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Determination of Correction Factor for the Calculation of 24 Hour I-131 Thyroid Uptake by Gamma Camera with HEGP Collimator

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Original Research Article

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Abstract: The aim of this study was to determine the correction factor for the calculation of 24 hour I-131 thyroid uptake using a Gamma Camera with HEGP Collimator in patients with thyroid disease. This study we initially performed on phantom and in second phase it was performed on randomly chosen 25 patients to ascertain the appropriate value of correction factor for the calculation of gamma camera based thyroid uptake. In these patients had benign thyroid disorders and most of who had been referred for Thyroid evaluation before radioiodine-131 treatment. For this study Neck Phantom (Capintec Inc., Ramsey, USA), made up of Lucite, Gamma Camera (Discovery NMCT/670, GE make, USA), Thyroid uptake probe (Captus 3000, Capintec Inc, USA), Pipettes (Tarson made) and Dose Calibrator (Captus 3000, Capintec Inc, USA) were used and fine tune the others relevant parameter. The desired amount of radioiodine-131 Sodium Iodide solution activity i.e. 1.85MBq (50 μCi) was prepared with the help of pipetting technique and was administered to the patient with adequate flushing of the vial to ensure maximum oral administration of the dose. Radioiodine-131 uptake was usually measured at 25 cm distance from the face of the crystal to the anterior neck or phantom and also 24 hours thyroid uptake was calculated by using a probe-based method and a camera-based method with a high-energy parallel-hole (HEGP) collimator. Gamma camera based thyroid uptake was calculated by two method syringe method and decay correction method for later method first we need to derived appropriate correction factor and then applies it. Radioiodine thyroid uptake value was measured by syringe method with gamma camera had a significant difference when we compare with the value we got by thyroid uptake probe. Therefore we need to derive an appropriate correction factor and by applying a study specific correction factor in gamma camera uptake value, we can equate the uptake value of probe method and gamma camera method. When we apply a correction factor 0.87 derived for gamma camera based thyroid uptake measurement we found that the uptake values with the help of gamma camera was very close to the uptake value obtains by thyroid probe system. Radioiodine-131 thyroid uptake measured by proper ROIs and corrected by applying correction factor 0.87 the gamma camera with High energy collimator (HEGP) method can yield accurate and consistent result and thus the camera based method is a good substitute for the thyroid probe based method.
Keywords: I-131, High Energy Collimator, Thyroid Uptake Probe, Gamma Camera, pertechnetate.

INTRODUCTION

The era of clinical nuclear medicine began with the radioiodine uptake test. In 1940, Hamilton reported the first external measurements of radioiodine uptake in the thyroid by means of Geiger counter [1]. The 24-hour RAIU test was introduced in 1950 by Werner et al. as a method to appraise thyroid function [2]. Radioiodine (I-131) therapy is an effective and well-tolerated option in patients with hyperthyroidism (thyrotoxicosis) due to Graves' disease and thyrotoxic multinodular goiter and in certain cases of non-thyrotoxic multinodular goiter [3-6].Radiotherapy with radioactive iodine -131 has been used to treat benign thyroid diseases for over 50 years [7]. Conditions associated with elevated or normal uptake can be distinguished from those associated with near-absent uptake (e.g., painless postpartum thyroiditis, subacute thyroiditis, or ingestion of thyroid hormone) [3-6]. The thyroid scan in this clinical context helps especially in determining the presence of nodularity: the uptake pattern in solitary thyrotoxic adenoma generally is focal in the adenoma and suppressed in the surrounding and contralateral thyroid tissue, whereas in thyrotoxic multinodular goiter there are multiple areas of focally enhanced and suppressed uptake. Although 123I is preferred for diagnostic scanning, 131I continues to be used in several developing nations where iodine-123 is currently not available [8].

Radioiodine thyroid uptake measurement test is a commonly performed in daily nuclear medicine practice [9]. Although most academic medical centers estimate thyroid uptake by using a thyroid uptake probe (which is ideal), some do not have this instrument and hence use pertechnetate (99mTcO4) scanning with a gamma camera–based method.99mTcO4 is not organified but trapped by the thyroid gland. This can result in a small range of normal uptake and high background activity, but total-body radiation exposure is less because 99mTc does not have a beta component. In addition, in nodular disease there may be discordance between radioiodine and 99mTc images, both have different physiologic uptake mechanism. For patients with differentiated thyroid cancer, the usually administered activity is 37–185 MBq (1–5 mCi) of I-131orally, and the neck and entire body are imaged at 48–96 h [10]. The aim of this study was determine a correction factor for the calculation of 24 hour radioiodine uptake with high energy Collimator in the same patient using a camera based method using high energy collimator (HEGP).

MATERIALS AND METHODS

Design Overview

This study was performed to find out the appropriate correction factor for the calculation of thyroid uptake by gamma camera method. For this initially we measured various values on neck phantom and in second phase, we performed study on randomly chosen 25 patients to ascertain the appropriate value of correction factor for the calculation of gamma camera based thyroid uptake . All these patients had benign thyroid disorders and most of who had been referred for thyroid evaluation before radioiodine-131 treatment.

In this study Neck Phantom (Capintec Inc., Ramsey, USA), made up of Lucite, Gamma Camera (Discovery NMCT/670, GE make, USA), Thyroid uptake probe (Captus 3000, Capintec Inc, USA), Pipettes (Tarson made) and Dose Calibrator (Captus 3000, Capintec Inc, USA) were used. The phantom Neck Phantom simulates a patient's neck.

Decay Correction Factor Calculation

First we noted the syringe count in dose calibrator and scanned the syringe with same collimator used for the patient's imaging. Pre injection syringe needs to be in neck phantom and at the same distance from the collimator that an average patient's neck would be. Camera's parameter will be the same for both syringe and patient then after the syringe image is loaded to the workplace. Correction factor is determined in the default workspace, by drawing an ROI around the full syringe image and a background ROI under the pre syringe image on default workspace and with the help of software, total count in ROI and total area in ROI (in pixels) are obtained. We ensure that the dose unit's utilized (milicurie, micro curie, MBq) are consistent between injected dose and correction factor and using same camera for pre syringe and performing thyroid uptake.

Total pre syringe count = T, total pre syringe area in pixels = AB
Total BKG count = B , BKG area in pixels = BA
C.F = [T] X [B X AB/BA]

This obtained value is divided by acquisition duration to determine the activity in cps.
After that, this obtained value (cps) is divided by dose in pre syringe to determine the correction factor in cps/mCi. And we calculated this value in cps/µCi by multiplying

Now factor is C.F in cps/sec/mCi = [T] X [B X AB/BA]/acquisition time of pre syringe x dose in syringe
Now factor is C.F in cps/sec/µCi = 1000 x [T] X [B X AB/BA]/acquisition time of pre syringe x dose in syringe
This correction factor can be applied to all uptake studies using the camera/isotope and collimator on which the correction factor will be determined.

Determination of Correction factor for Gamma camera based uptake calculation

We have Xeleris software for thyroid uptake calculation that was supplied with Discovery NMCT/670 Dual head gamma camera. In this software no need of pre and post syringe count. Information needed for this software is done in proper unit, decay correction factor concerning the unit of dose and time of measurement of uptake.

This study was carried out in the department of nuclear medicine at DRRMLIMS, Lucknow, from December 2015 to June 2017 after written informed consent was taken from the participants. Maximum patients coming into department were for thyroid gland evaluation. The consent forms and study procedure were reviewed and approved by the institutional ethics committee.

Inclusion Criteria

Adult patients with a clinical diagnosis of benign thyroid disorder

Exclusion criteria

Patients who were having younger than 18 years, taking Antithyroid drug within seven days and in case of female patients, if she was pregnant and or lactating and others patients who did not give written consent for the study.

If anyone of the patients was suffering from deranged TSH level, a preliminary clinical workup was performed, the previous history of the thyroid was recorded; history of hypertension, history of LMP, and current blood report of TSH and detail of previous treatment was received.

Method for the preparation of 1.85MBq (50 microcuries) dose of iodine-131

Dose preparation was done with the help of pipetting technique. It is based on the principle of dilution.

Patient Information

Thyroid studies must be interpreted in light of the patient's clinical history, serum thyroid function studies, and findings at thyroid palpation.

Patient preparation

The standard precaution for Radioiodine uptake and scanning were taken with regards to food and medications that interfere with radionuclide thyroid studies and pregnant and lactating mothers were excluded from this study.

All the Patients should have nothing by mouth for 3-4 hours before radioiodine administration to ensure good absorption with no restriction on the normal intake of water. Activity 1.85 MBq (50µCi) of iodine-131 prepared with the help of pipetting technique.

Thyroid Uptake

Radioactive Iodine Percent Uptake

I-131 Sodium Iodide solution was used for calculation of the % RAIU. Room background activity is first determined. The radioiodine in liquid form inside the vial with known calibrated activity is placed in a Lucite neck phantom and counts are obtained with the detector placed at a standardized distance of 25cm.After that pre administered syringe count take under gamma camera with the matrix of 128x128, zoom of 2 for 60 seconds and then radioiodine dose was administered to the patient. After that post administered syringe count take under the gamma camera. Both counts taken at 25 cm distance from detector and acquisition time for each is 60 seconds.

At 24 hour intervals, the probe was placed 25 cm from the anterior surface of the patient's neck, so that the entire gland can be detected by the probe and this also ensures that most of extra thyroidal activity was not cross talk with probe. The patient's thigh (background) was also counted for the background correction.
To calculate the %RAIU, counts are obtained for the patient's neck and thigh (for background). The percent radioiodine uptake is calculated according to the formula:

$$RAIU = \frac{\text{Neck Count (cpm)} - \text{Thigh Count (cpm)[background corrected]}}{\text{Administered Count (cpm)} - \text{Background Count (cpm) [decay and background corrected]}}$$

After 24 hours patients was positioned for thyroid scan under gamma camera at distance 25 cm away from the detector. The matrix of 128 x 128 for 5 minute or 300 k count of thyroid scan. Patient neck extended and pillow below the shoulder.

Gamma Camera uptake calculated with the help of software thyroid index available with GE Manufactured Discovery NM/Cy Discovery 670 dual Head Gamma Camera in our department. RAIU calculation with camera based method done by two methods one with decay correction method and another without decay corrected method.

Without decay correction method

First, draw an ROI on thyroid scan image and determine background near the thyroid gland after that with the help of thyroid Index software we calculated the radioiodine uptake.

Decay correction method

In this method first, we established a decay correction factor for 24-hour activity, then entered the values in the thyroid Index software and calculated the radioiodine uptake.

Fig-1: Lucite Neck Phantom

Fig-2: Thyroid Uptake Probe

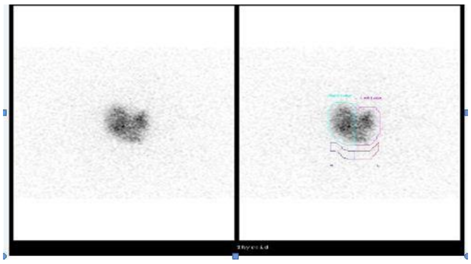


Fig-3: Thyroid Scan using Gamma Camera

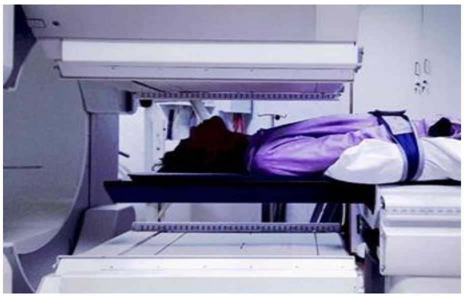


Fig-4: Thyroid Scan Acquisition under Gamma Camera

This Is the Image of Thyroid Scan [After the Scan we drew an ROI on this image and calculated the radioiodine uptake using the software. (Xeleris, thyroid uptake index)].

RESULTS

In this study most of the patients in this group were suffering from the different thyroid disorder.TSH range was 0.005 to 4.40 (µIU/ml) and mean of TSH was 0.35 (µIU/ml). Mean TSH range was meagre which showed most of the patients belonged to Graves' disease.

Table-1: Radioiodine uptake data of patients by using Thyroid probe as well as Gamma Camera based [using different Correction factor (C.F)]

Patient	Sex	Age	Probe based Uptake (I-131) %	Gamma Camera based Uptake (I-131) Syringe Method % (A)	Gamma Camera based Uptake (I-131) with C.F=1 (%)	Gamma Camera based Uptake (I-131) with C.F= 0.9 (%)	Gamma Camera based Uptake (I-131)with C.F = 0.87 (%)	TSH Level
1	M	30	2.3	0.6	1.5	1.6	1.7	0.07
2	M	50	56.1	29.1	53.5	54.9	56.2	0.11
3	M	62	17.4	8.7	13.2	15	16.9	0.01
4	F	50	60.7	29.3	57.9	58.2	61.5	1.01
5	F	26	54.3	25.4	50.6	53.7	55.4	2.2
6	F	21	69.1	47.8	67.7	73.6	75.7	0.1
7	F	44	8.3	3.7	7.5	8.7	8.5	0.01
8	F	43	36.4	36.4	33	34.9	36.4	0.01
9	M	36	45.2	21.1	42.9	44.5	45.5	0.05
10	F	51	69.2	36.9	65.8	67	68.8	0.01
11	M	50	2.3	0.8	1.4	1.8	1.8	0.04
12	F	24	45.2	16	34.7	37.9	38.9	0.01
13	F	40	58.5	21.2	45.1	48.9	51	0.011
14	F	49	49	20.9	46.3	49.1	50.9	0.01
15	F	40	28.6	10.7	20.8	21.5	23.2	4.4
16	M	30	50.4	30	42.4	46	47.5	0.01
17	M	40	34.8	13.3	28.3	30.7	32.9	0.2
18	F	46	29.7	10.4	21.3	24	24.8	0.1
19	F	30	46.2	18.8	38.1	41.6	43.3	0.11
20	F	40	66.6	25.8	56.4	62.8	66.8	1.19
21	M	57	17.6	10.1	15.2	17.2	17.6	0.08
22	M	30	11.4	3.4	7.8	9.1	10	0.02
23	M	34	72.1	29.8	68.4	75.5	78.5	0.03
24	F	42	59.1	23.7	52.1	53.7	58.4	1.1
25	F	50	34.7	16.8	27.2	29.6	32.1	0.7

Uptake range in probe-based standard method was 2.3-72.1% and mean uptake was 41.008%. Uptake ranges in gamma camera method using syringe method was 0.6-47.8% and means uptake was19.63%.Using decay correction factor 1.0 uptake range in gamma camera method was 1.4-68.4 % and mean uptake was 35.96 %.

Using decay correction factor 0.9 Uptake range in gamma camera method was 1.6-75.5 % and mean uptake was 38.46 %. Using decay correction factor 0.87 uptake range in gamma camera method was 1.7-78.5 % and mean uptake was 40.17 %.

After comparing these all methods with each other, we found that the about fifty percent of mean uptake value of standard probe based method and by applying statistical analysis, we derived a relation, i.e., correction factor between probe uptake, and gamma camera uptake and equated the uptake values of both, i.e. the gamma camera syringe method and probe based uptake value.

$P = (A + 0.379)/0.478$
P = probe uptake percent
A = gamma camera uptake percent (by syringe method)

Mean uptake of gamma camera decay correction method using decay correction factor of 1 and 0.9 was near about to the mean uptake value of the standard probe based method. However, mean uptake of gamma camera based decay correction method using decay correction factor of 0.87 was very close to mean uptake value of standard probe based method.

Standard deviation between probe uptake method and gamma camera decay method was very less and low standard deviation indicates that the data points tend to be close to the mean (also called the expected value) of the set, while a high standard deviation indicates that the data points are spread out over a broader range of values. So gamma camera method with Correction Factor (C.F) of 0.87 can substitute for the probe based method. However, there was the significant difference in different uptake methods. Repeated measure, Statistical analysis was done by using Analysis of variance (ANOVA) and pair t-test of different uptake method.

TEST1 = Thyroid Probe Uptake
TEST2 = Gamma Camera Syringe Method
TEST3 = Gamma Camera method decay correction method with Correction Factor 1.0
Test 4 = Gamma Camera method decay correction method with Correction Factor 0.9
Test 5 = Gamma Camera method decay correction method with Correction Factor 0.87

Table-2: Mean uptake value of Test-1 and Test-5 are very close to each other and test 1 value is standard value from which we are comparing the other test value. Test 1 and test-5 show same result such as mean and S.D so test-5 can be the alternative of test 1

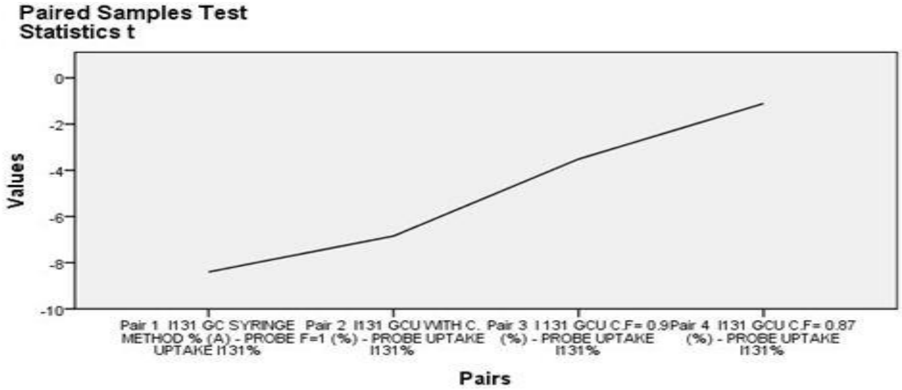
Test	Mean	No.	Std. Deviation	Median	Minimum uptake	Maximum uptake
TEST 1	41.0080	25	21.67471	45.2000	2.30	72.10
TEST 2	19.6280	25	12.13193	20.9000	0.60	47.80
TEST 3	35.9640	25	20.85751	38.1000	1.40	68.40
TEST 4	38.4600	25	21.95135	41.6000	1.60	75.50
TEST 5	40.1720	25	22.76264	43.3000	1.70	78.50
Total	35.0464	125	21.44933	34.7000	0.60	78.50

Correlations

Table-3: There is significant correlation between Uptake calculated probe based method and Gamma Camera method with correction factor 0.87

	Thyroid probe uptake	Gamma Camera Syringe based Uptake	Gamma Camera method with C.F=1	Gamma Camera method with C.F=0.9	Gamma Camera method with C.F= 0.87
Pearson Correlation with Sig. (2 tailed) in total numbers of 25 subjects	1.00	0.872**	0.988**	0.989**	0.991**
	0.872**	1	0.899**	0.895**	0.891**
	.988**	.899**	1	.998**	.997**
	.989**	.895**	.998**	1	.999**
	.991**	.891**	.997**	.999**	1

** Correlation is significant at the 0.01 level (2-tailed).



In this graphical representation each tests comparing with the gold standard probe-based method and pair 4 (probe-based method and gamma camera based method with C.F of 0.87) showed linear relations.

DISCUSSION

In past many of this kind study had been performed by various investigators to fine tune the standard recommended protocol. Wasilewski-Radwanska *et al*. compared 99mTcO4 thyroid uptake measurement measured using a gamma probe and a gamma camera and observed an excellent correlation between them [11].

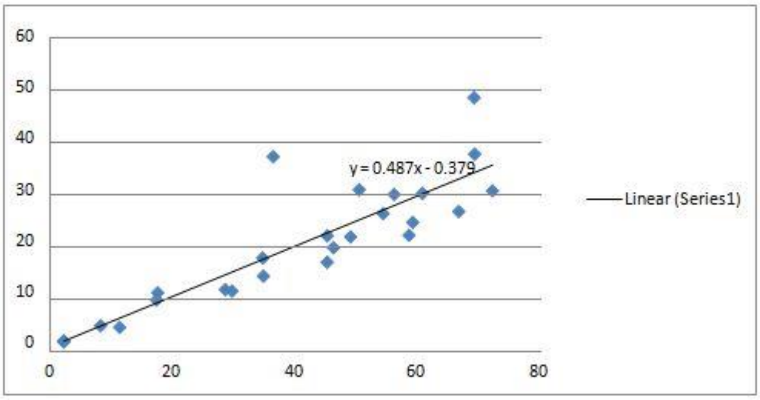
Calculation of thyroid uptake with the help of thyroid uptake probe is the well established method. In this study, we have determined the correction factor and after applying correction factor we found that gamma camera based iodine-131 uptake method can be used a substitute for the thyroid uptake probe based method and thyroid uptake values obtained by these two methods correlated well ($P < 0.005$) with each other, for various types of patients provided appropriate ROIs applied while calculation of thyroid uptake.

For thyroid uptake test, radioiodine-131 has been used in more than one form, and in developing countries most commonly used form of Radioiodine-131 is sodium iodide solution form and another one is iodine-131 capsule form. Because of cheaper in cost sodium iodide solution form of radioiodine is most widely used instead of capsule. and thus Radioiodine-131 (sodium iodide solution) is cost-effective and activity easily be prepared with the help of pipette using isotope dilution technique because the dose calibrator cannot give an accurate measurement of activity below 0.5 mCi as at this level values are not stabilising appropriately.

Also in this study, the thyroid uptakes were calculated usually by two methods, most commonly used method is thyroid uptake probe method and second method is gamma camera method. In thyroid uptake probe method, the system itself performs desired calculations for various corrections, hence no further decay correction was required, while in gamma camera method for the calculation of thyroid uptake manual intervention would be required and it was calculated by two different ways, most commonly used method is syringe method in with decay correction does not required and another method that is as per our study more accurate is with decay correction method.

In Syringe method

We draw an ROI around the thyroid gland and a semi lunar background, then the calculation of uptake was done automatically with the help of software. By applying statistical analysis, we derived a relationship i.e. correction factor between probe uptake and gamma camera uptake.



Graph-1: Y-axis shows radioiodine probe based uptake, and x-axis shows gamma camera uptake with syringe method

Decay correction factor method

This method manual intervention is required as a correction factor only and no need to acquire pre administration and post administration syringe count. We need to fill desired information in appropriate unit and correction factor and time of measurement of uptake.

In this study we applied three different values of correction factors; However first correction factors value 1.0 was on highly assumptive that can be possible with radioactive decay characteristics of any radioisotopes.

In this we assuming that there will be no decay in patient body, but that is impossible, and with this assumption, we apply the decay correction factor of 1.

Correction factor 0.9 was calculated after decay factor calculation for 24 hours, because iodine-131 decay 10 % per day means 90 % of activity remains after 24 hours and hence we choose a correction factor of 0.9.

But upon review of various literatures related to digital imaging, we factorised the value on the basis of counts received in ROIs and it was corrected with background and finally derives a correction factor, which is 0.87 for iodine-131.

After applying all three correction factors for the same patient, according to our results, the gamma camera method using the decay correction factor of 0.87 and 0.9 shows a very strong correlation coefficient of 0.999(table 3).

Gamma camera method using decay correction factor of 1 and 0.9 also shows a very strong correlation coefficient between them. Gamma camera method using decay correction factor of 1 and 0.87 shows strong correlation, but with minor deterioration (table 3).

Correlation coefficient between gamma camera method with decay correction factor of 0.87 and thyroid probe uptake is 0.991, this value is the most reliable correlation value between gamma camera method and thyroid uptake probe method. Hence merely it can be concluded that the gamma camera using decay correction factor of 0.87 shows most robust relation, i.e., highest correlation coefficient with thyroid uptake probe method (table 3).

Hence, according to our study gamma camera method with decay correction factor of 0.87 can be the best substitute of thyroid uptake probe method, between all of these i.e. gamma camera syringe method (no correction factor) Gamma camera method with decay correction factor of 1 and 0.9 (decay correction).

At last, our study strongly recommends that gamma camera method can be a good alternative of thyroid probe system and among the several methods for thyroid uptake gamma camera method with decay correction factor of 0.87 is the best substitute.

Recently, B K Menon *et al*. show a comparison of I-131 thyroid uptake values between gamma camera method and probe-based method. However, in their study, they did not mention about decay correction factors like we did and also our study well reveals the importance of appropriate decay correction, and this is why we embarked upon this study. We derived a decay correction factor and applied it to the Gamma camera thyroid uptake values and then compared these values with the thyroid uptake values by thyroid uptake system, which shows a very strong correlation coefficient.

Wasilewski-Radwanska M Studied the comparison between the data obtain in thyroid 99mTc uptake measurements with a gamma camera against thyroid probe (scintillation probe) system.

They study 30 patient (average age of 52) with hyperthyroidism contrary. We studied on 25 patient out of them 20 were hyperthyroidism patient similar to our result they also concluded that gamma probe could be an alternative to the gamma camera as a simple and efficient technique.

As discussed above our result dictated that the gamma camera can be a good alternative of scintillation probe so it is very clear from the conclusion of Wasilewska-Radwanska M and ours that both of the methods for thyroid uptake i.e. gamma camera method and thyroid uptake probe method can be used alternatively with similar and efficient thyroid uptake value.

CONCLUSION

Radioiodine-131 thyroid uptake measured by proper ROIs and corrected by applying correction factor 0.87 the gamma camera with High energy collimator (HEGP) method can yield accurate and consistent result and thus the camera based method is a good substitute for the thyroid probe based method[8].

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