Original Article

Determination of Absorbed Dose of Organs (Thyroid, Sternum, Cervical vertebra) in Thyroid Cancer Patients Following Radioiodine Therapy

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(Received 12 October 2008, Revised 3 February 2009, Accepted 6 February 2009)

ABSTRACT

Introduction: In patients with thyroid carcinoma, radiation absorbed doses of the thyroid and surrounding tissues is important to weigh risk and benefit considerations. In nuclear medicine, the accuracy of absorbed dose of internally distributed radionuclides is estimated by different methods such as MIRD and direct method using TLD. The aim of this study is using TLD and a phantom to determine the amount of cumulated activity in thyroid and surrounding tissues.

Methods: Thermoluminescent dosimeter (TLD) measurements were performed on 27 patients on the skin over the 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. Several TLDs were placed putted on the surface of thyroid on phantom (similar to patients) for 24 hr and then compared the dose of phantom and patients followed by calculation of the activity in patient's thyroid.

Results: TLD measurements showed cumulated radiation absorbed doses (cGy) of 315.6, 348.1 and 361.9 for thyroid with administration of 100, 150 and 175 mCi of ^{131}I, respectively. For sternum the values found to be 201.5 cGy, 275.2 cGy and 242.6 cGy. For cervical vertebra results were 311.5 cGy, 184.1 cGy and 325.9 cGy. The average of measurements was 33.3 cGy using of TLDs on phantom and absorbed activity in thyroid were 94.9, 104.6 and 108.8 mCi in 24 hr for mentioned doses administration.

Conclusion: In this work a method to obtain the absorbed activity in the thyroid and other surrounding tissues is described. By this method, the amount of ^{131}I needed for each patient also could be determined. The results of this work can be used in estimation of absorbed dose in thyroid and other organs using of MIRD method.

Key words: Radioiodine therapy, TLD, Thyroid cancer, absorbed dose.

Iran J Nucl Med 2009; 17(1): 27-33

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INTRODUCTION

Radioiodine therapy with ^{131}I has been used as a clinical technique since 1947 (1-4). This radioisotope has been used effectively for the diagnosis and treatment of thyroid diseases particularly differentiated thyroid cancer (DTC) (2, 3). In patients with differentiated cancer of thyroid a total thyroidectomy is recommended followed by ^{131}I ablation of any remaining normal tissue (1).

Iodine-131 has been used for therapy which emits both beta rays (maximum energy of 606 kev) which travel a maximum distance of 3 mm in tissue and therapy ensure local treatment of the tissue under consideration and 364 kev gamma rays (5-7). Advantages of ^{131}I consisting of the low production cost and its easy availability. The efficacy of radioiodine therapy is directly related to tumor uptake and retention. Effective tumor uptake is achieved if there is a concentration of 0.5% of the dose per gram of tumor tissue with an effective half life of at least 4 days. The radiation absorbed dose delivered to the thyroid is related to the activity administered and the fraction of the dose uptake by thyroid (5). But ^{131}I has some radiation effects on normal organs so it is important to perform dissymmetric studies prior to therapy in order to maximize the dose delivered to the tumor while limiting the normal organs exposure.

The amount of activity in patients' thyroids depends on many factors such as type, grade, structure and the residue of thyroid tissue. There are different methods such as mathematical methods of MIRD, Monte Carlo and direct methods using of TLD to measure absorbed dose in other organs. Using TLD is well established in medical and health physics. The accuracy of absorbed dose of internally distributed radiopharmaceuticals estimated by the MIRD method depends on the cumulated activity of the source organs and their mass. The usual methods for obtaining the cumulated activity are, positron Emission tomography (PET), single photon Emission computed tomography (SPECT), extrapolation from animal data, calculations based on the mathematical biokinetic model and use of TLD (8).

The aim of this study is to obtain absorbed dose in three organs (thyroid, sternum and cervical vertebra) in patients who received ^{131}I and to develop a method for estimation of cumulated activity in thyroid using TLD and a head and neck phantom.

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 DTC. based on administered doses 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. They were dose calibrated with a ^{60}Co source located in the radiotherapy section of hospital. 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 ^{131}I administration. All TLD doses were read using the Solaro 2A reader located in our department.

The cumulative doses per hour were obtained. Since 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.

Table1. Results of dosimetry on studied patients.

Activity	Organ	Time	Average	Cumulated dose
100 mCi	Thyroid	4	5.27	5.27
		8	42.26	36.99
		12	52.17	9.90
		20	62.20	10.03
		24	65.96	3.75
	Sternum	4	7.47	7.47
		8	16.37	8.89
		12	33.60	17.23
		20	37.90	4.30
		24	42.34	4.44
	Vertebra	4	8.04	8.04
		8	18.73	10.68
		12	42.20	23.47
		20	57.10	14.90
		24	61.04	3.93
150 mCi	Thyroid	4	10.17	10.17
		8	39.64	29.47
		12	55.24	15.60
		20	69.76	14.51
		24	74.15	4.38
	Sternum	4	8.26	8.26
		8	20.78	12.55
		12	38.99	18.20
		20	51.62	12.62
		24	57.47	5.85
	Vertebra	4	5.63	5.63
		8	14.42	8.79
		12	24.10	9.68
		20	34.98	10.87
		24	40.04	5.06
175 mCi	Thyroid	4	18.07	18.07
		8	53.64	35.57
		12	63.80	10.15
		20	80.01	16.21
		24	87.57	7.56
	Sternum	4	7.53	7.53
		8	18.05	10.51
		12	33.33	15.28
		20	45.80	12.46
		24	51.17	5.37
	Vertebra	4	8.23	8.23
		8	33.49	25.26
		12	47.82	14.32
		20	63.38	15.55
		24	69.31	5.93

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. Because the amount of activity in phantom was known, the amount of iodine in patient thyroid could be estimated.

RESULTS

To estimate the absorbed activity in each organ according to the therapeutic dose of ^{131}I, patients were divided into three groups of 100, 150 and 175 mCi. TLDs were fixed on the surface of thyroid, sternum and neck vertebra before administration of ^{131}I. Following the administration of the dose, the TLDs were removed after 4, 8, 12, 20 and 24 hrs.

Table 1 shows data of TLD measurements on the skin over the thyroid, sternum and neck vertebra for three mentioned groups after 4, 8, 12, 20 and 24 hrs. The average dose measurements and cumulative dose for the patients in each group are shown in this table.

By generating time-dose curves of each organ, the cumulative absorbed dose can be obtained by calculating the area under the curve.

Figure 1 shows the curve for thyroid in three groups 100, 150 and 175 mCi of administrated dose. The area under the curve was obtained by integrating of function of curve from 4 to 24 hr. Figure 2 and 3 shows the amount for sternum and cervical vertebra in each group. Table 2 also summarized the amount of cumulated absorbed dose for different organs that obtained by integrating of curves formula.

The next step was obtaining cumulated dose on the surface of thyroid on phantom in 24 hr for 10 mCi of ^{131}I. Similar to patients, TLDs were placed on the surface of thyroid on phantom and bottles of 10 mCi of ^{131}I were used in the place of thyroid and after 24 hr TLDs removed and read by TLD reader. The average of absorbed dose on the surface of thyroid on phantom was found to be 33.27 cGy. Table 3 shows the amount of ^{131}I in thyroid obtained by comparison of absorbed dose in patients and phantom.

DISCUSSION

Many researchers used TLD as a direct dosimetry method for thyroid (1, 6, 9). According to different studies (6), TLD measurements proved to be an accurate method of monitoring effective half times of ^{131}I in the thyroid. TLDs may be applied by the patients themselves at home, eliminating the need for frequent thyroid radioactivity measurements in the clinic. The results here showed maximum amount of ^{131}I uptake by thyroid at 8 hr after administration of ^{131}I (Fig. 1-3).

Our results showed absorbed doses at all three locations were significantly correlated with the amount of radioiodine retained in the thyroid at 24 hr (Fig. 2, 3).

Absorbed doses in the vertebra and sternum was lower than those measured at skin level over the thyroid gland because the distance between the posterior edge of the thyroid and other organs is considerably larger than the distance between the anterior edge of the thyroid and the surface of the skin.

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 it is shown in Table 2, 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 I-131. Table 3 shows the results of comparing patient's direct dosimetry and phantom dosimetry. The last row of this table shows the amount of activity in thyroid of patients.

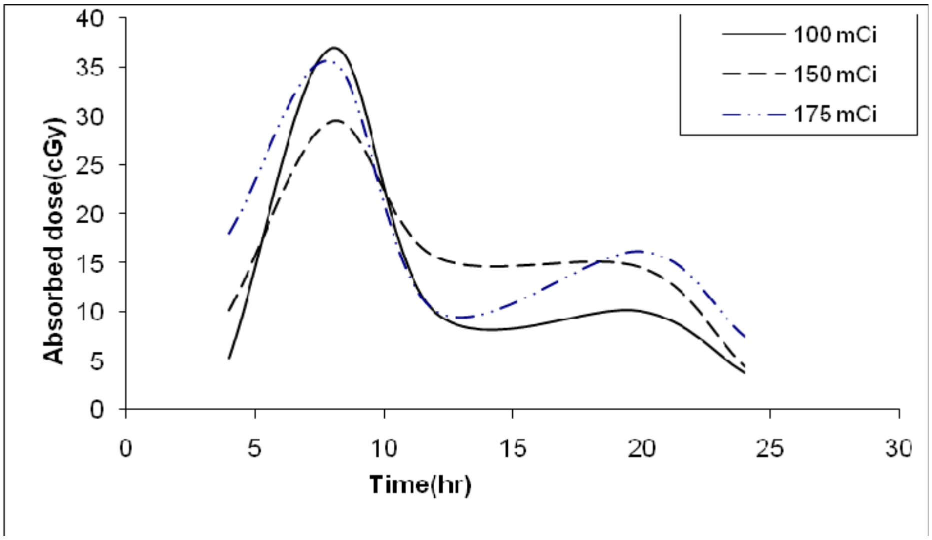

Figure 1. The cumulated dose of thyroid for patients in three groups.

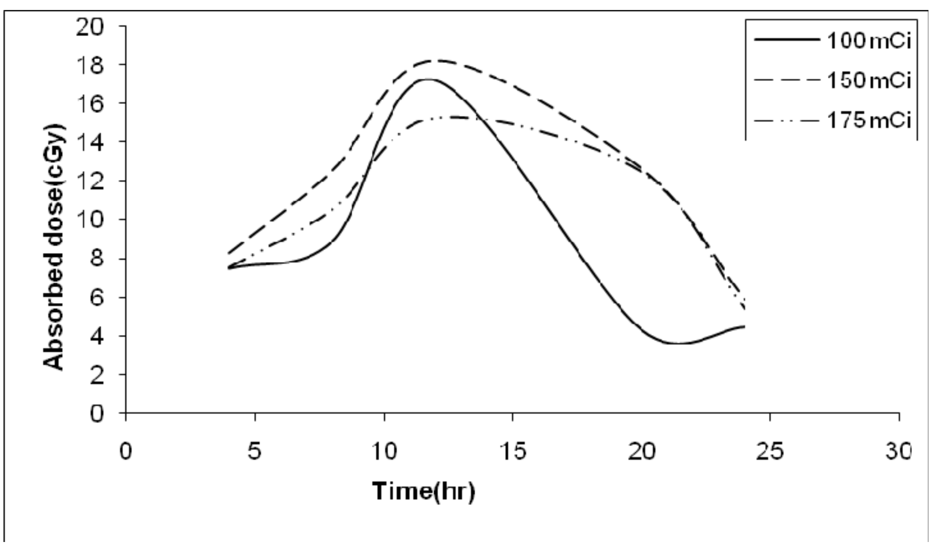

Figure 2. The cumulated dose of sternum for patients in three groups.

Table 2. Accumulated dose in organs for each group (cGy)

Organ	Group1(100 mCi)	Group2 (150 mCi)	Group3 (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
Neck vertebra	311.5 ± 0.5	184.1 ± 0.4	325.9 ± 0.2

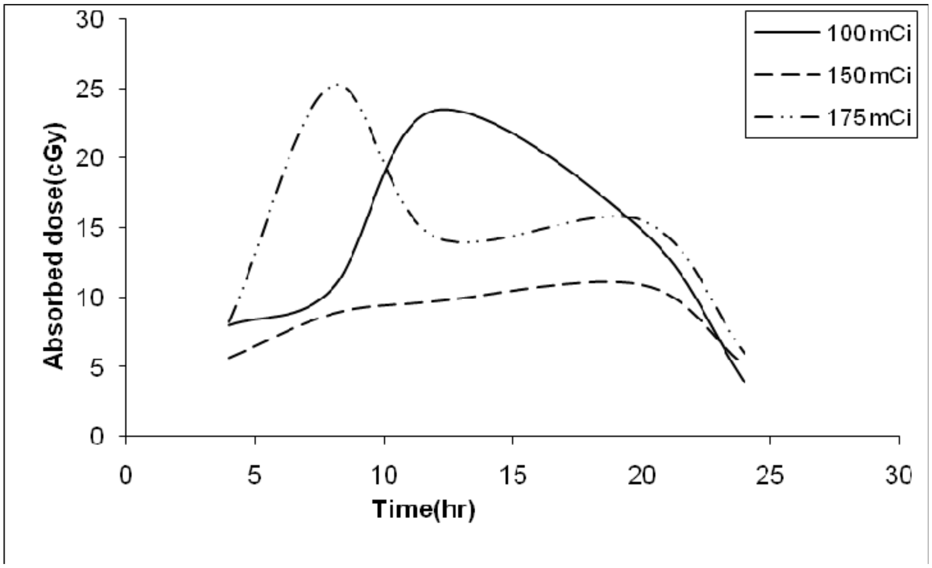

Figure 3. The cumulated dose of cervical vertebra of patients in three groups.

Table 3. The activity calculated using 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 ± 0.6	108.8 ± 0.3

The results of ^{131}I activity in thyroid showed that all amount of administered activity was not absorbed in thyroid in first 24 hr and perhaps needs that another work to be done in longer period to find exactly how much of activity can be absorbed in thyroid.

The current procedure of measuring dose by this method can be affected by different sources of statistical and systematic error. Systematic errors are mainly due to uncertainty in individual TLDs used in practice. Systematic errors arise from differences between TLDs and tissue dose responses and TLD positioning. But the TLD method has great advantages because of cumulated activities in several organs can be obtained easily with a single procedure and the measurements of body surface dose are performed simultaneously with the nuclear medicine procedure.

The results of this work are similar to the results of direct dosimetry using TLDs.

comparison of results with MIRD method is suggested and is underway by our group.

CONCLUSION

One of the physical method to dosimetry is using of TLDs. The results of this work showed that this method is simple and cost-effective, and may play an important role in estimating the organ bio-distribution of cumulated activities. The findings here showed a method to obtain the absorbed activity in thyroid of patients and also may be used in MIRD calculations in estimation of organ doses.

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