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^{99m}Tc Pertechnetate Thyroid Uptake and Scintigraphy: Standardization in Euthyroid Subjects

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ABSTRACT

Thyroid uptake and scintigraphy at 20 minutes of intravenously administered ^{99m}Tc sodium pertechnetate were studied on 50 euthyroid and healthy Bangladeshi individuals. The aim of this study was to standardize a simple and fast methodology for performing thyroid uptake and scintigraphy and to determine the euthyroidism range for ^{99m}Tc pertechnetate uptake. The laboratory assessment of thyroid function consisted of serum dosages of ultrasensitive thyroxin and thyrotropin. The images were obtained on a computerized scintillation camera equipped with a low-energy high-resolution parallel-hole collimator. The present study observed that the assessment of thyroid structure and function using ^{99m}Tc-pertechnetate is a simple, fast and efficient method. The observed thyroid uptake range for euthyroid individuals are from 2.1 to 4.1% of the injected dose.

Keywords: Thyroid uptake; Scintigraphy; ^{99m}Tc-pertechnetate; Standardization; Euthyroidism.

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INTRODUCTION

There is an apparent consensus that standardization of thyroid uptake study is necessary, since ethnic, nutritional and geographical variations could be of importance in the metabolism of radiopharmaceuticals used in nuclear medicine examinations. Nevertheless, a good standardization studies is still in lack worldwide. It is, therefore, very much important to perform well controlled experimental studies that may have the capability to confirm and explain epidemiological or anecdotal data in humans. As an example, thyroid uptake of ^{99m}Tc pertechnetate, which is used especially in the diagnosis of Plummer's disease, can be influenced by the iodine supply [1]. Recently, Passos et al. [2] published an evaluation of ^{99m}Tc pertechnetate biodistribution, which became altered in diverse tissues in protein-restricted or energy restricted rats, both when malnutrition was initiated in adulthood and in adult rats fed normally whose mothers were malnourished during lactation [3]. In addition, the use of drugs can interfere with the biodistribution of radiopharmaceuticals in experimental studies [4]. Thus, there is a need for all the studies that are capable of defining better standards for specific groups of patients, so that nuclear medicine examinations can become a reliable diagnostic tool.

Early uptake studies of ^{131}I have been shown to be helpful in the thyroid uptake and scintigraphy, but they have serious disadvantages of high radiation doses to the gland (1–3 rad/mCi) caused by its long half-life and β^- particle emission. Its main gamma photon has high energy (364 keV) that is inadequately collimated by most conventional scintillation cameras, and therefore poor quality images are produced. In the United States, the use of ^{131}I for thyroid imaging has been prohibited and its use restricted to staging and follow-up of patients with differentiated thyroid carcinoma [5]. ^{123}I may be a good substitute for ^{131}I because it has a shorter half-life (13 hr), a gamma photon suitable for imaging using conventional scintillation cameras (159 keV) and no β^- radiation. However, its main limitations are its high cost and reduced availability, due to its expensive and complex production in a cyclotron. In addition, depending on the production process chosen, contaminants such as ^{124}I and ^{125}I may be formed increasing the dosimetry and image degradation [6, 7].

Harper et al. [8, 9] first showed that ^{99m}Tc was concentrated in the thyroid gland and because of its short half-life, its ready availability and desirable radiation characteristics suggested that it might be used for thyroid scanning. Since then a number of workers [10-19] have shown that excellent thyroid scans can be obtained with ^{99m}Tc. Scans performed with ^{99m}Tc are superior to those performed with ^{131}I because of the high counting rates, greater statistical reliability and superior resolution [20]. Moreover, ^{99m}Tc is readily available in all nuclear medicine laboratories and thus relatively inexpensive.

Bangladesh Atomic Energy Commission (BAEC) now regulates about 15 Institutes of Nuclear Medicine and Allied Sciences (INMAS) in where patients are referred to measure thyroid uptake. All of these Institutes, however, use the radiopharmaceutical ^{131}I-iodide to study the thyroid gland. This practice can in part be explained by the fact that there is a lack of standard values for ^{99m}Tc-pertechnetate uptake by the thyroid gland. The absolute ^{99m}Tc-pertechnetate uptake by the thyroid gland is low and ranges from 0.3 to 3.0% [19, 21]. It has been shown in the literature that normal values of thyroid uptake depend on the technique used and on the geographical location. Each laboratory should, therefore, establish its own normal values [10, 19, 21]. Encouraged by our recent measurements [22] involving standardization of serum T4, T3 and TSH on normal individuals the present study is designed to standardize a simple and fast methodology for performing thyroid uptake and scintigraphy and to determine the normal values for ^{99m}Tc-pertechnetate uptake.

The rest of this paper is organized as follows. Section 2 outlines the experimental procedures. Section 3 provides the results of the present study and compares them with the experimental data. In section 4, we conclude with a brief summary.

MATERIALS AND METHOD

Physical and Chemical Properties of ^{99m}Tc

^{99m}Tc is produced by bombarding molybdenum ^{98}Mo with neutrons[23]. The resultant ^{99}Mo decays with a half-life of 66 hours to the metastable state of Tc (Z = 43). This process permits the production of ^{99m}Tc for medical purposes. Since ^{99}Mo is a fission product of ^{235}U fission, it can be separated from the other fission products and used to generate ^{99m}Tc. For medical purposes, the ^{99m}Tc is used in the form of pertechnetate ($^{99m}TcO_4$-). Its physical half-life is 6.03 hours after which it disintegrates into ^{99}Tc through gamma emissions. The dominant decay mode gives the useful gamma ray at 140.5 keV. Both the physical and biological half-lives of ^{99m}Tc are so short that leads to very fast clearing from the body after an imaging process.

Sample Specification

The thyroids of all the individuals were in clinically normal condition. Among the individuals 20 were men and 30 women, with ages ranging from 20 to 79 years. Around half of the total subjects were within the age range of 20-40 years and around 90% were within 20-60 years. The mean age of the studied subjects was 42.7±15.3 years. Prior to oral administration of the isotope, a history to rule out the intake of any iodine containing agents or drugs known to affect thyroid function was asked from all the patients. Patients with deficient records, e.g. incomplete patient records, were excluded.

Thyroid Scintigraphy and Uptake

Thyroid scintigraphy was studied 20 minutes after the intravenous injection of ^{99m}Tc-pertechnetate with a gamma-camera (Mediso Nucline X- Ring Single Head Gamma Camera, Hungary). It is a NaI(TI) scintillator equipped with a LEAP (Low Energy All Purpose), high-resolution, parallel hole collimator. It consists of 75 photomultiplier tubes. Images were obtained on a 128 × 128 matrix and at zoom 2. At first the patients were given a 2 mCi (74 MBq) intravenous dose of ^{99m}Tc-pertechnetate. Drinking water was given immediately before performing imaging to flux away any secreted radionuclide in saliva. The patient was then placed supine, and the gamma camera was placed over the neck 30 cm from the skin surface. The radioactivity in the neck was continuously recorded for 1 - 2 minutes.

In the present study the radioactivity counts for uptake measurement were taken at 30 cm, using a gamma probe consisting of a collimated sodium-iodide crystal with a cylindrical straight-bore collimator connected to a pulse height analyzer (PHA) and scalar. Neck counts, lower thigh counts (body background), counts of the administered dose and room background counts were obtained at each counting session. The percentage uptake of the radioactive material by the thyroid was estimated using the following relation [10, 24].

$$Uptake\ (\%) = \frac{X_f}{MF \times A_t} \times 100$$

Here, X_f and A_t represent, respectively, the net count of neck and true activity of the injected dose. *MF* is the multiplication factor. It is worth mentioning that the applied dose (2 mCi) was corrected for the acquisition time (time interval between dose applying and scanning) as well as for decay factor of ^{99m}Tc to get the true activity of the injected dose (A_t).

Data Analysis

All the data collected were entered and analyzed in Statistical Package of Social Sciences version 20. The relationships between thyroid uptake values and various age groups were determined using one way ANOVA. Statistical significance level was fixed at $p < 0.05$. The graph was constructed using MS Excel program.

RESULTS AND DISCUSSION

In total, 100 studies were performed in 50 Bangladeshi individuals referred to the INMAS, Dhaka Medical College Hospital, Dhaka-1000. The total subjects in the present study were classified into three groups according to their age: younger (≥20 – 40 years); adult (>40 – 60 years) and old age (>60 years). The present results of thyroid uptake measured 20 minutes after the intravenous injection of ^{99m}Tc-pertechnetate are summarized in Table 1. The uncertainties quoted in the values represent the statistical and systematic errors. The frequency histograms of uptake values observed in this study are shown in Fig. 1. The frequency histograms revealed a non-Gaussian data distribution as previously observed by others [10, 24]. The mean and standard deviation (±SD) are, therefore, not presented in these normal distribution curves.

Table 1: Thyroid uptake values using ^{99m}Tc-pertechnetate, *n* = 50

Age Group	Average age ±SD	Frequency (%)	Uptake range (%)	Average uptake ±SD
Total	42.7±15.3	100	2.1 - 4.1	3.36±0.64
Younger	29.3±6.8	46	2.1 - 4.1	3.17±0.69
Adult	48.9±5.2	40	2.4 - 4.1	3.53±0.58
Old age	69.1±6.0	14	2.6 – 4.1	3.53±0.51
F value				3.328
P value				0.074

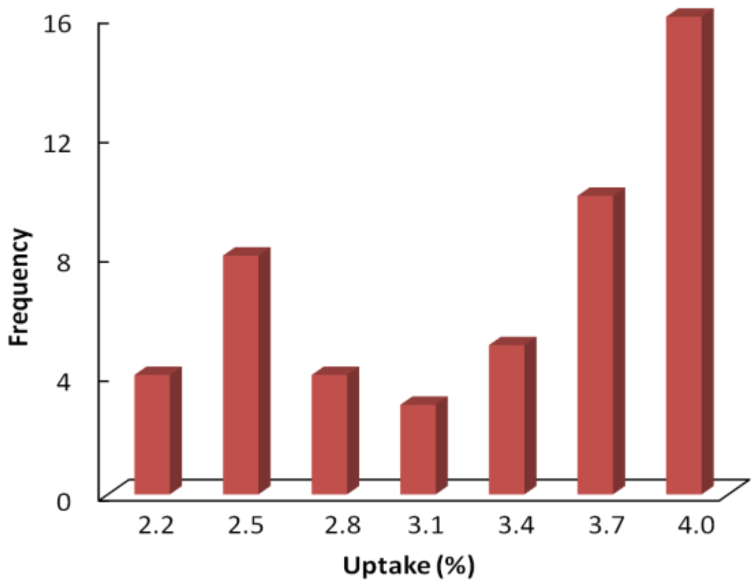

Figure 1 Frequency histogram of thyroid uptake values with ^{99m}Tc-pertechnetate observed in 50 euthyroid Bangladeshi individuals.

The mean uptake for euthyroid subjects observed in the present study is 3.36% with an observed range of 2.1 - 4.1% and a standard deviation of 0.64%. The Mean±SD of uptake values obtained for younger age group is found to be 3.17±0.69% with range 2.1 – 4.1%, for adult group it is 3.53±0.58% with range 2.4% to 4.1%, and for old age group it is 3.53±0.51% with a range of 2.6-4.1%.

DISCUSSION

Thyroid uptake and scintigraphy are useful tools for evaluating thyroid status. Thyroid uptake is a measure of the rate of accumulation of radioactive tracer by the thyroid and the ability of the gland to trap that tracer. Scintigraphy, on the other hand, is the use of gamma cameras to capture emitted radiation from internal radioisotopes to create two-dimensional images. Currently the most widely used radionuclide for imaging by γ-scintigraphy is ^{99m}Tc which is available as the daughter product of ^{99}Mo in a generator system [23]. Its physical characteristics make it particularly suitable for scintillation scanning [8, 9, 25].

Technetium is trapped by the thyroid, as is iodide, but soon after administration no significant organic "binding" takes place. The maximum thyroid uptake of ^{99m}Tc-pertechnetate takes place 10 to 30 minutes after intravenous injection, in contrast to ^{131}I-iodide, which requires a 24-hour measurement period [19]. 20 minutes after intravenous injection, however, there is a very good correlation between the thyroid uptakes of ^{131}I and ^{99m}Tc [26]. Moreover, the technetium study does not interfere with the iodine study if one wants to perform it as well because the 140-keV technetium gamma photon is easily discriminated against and in 24 hr physical decay alone reduces the amount present by a factor of 16. Thus both the "trapping" and "binding" functions of the thyroid can be examined separately.

In the present study, thyroid uptake was studied 20 minutes after the intravenous injection of ^{99m}Tc-pertechnetate. Some authors [19, 21, 24] reported the absolute ^{99m}Tc-pertechnetate uptake by the thyroid gland ranges from 0.3 to 3.0%. Both the lower and upper limits of normality in this study are higher than that of aforementioned reported series. This difference could be due to the different techniques used and the population studied.

On comparing the uptake ranges in different age groups, it is amazing to observe that the upper limits of uptake values are same for all three groups. However, the lower limits slightly differ from each other. The mean uptake is same for the adult and old age groups, and is higher than that of younger age group. However, no statistical significant difference has been found by age among the mean uptakes at $p<0.05$. To the best of our knowledge there is no such data available in literature to compare with.

CONCLUSION

In this paper, thyroid uptake and scintigraphy at 20 minutes of intravenously administered ^{99m}Tc sodium pertechnetate observed in 50 euthyroid and healthy Bangladeshi individuals: 60% female and 40% male are presented. The thyroid uptake observed in this study ranges from 2.1 to 4.1% of the injected dose, which is reasonably agree well with the reported data. The present study also has observed that the assessment of thyroid structure and function using ^{99m}Tc-pertechnetate is a simple, fast and efficient method. The improved acceptability of this methodology all over the world lies in its simplicity, reproducibility, low cost and availability. Nevertheless, the use of ^{131}I for thyroid scintigraphy still in most of the nuclear medicine facilities in Bangladesh may be due to the lack of standard values for ^{99m}Tc-pertechnetate uptake by the thyroid gland. It is, therefore, the present results will play a great role in choosing ^{99m}Tc-pertechnetate as a tracer for the assessment of thyroid status in

Bangladesh. More experimental data on ^{99m}Tc-pertechnetate thyroid uptake and scintigraphy are needed for further testing and refinement of this methodology.

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