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Determination of organ doses in radioiodine therapy using medical internal radiation dosimetry (MIRD) method

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Background: Radioiodine therapy has proven to be an effective method in the treatment of patients with differentiated thyroid carcinoma after thyroidectomy. The scope of this study is to describe a method to obtain the dose of organs using medical internal radiation dosimetry (MIRD) method. At the end, the results of MIRD calculations were compared with thermoluminescent dosimeter (TLD-100). ***Materials and Methods:*** The study was performed on 27 patients using TLD for thyroid, sternum and cervical vertebra. There were 5 TLDs for each organ which they were taken after 4, 8, 12, 20 and 24 hr. To calculate the amount of activity in the thyroid a head and neck phantom with a source of 10 mCi of ^{131}I was used. A head and neck phantom was used to determine the absorbed dose. A source of 10 mCi of ^{131}I was putted on phantom. Several TLDs were placed on the surface of thyroid on phantom for 24 hr and then compared with the dose of phantom and patients followed by calculation of the activity in patient's thyroid. Finally, MIRD formula was used to calculate absorbed dose in cervical vertebra and sternum. ***Results:*** The average of measurements of TLDs on phantom for 10 mCi of iodine was 33.3 cGy. The absorbed activity in thyroid in three groups for 100, 150 and 175 mCi administered ^{131}I were 94.9, 104.6 and 108.8 mCi cumulated activity in 24 hrs. The absorbed dose obtained by MIRD calculations was found to be 419.9, 463.2, and 481.5 for thyroid, 288.9, 252.4 and 252.4 for sternum and 288.9, 252.4 and 252.4 for cervical vertebra. ***Conclusions:*** The results of MIRD method was similar to the results obtained experimentally. It was shown that 75% of absorbed dose calculated by the MIRD method is detectable by the TLD method. **Iran. J. Radiat. Res., 2011; 8(4): 249-252**

Keywords: *Radioiodine therapy, thyroid cancer, cumulative dose, phantom, MIRD.*

INTRODUCTION

Radioiodine therapy has proven to be an effective method in the treatment of patients with differentiated thyroid carcinoma after thyroidectomy (1-6). In this therapy method, the prescription of sodium iodine is done orally (7). Radioiodine is a beta emitting radionuclide with a physical half life of 8.1 day, a principal gamma ray of 364 keV, and principal beta particle with a maximum energy of 0.61 MeV and average of 0.192 MeV and a range in tissue of 0.8 mm (7). Usually 30-100 mCi of ^{131}I is prescribed for the first radioiodine therapy and higher amounts are given in subsequent therapies or in the case of metastatic disease. Usually the activity is limited for safety aspects around 200 mCi. However, a higher administered activity is desired to achieve higher tumor doses (1). Treatment with ^{131}I may result in abnormalities in other organs so it is important to estimate organ doses. The accuracy of absorbed dose of an internally distributed radio-nuclides estimated by different methods such as MIRD (Medical Internal Radiation Dosimetry).

Dosimetry is required by the clinician for several reasons. First, treatment is often limited by the dose delivered to critical organs, for example bone marrow. Second, dosimetry is required to prescribe the correct activity of radioiodine. Indeed, internal radiation dosimetry of radiopharmaceuticals is an important aspect of nuclear medicine to weigh risk versus benefit considerations. In MIRD method, the dose absorbed in the target organs are estimated by the activities accumulated in

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the source organ [8-11].

In iodine therapy the source organ is thyroid and estimation of the accumulated activity is done in this organ. Many studies have been performed to estimate organ's activity using MIRD [4-6]. The aim of this study was to describe a method to obtain absorbed dose of organs using MIRD method and the results were compared with experimental results (TLD).

MATERIALS AND METHODS

A total of 27 patients (4 men and 23 women with age average of 39.7 ± 0.07) were entered in the study. They received different doses of ^{131}I for treatment of differentiated thyroid cancer (DTC). Based on the administered doses, the patients were divided into three groups of 100, 150 and 175 mCi. Two different types of TLDs, GR-200 (LiF: Mg, Cu, P) and TLD-100 (LiF: Mg, Ti) were used.

TLDs were dose calibrated with a ^{60}Co source located in the radiotherapy section of Seyed Al-shohada hospital of Isfahan, Iran. For each patient 15 TLD was used (five for each organ). TLDs were positioned on the patient's skin in three locations: directly over the thyroid gland, over the sternum and over the cervical vertebra. For fixing the TLDs on the surface of organs, 5 TLDs were placed on a holder (with 5 separate components for each TLD to prevent direct contact) and were fixed on organs. TLDs were removed after 4, 8, 12, 20, 24 hrs following sodium iodide administration. All TLD doses were read using the Solaro 2A Reader located in the Department of Medical Physics of Isfahan University of Medical Sciences.

The cumulative doses per hour were obtained. Since the distance between the surface of thyroid and the surface of skin is more than 5 mm, therefore, the contribution of beta irradiation was assumed to be negligible. The measured values and the integral of the extrapolated function were summed for each location in order to determine cumulated absorbed dose on the skin [6]. To calculate the amount of iodine activity in thyroid of patients, a head and neck phantom of perspex was designed.

In the place of two lobes of thyroid two bottles of 5 mCi of ^{131}I were used and TLDs were placed on the surface of thyroid phantom for 24 hr. Subsequently, dose measurement on patients and phantom were compared. Since the amount of activity in phantom was known, the amount of iodine in patient thyroid could have been estimated.

After these steps, the exact activity in thyroid was available and is applicable in MIRD formula as follows:

$$D(s\rightarrow t) = 1.44\ T_{1/2}(FA/M) \times 0.433 = 1.44 \times 7.1 \times 0.433 \times (FA/M)$$

Where FA/M is cumulated activity in thyroid, the data is calculated by integrating the activity over time. To obtaining dose in other organs another formula is used. Because for other organs, thyroid is source organ and the absorbed dose is from the activity in source organ, so the formula is:

$$D(s\rightarrow t)=1.44\times 7.1\times \text{thyroid activity} \times S(s\rightarrow t)$$

$$D(\text{thyroid}\rightarrow\text{sternum})= 1.44 \times 7.1 \times \text{thyroid activity} \times S(\text{thyroid}\rightarrow\text{sternum})$$

$$D(\text{thyroid}\rightarrow\text{vertebra})= 1.44 \times 7.1 \times \text{thyroid activity} \times S(\text{thyroid}\rightarrow\text{vertebra})$$

"S" factor obtained from tables in text books [10] for ^{131}I when thyroid is source organ. Table 3 shows the results of these calculations.

RESULTS

The accumulated surface dose was obtained from integrating dose per hour [9, 12]. Table 1 summarizes the amount of cumulated absorbed dose for different organs which are obtained by integrating the curves, formula.

By generating time-dose curves for each organ, the cumulative absorbed dose was obtained by calculating the area under the curve. The average of absorbed dose on the surface of thyroid on phantom was 33.3 cGy.

Table 2 shows the amount of ^{131}I in thyroid obtained by comparison of absorbed dose in patients and phantom.

Table 3 also shows the result of calculating methods of MIRD compared to experimental methods (TLD).

DISCUSSION

There are different methods to obtain organ's doses such as MIRD, Monte Carlo and direct dosimetry of TLDs. In this work, the radiation dose to three organs (thyroid, sternum and neck vertebra) was measured, using MIRD method, and the result was compared with dosimetry results using TLD. The TLD method is easy and can be used in all nuclear medicine centers, but it has some limitations. ^{131}I has been used for therapy which emits both beta rays and travels a maximum distance of 3 mm in tissue and therapy ensure local treatment of the tissue under consideration and 364 keV gamma rays. But, TLDs show a just dose of gamma rays. So, there is a difference between the results of TLD dosimetry and other calculation methods such as MIRD.

The significant correlation between absorbed doses on the skin and the amount of radioiodine in the thyroid at 24 hr suggests that these doses were for a large part, caused by gamma radiation from radioiodine in the thyroid gland. As shown in table 1, to calculate cumulated dose in organs, the formula of each curve obtained and by integrating of these formulas during 4 to 24 hr all needed parameters were measured. TLDs on the surface of thyroid on phantom showed an average of 33.3 cGy for 10 mCi of ^{131}I. Table 2 shows the results of comparing patient's direct dosimetry and phantom dosimetry.

MIRD method has also some limitations. For example, to calculate dose in target organ the source activity must be known. To calculate the required parame-

Table 1. Accumulated dose in organs for each group (cGy).

Organ	Group 1 (100 mCi)	Group 2 (150 mCi)	Group 3 (175 mCi)
Thyroid	315.6 ± 0.4	348.1 ± 0.7	361.9 ± 0.6
Sternum	201.5 ± 0.3	275.2 ± 0.6	242.6 ± 0.5
Cervical vertebra	311.5 ± 0.5	184.1 ± 0.4	325.9 ± 0.2

Table 2. The activity obtained by use of phantom.

Administrated activity (mCi)	10	100	150	175
Absorbed dose (cGy)	33.3 ± 0.4	315.6 ± 0.7	348.3 ± 0.3	361.9 ± 0.2
Activity (mCi)	10.0 ± 6	94.9± 0.4	104.6 ± 0.3	108.8 ± 0.3

Table 3. Results of MIRD calculations.

Activity (mCi)	Organ	Calculated dose in MIRD (cGy)	Obtained dose from TLD (cGy)
100	thyroid	419.9	315.6
150	thyroid	463.2	348.2
175	thyroid	481.5	361.9
100	sternum	228.9	201.5
150	sternum	252.4	275.2
175	sternum	252.4	242.6
100	Cervical vertebra	228.9	311.5
150	Cervical vertebra	252.4	184.1
175	Cervical vertebra	252.4	325.9

ters a head and neck phantom was used.

In MIRD calculations, to obtain sternum and cervical vertebra dose "S" factor of these organs for ^{131}I with photon of 1.25 MeV energy is the same. Comparing the results of MIRD and TLD showed that TLDs obtain lower dose and it may be due to this fact that TLDs just absorb gamma rays and beta rays are ignored in TLD method (table 3). About 25% of all radiations are beta, which cannot be measured by TLD. Hence, using TLD, of the absorbed dose was approximately 25% lower than the amount of the dose on thyroid place.

In each period of radioiodine therapy in thyroid carcinoma patients, thyroid should absorb about 4-6 Gy. This amount is approximately the same as 4.2 Gy for thyroid which reported by Huysmans *et al.* and colleagues [9]. Results of MIRD method in this work showed that thyroid of patients absorbed this amount of radiation and are in good agreement with previous work done by author [12]. Measurements proved MIRD calculations as an effective method to obtain the amount of iodine absorbed in thyroid. For this purpose, TLDs may be put for longer time on patients and phantom, and it must be done in a longer period and TLDs could be applied by the patients themselves at home.

In conclusions, The findings here showed a method to obtain the absorbed activity in thyroid of patients and also used in MIRD calculations to estimate of organ doses. The results of direct dosimetry methods using TLD showed that an approximately 25% dose was lower than that of MIRD methods.

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