gezira, Sudan). This study included 64 patients (58 females and 6 males) aged 13-81 years (37.25±14.58 years) with normal TU. Most patients (43.8%) were in the age subgroup of 31-48 years, followed by 39.1% in the age subgroup of 13-30 years.Two calibration methods were used to calculate full and empty syringes before and after radiopharmaceutical injection: a) using a dose calibrator measuring in MBq; b) with gamma camera images of the full and empty syringes for 1 minute (counts). In the dose calibrator, the activity and time of a ^{99m}Tc point source in a syringe were monitored, the point source was precisely aligned with the center of the camera, and a static image was obtained with static parameters at a distance of 5cm and 7cm between source and pinhole collimator (265×265 matrix).

The study showed that the TU values using the dose calibrator method were more consistent with radiation protection principles of minimizing the exposure to radiation for staff. The method also had higher values than those measured with a gamma camera due to the scatter radiation. The relationship between TU of ^{99m}TcO4$^-$ with syringe measured by dose calibrator and gamma camera at a distance of 5 cm and 7 cm, given a coefficient of determination (R^2) of 0.9937 and 0.9591, respectively.

***Conclusion*:** There was no big change in the TU between the two methods, especially at 5 cm object-to-pinhole distance, where it gave the best result for optimum imaging in the ^{99m}TcO4$^-$ TU test. (**International Journal of Biomedicine. 2022;12(3):380-384.**)

Keywords: Technetium-99m • thyroid uptake • dose calibrator • gamma camera

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Abbreviations

TU, thyroid uptake; **TS**, thyroid scintigraphy; **^{99m}TcO4$^-$**, Technetium-99m (^{99m}Tc) pertechnetate.

Introduction

An accurate estimation of the thyroid gland volume is considered important in several pathological situations, such as iodine deficiency, goiter, thyroiditis, multinodular goiter, and others.[1,2] The thyroid scintigraphy (TS) and thyroid uptake (TU) examination are simple, non-invasive, and safe methods of evaluating thyroid function and structure. More than five decades ago, radiopharmaceuticals (i.e., ^{131}I, ^{123}I, ^{99m}Tc) were commonly used to measure TU by determining the degree of trapping or organification within the thyroid gland. Due to its long half-life and beta particle emission, Iodine-131 (^{131}I) is not recommended for TS and TU studies because there is a high radiation impact on the gland (1-3 rad/mCi administered). Because Iodine-123 (^{123}I) is a complex product in a cyclotron, it has limitations, such as high cost and unavailability.[2-4]

Technetium-99m (^{99m}Tc) in the chemical form of pertechnetate ($^{99m}TcO4^-$) is also used for TS and TU. The similarity in volume and charge between iodide and pertechnetate ions is the reason why $^{99m}TcO4^-$ is so effectively used for studying thyroid function throughout the world. Because of its short half-life (6 hours), short retention in the gland, and lack of β-radiation, it provides low-dose radiation to the thyroid gland (10,000 times less than ^{131}I), as well as to the body as a whole. Its gamma photon of 140keV is ideal for imaging using scintillation cameras.[3-8]

A pinhole collimator or a parallel-hole collimator is generally used in TS and TU studies. When used with small organs such as the thyroid, brain, or heart, it is used along with rotating gamma cameras that have large crystal areas to enhance transmission and emission of computed tomography. The best scintillation gamma cameras for thyroid imaging are equipped with a pinhole collimator. There is a low absolute $^{99m}TcO4^-$ uptake in the thyroid gland, ranging from 0.3% to 3.0%, depending on the method used. $^{99m}TcO4^-$ uptake has shown higher inter- and intra-observer variability because of semi-quantitative parameters used.[7,9-12]

The problem is that the method currently used for TU (full and empty syringe images) exposes the staff to high radiation doses, in addition to the possibility of contamination. The dose calibrator method should be used instead. It was a pioneer study in Sudan that addressed the above-mentioned issue and could serve as a basis for future studies on this topic. In the study, the gamma camera method was compared with the dose calibrator method to determine which one gives the most accurate TU results and to establish a protocol for calculating TU accurately; additional information on radiation hazards and a comparison with international TU levels were also provided.

Materials and Methods

The study was conducted in 2020 at the National Cancer Institute (Wad Madani state, University of Gezira, Sudan). This study included 64 patients (58 females and 6 males) aged 13-81 years with normal TU (Table 1). Inclusion criteria were individuals without thyroid disease. Exclusion criteria were patients with thyroid disorders and abnormal laboratory tests, children, age over 81. Written informed consent was obtained from all patients before inclusion in the study.

Table 1.
Gender differences of the study patients

Gender	Frequency	Percent	Valid Percent	Cumulative Percent
Male	6	9.4	9.4	9.4
Female	58	90.6	90.6	90.6
Total	64	100.0	100.0	

Data were collected with a MEDICO Planar Gamma Camera (1995). $^{99m}TcO4^-$ was given intravenously (1-3.5 mCi/40-130 MBq) using a low-energy pinhole collimator with a 20% window (depending on body weight). The information was collected by means of a questionnaire that included all of the necessary information.

Technique used

The patient was advised to stop taking thyroid medication and avoid eating any iodine-containing foods. If the patient was a woman, she was examined to see if she was pregnant. If the patient was breastfeeding, she was instructed to stop feeding for some time until the radioactive substance had been expelled from the body (with minimizing the injected dose). The patient's medical history was considered, as well as the clinical state. The planar gamma camera's extrinsic sensitivity was calibrated first. In the dose calibrator, the activity and time of a ^{99m}Tc point source in a syringe were monitored, the point source was precisely aligned with the center of the camera, and a static image was obtained with static parameters at a distance of 5cm and 7cm between source and pinhole collimator (265×265 matrix). Following that, the computer program calculated the number of counts in one MBq. The findings were incorporated into the dosage calibrator processing procedure.

The radioactive dose was precisely measured in the dose calibrator before the injection. Different calculating methods were used to reduce the dose in patients who were underweight (these methods also can be used to maximize the dose in cases of high-weight patients). The TU was measured 15-20 minutes following a thyroid scan with an intravenous injection of 40-130MBq (1-3.5mCi) of $^{99m}TcO4$ (for maximum concentration of pertechnetate). Two calibration methods were used to calculate full and empty syringes before and after radiopharmaceutical injection: a) using a dose calibrator measuring in MBq; b) with gamma camera images of the full and empty syringes for 1 minute (counts).

A planar gamma camera was equipped with a low-energy, general-purpose, pinhole collimator. Images were obtained on a 265×265 matrix. The patient was in a supine position with a pillow under the shoulder, chin hyperextended, and camera over the neck for good visualizations of the thyroid gland, then a 150,000 count anterior image was obtained; this image was used in TU calculation (marker with point source, ^{99m}Tc was used in the suprasternal notch to determine the extension of the gland).

TU was calculated by two methods: 1) based on images of the syringe counts before and after radiopharmaceutical injection, and 2) based on a dose calibrator with the camera sensitivity that was calibrated in advance. An automatic or manual region of interest (ROI) was drawn around the borders of the thyroid gland in both methods, and the background was subtracted.

The procedure of the TU in one method was calculated automatically by introducing the data of syringes before and after injection using a dose calibrator(in MBq), and an image of the full and empty syringe was made in the other method. All counts were corrected for the acquisition time and decay of technetium-99m. Then the computer program measured the actual quantity injected into the patient by subtracting the empty syringe from the full (MBq/counts). After that, the TU was measured using a special nuclear medicine program according to the formula: TU(%) = T-BG/F-E, where (F) is a full syringe, (E) is an empty injector, (T) is anterior neck region thyroid, and (BG) is background activity values.

Statistical analysis was performed using statistical software package SPSS version 23.0 (Armonk, NY: IBM Corp.). Baseline characteristics were summarized as frequencies and percentages for categorical variables and as mean±SD for continuous variables. Inter-group comparisons were performed using Student's t-test. Multiple comparisons were performed with one-way ANOVA. Linear regression analysis was used to predict the value of a variable based on the value of another variable. A probability value of $P<0.05$ was considered statistically significant.

Results

Figure 1 shows the frequency distribution of age subgroups: most patients (43.8%) were in the age subgroup of 31-48 years, followed by 39.1% in the age subgroup of 13-30 years (Fig.1). The sensitivity of the planar gamma camera with the source at a distance of 5 cm was 160 Cps and at a distance of 7 cm -109 Cps (Table 2).

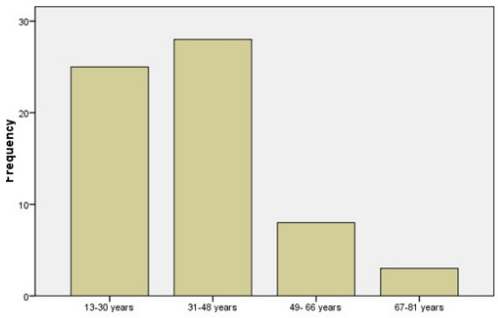

Fig. 1. *The frequency distribution of age groups.*

Descriptive statistics for TU of $^{99m}TcO4^-$ are presented in Table 3. The min, max, and mean±SD values for TU of $^{99m}TcO4^-$ with the dose calibrator at a distance of 5 cm and 7 cm were 0.32%, 3.44%, and 1.67±0.86%, respectively, and 0.42%, 4.00%, and 1.95±0.98%, respectively. The min, max, mean±SD for TU values with the gamma camera at a distance of 5 cm and 7 cm were 0.30%, 3.38%, and 1.57±0.83%, respectively, and 0.40%, 3.72%, and 1.78±0.90%, respectively. The maximum and minimum patient doses were 130 Mbq and 40 Mbq, respectively, with a mean dose of 83.25±18.70 Mbq. The maximum and minimum for the empty syringe were 14 Mbq and 2 Mbq, respectively, with a mean of 6.53±3.13 Mbq. The total mean of TU values with both dose calibrator and gamma camera at 5 cm and 7 cm distance was 1.67±0.86% and 1.57±0.83%, respectively, and 1.95±0.98 and 1.78±0.90, respectively.

Table 2.

Sensitivity of the planner gamma camera at a distance of 5 cm and 7 cm

Distance	Sensitivity
5 cm	160 Cps
7 cm	109 Cps

Table 3.

Descriptive statistics for TU of $^{99m}TcO4^-$

Characteristics	n	Minimum	Maximum	Mean	SD
Age, yrs	64	13.00	81.00	37.25	14.58
Dose Calibrator at a distance of 5 cm, %	64	0.32	3.44	1.67	0.86
Dose Calibrator at a distance of 7 cm, %	64	0.42	4.00	1.95	0.98
Gamma Camera at a distance of 5 cm, %	64	0.30	3.38	1.57	0.83
Gamma Camera at a distance of 7 cm, %	64	0.40	3.72	1.78	0.90
Full Syringe, Mbq	64	40.00	130.00	83.25	18.70
Empty Syringe, Mbq	64	2.00	14.00	6.53	3.13

The mean TU of $^{99m}TcO4^-$ in males and females with the dose calibrator at a distance of 5 cm and 7 cm was 1.77±1.22% and 1.66±0.83%, respectively, and 2.03±1.40% and 1.94±0.94%, respectively. In males and females, TU with the gamma camera at a distance of 5 cm and 7 cm was 1.61±1.16% and 1.57±0.81%, respectively, and 1.88±1.32% and 1.77±0.86%, respectively. Thus, TU of $^{99m}TcO4^-$ was slightly higher in males than in females, but with no significant differences ($P>0.05$) (Table 4A). There was no significant difference between total TU of $^{99m}TcO4^-$ with the dose calibrator and gamma camera (Table 4B).

Table 4A.

TU (%) of $^{99m}TcO4^-$ in males and females with the dose calibrator (DC) and gamma camera (GC) at a distance of 5 cm and 7 cm

Gender		DC (5 cm)	DC (7 cm)	GC (5 cm)	GC (7 cm)
Male	Mean	1.77	2.03	1.61	1.88
	n	6	6	6	6
	SD	1.22	1.40	1.16	1.32
Female	Mean	1.67	1.94	1.57	1.77
	n	58	58	58	58
	SD	0.83	0.94	0.81	0.86
P-value		0.79	0.83	0.91	0.78
Total	Mean	1.67	1.95	1.57	1.78
	n	64	64	64	64
	SD	0.86	0.98	0.83	0.90

Table 4 B.

Levene's test for equality of variances (independent samples t-test).

Characteristic		t-test for equality of means						
		T	Df	Sig. (2-tailed)	Mean difference	Std. Error difference	95% CI of difference	
							L	U
DC (5 cm)	EVA	0.28	62	0.78	0.10	0.37	-0.64	0.85
	EVNA	0.20	5.48	0.84	0.10	0.51	-1.18	1.38
DC (7 cm)	EVA	0.21	62	0.83	0.08	0.42	-0.75	0.93
	EVNA	0.15	5.47	0.88	0.08	0.58	-1.37	1.55
GC (5 cm)	EVA	0.11	62	0.91	0.03	0.36	-0.68	0.76
	EVNA	0.08	5.51	0.93	0.03	0.48	-1.17	1.25
GC (7 cm)	EVA	0.26	62	0.79	0.10	0.39	-0.68	0.88
	EVNA	0.18	5.45	0.86	0.10	0.55	-1.28	1.48

DC - dose calibrator; GC- gamma camera; EVA - equal variances assumed; EVNA - equal variances not assumed; L-Lower; U-Upper

The total TU of $^{99m}TcO4^-$ in the age groups of 13-30 years, 31-48 years, 49-66 years, and 67-81 was 2.04±0.86%, 1.45±0.78%, 1.97±0.82%, and 1.40±1.76%, respectively (Table 5).

Table 5.

TU of $^{99m}TcO4^-$ in the different age groups

Age group		DC (5 cm)	DC (7 cm)	GC (5 cm)	GC (7 cm)	Total TU
13-30, years	Mean	1.98	2.26	1.88	2.04	2.04
	n	25	25	25	25	
	SD	0.82	0.94	0.80	0.86	0.86
31-48, years	Mean	1.36	1.64	1.29	1.52	1.45
	n	28	28	28	28	
	SD	0.72	0.86	0.73	0.82	0.78
49- 66, years	Mean	1.94	2.19	1.75	2.00	1.97
	n	8	8	8	8	
	SD	0.84	0.85	0.78	0.79	0.82
67-81, years	Mean	1.30	1.61	1.18	1.50	1.40
	n	3	3	3	3	
	SD	1.65	2.04	1.48	1.88	1.76
P-value		0.0373	0.1017	0.0494	0.1613	0.0781

DC - dose calibrator; GC- gamma camera.

The relationship between TU of $^{99m}TcO4^-$ with syringe measured by dose calibrator and gamma camera at a distance of 5cm and 7cm, given a coefficient of determination (R^2) of 0.9937 and 0.9591, respectively (Table 6, Fig.2). Figure 3 presents TU of ^{99m}Tc.

Table 6.

Coefficient of determination (R^2) between the dose calibrator and gamma camera at a distance of 5 cm and 7 cm

	Dose calibrator and gamma camera at a distance of 5cm	Dose calibrator and gamma camera at a distance of 7cm
R^2	0.9937	0.9591

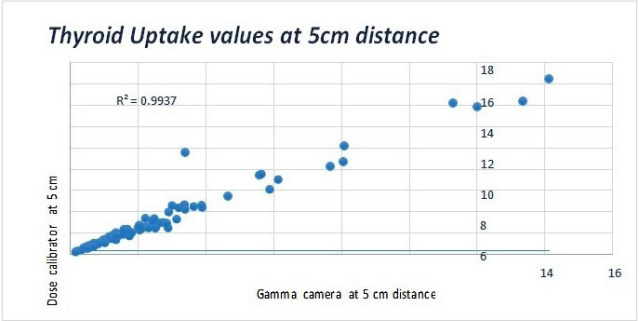

Fig. 2. *A linear regression analysis for TU of $^{99m}TcO4^-$ with the dose calibrator and gamma camera at a distance of 5 cm.*

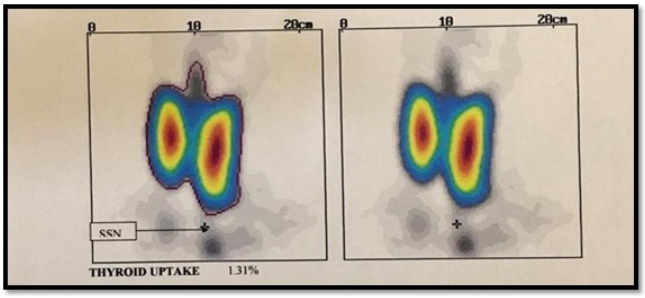

Fig.3. *TU* of ^{99m}Tc.

Discussion

This was a cross-sectional study carried out in Wad Medani, Sudan, in 2020; it aimed to evaluate the TU using gamma camera and dose calibrator methods. The study was done on 64 (58 females and 6 males) patients with mean age of 37.25±14.58 years. A high incidence of thyroid problems among females is always expected due to hormone disturbances unique to females, which agrees with the study by Elmadani et al.[13] Our study showed that the increase in source-to-detector distance decreases the sensitivity of the planar gamma camera, and this result agreed with the study by Bugby et al.[4]

Our results showed that the TU values with syringes measured by a dose calibrator were higher than those measured with a gamma camera. Another study, by Zobly et al.,[14] agrees with the current results. In our study, we found no significant differences between TU with a dose calibrator and gamma camera in males and females. Our results revealed that the TU of $^{99m}TcO4^-$ showed a tendency

to decrease in the first 1.7 decades and then a tendency to increase in the second 1.7 decades.

Conclusion

The TU is usually affected by the sensitivity of the gamma camera and dose calibrator. The maximum dose of $^{99m}TcO4^-$ given to the patient was 130Mbq and the minimum dose was 40Mbq, according to weight, with a mean of 83.25±18.70 Mbq. The TU values with syringes measured by the dose calibrator method were higher than those measured with a gamma camera, and hence more accurate due to radiation scatter in the gamma camera; the method was also consistent with radiation protection principles of minimizing ataff exposure to radiation. The relationship between TU of $^{99m}TcO4^-$ with syringe was measured by a dose calibrator and by a gamma camera at a distance of 5 cm and 7 cm, given a correlation coefficient of 0.9937 and 0.9591, respectively. According to these coefficients, there was no big change in the TU between the two methods, especially at 5 cm object-to-pinhole distance, where it gave the best result for optimum imaging in the $^{99m}TcO4^-$ TU test.

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Competing Interests

The authors declare that they have no competing interests.

References

1. Zimmermann MB, Molinari L, Spehl M, Weidinger-Toth J, Podoba J, Hess S, Delange F. Toward a consensus on reference values for thyroid volume in iodine-replete schoolchildren: results of a workshop on inter-observer and inter-equipment variation in sonographic measurement of thyroid volume. Eur J Endocrinol. 2001 Mar;144(3):213-20. doi: 10.1530/eje.0.1440213.

2. Gül SS. Wrongs known as right in thyroid scintigraphy and uptake study. The European Research Journal. 2019;5(1):142-7. doi: 10.18621/eurj.410060

3. Ramos CD, Zantut Wittmann DE, Etchebehere EC, Tambascia MA, Silva CA, Camargo EE. Thyroid uptake and scintigraphy using 99mTc pertechnetate: standardization in normal individuals. Sao Paulo Med J. 2002 Mar 7;120(2):45-8. doi: 10.1590/s1516-31802002000200004.

4. Bugby SL, Lees JE, Bhatia BS, Perkins AC. Characterisation of a high resolution small field of view portable gamma camera. Phys Med. 2014 May;30(3):331-9. doi: 10.1016/j.ejmp.2013.10.004.

5. ANDROS G, HARPER PV, LATHROP KA. PERTECHNETATE-99M LOCALIZATION IN MAN WITH APPLICATIONS TO THYROID SCANNING AND THE STUDY OF THYROID PHYSIOLOGY. J Clin Endocrinol Metab. 1965 Aug;25:1067-76. doi: 10.1210/jcem-25-8-1067.

6. Ali WM, Yousef M, Ali Omer MA, Gar-alnabi MEM, Ahmed B. Correlation of Thyroid Hormone Levels with Radioactive 99mTcThyroid Uptakes. IOSR Journal of Pharmacy and Biological Sciences. 2014;9(2):165-169.doi: 10.9790/3008-0922165169

7. Nygaard B, Nygaard T, Court-Payen M, Jensen LI, Søe-Jensen P, Gerhard Nielsen K, Fugl M, Hegedüs L. Thyroid volume measured by ultrasonography and CT. Acta Radiol. 2002 May;43(3):269-74. doi: 10.1080/j.1600-0455.2002.430307.x.

8. Kollorz EK, Hahn DA, Linke R, Goecke TW, Hornegger J, Kuwert T. Quantification of thyroid volume using 3-D ultrasound imaging. IEEE Trans Med Imaging. 2008 Apr;27(4):457-66. doi: 10.1109/TMI.2007.907328.

9. Ghervan C. Thyroid and parathyroid ultrasound. Med Ultrason. 2011 Mar;13(1):80-4.

10. Berman M, Hoff E, Barandes M, Becker DB, Sonenberg M, Benua R, Koutras DA. Iodine kinetics in man--a model. J Clin Endocrinol Metab. 1968 Jan;28(1):1-14. doi: 10.1210/jcem-28-1-1.

11. Brucer M. Thyroid radioiodine uptake measurement: a standard system for universal intercalibration. United States Atomic Energy Commission, Technical Information Service; 1959.

12. Gomez Crespo G, Vetter H. The calibration and standardization of thyroid radioiodine uptake measurements. Int J Appl Radiat Isot. 1966 Sep;17(9):531-49. doi: 10.1016/0020-708x(66)90114-1.

13. Elmadani A, Gasmelseed N, Abuidris D, Hamdoun A. Pattern of thyroid diseases in central Sudan: Nuclear medicine perspective. Sudan Journal of Medical Sciences. 2009;4(4). doi: 10.4314/sjms.v4i4.50999

14. Zobly SM, Osman AO. Radioactive Dose Measurement Based on SPECT Gamma Camera: Patient's Dose. Gezira Journal of Health Sciences. 2015 Dec 31;11(2).

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