

The Measurement of Absorbed Dose in Thyroid, Parathyroid, Eye Lens and Gonads in Radiotherapy of Head and Neck Epithelial Tumors by Thermoluminescent Dosimeter (TLD) Method

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Abstract

Purpose: Owing to the abundance of head and neck epithelial tumors and their treatment by radiotherapy and the complications of ionizing rays on the organs that may be in the radiation field and/or in the vicinity of radiation field during radiotherapy as well as the sensitive organs such as gonads to the radiation, to be aware of the absorbed dose of such organs in radiotherapy of head and neck tumors and to reduce the absorbed dose of these organs seem a very crucial issue. This study aims to measure the absorbed dose of thyroid, parathyroid, eye lens and gonads (ovaries and testicles) in radiotherapy of head and neck epithelial tumors and to compare it with the tolerance dose values (TD_{5/5}) of each organ.

Materials and Methods: In this research, the received dose to the thyroid, parathyroid, eye lens and gonads in designing a 2-D treatment was measured by TLD-100 for curing the head and neck cancers by Cobalt-60 Device on a tissue-equivalent human phantom and on 20 patients (10 men, 10 women) with head and neck epithelial cancer. The values of absorbed dose were compared using t-test at various depths in phantom and in the area of intended organs. Then, the results were analyzed using Excel@-2010 software.

Results: According to the measurements on phantom, the results of absorbed dose are 176.5 ± 17.3 cGy, 6.22 ± 0.14 cGy, 0.37 ± 0.07 cGy and 0.12 ± 0.08 cGy for thyroid-parathyroid, eye lens, ovaries, and testicles, respectively. Meanwhile, the values of average absorbed dose based on measurements on patients are 145.4 ± 12.7 cGy, 7.79 ± 0.36 cGy, 0.26 ± 0.03 cGy and 0.18 ± 0.08 cGy for thyroid-parathyroid, eye lens, ovaries, and testicles, respectively.

Conclusion: The measurements on phantom at various depths and the analysis of results showed that the absorbed dose does not entail a significant difference in the thyroid and parathyroid regions during the radiotherapy of head and neck epithelial tumors and in the assumed treatment fields (P-Value < 0.05). There was a significant difference in the area of ovaries in the absorbed dose of various depths (P-Value < 0.05). The average absorbed dose of above-mentioned organs is smaller than their tolerance dose (TD_{5/5}).

1. Introduction

The head and neck cancers generally have 2-3% of total cancers in the U.S. and lead to death in the number of 1-2% of total cancers. The cancers of this area are determined based on the part they are originated [1]. Over 90% of head and neck cancers are originated from

squamous epithelial cells which are covering the mucus surfaces of this area [1, 2]. At first, it appears with little development in the form of surface lesions with erythema. Sinuses around nose, throat, pharynx and lymph glands in the upper part of the neck are the most prevalent areas for the occurrence of squamous cell carcinoma. When the lesion is a palpable mass, the

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symptoms such as throat congestion and/or ear infections are seen. In more advanced cases, it is distributed at both sides of submandibular area [2].

Drinking alcohol and using tobacco are the most important risk factors to be afflicted with the cancers such as throat and larynx. In the squamous cell carcinoma, mutation in gene P-53 relates fully to the consumption of these materials. Occupational and environmental factors such as wood industry, plastic sub-products, asbestos, UV rays and virus factors can create cancers in these areas [1, 2].

A variety of treatment methods exist for curing the head and neck cancers. Surgery, radiotherapy, chemotherapy, immunotherapy, targeted therapy, gene therapy etc. are the typical examples. The effective factors in selecting the type of treatment depend on various factors both in terms of tumor situation and the patient condition. But the ultimate aim of all these methods is to remove the cancer agent, maintain the life quality of a patient and to prevent the formation of subsequent tumors [2].

Due to the frequency of head and neck epithelial tumors, especially considerable amount of its incidence among the younger generation for whom the preservation of genital organs possesses so much importance, and whom they want to live longer after treatment, on the other hand, the significance of reducing radiotherapy-based complications, understanding the absorbed dose of these organs exposed to head and neck tumors and trying to reduce their absorbed dose are very crucial issues. To do so, the present study measures the absorbed dose of thyroid, parathyroid, eye lens, and gonads against the radiotherapy of head and neck epithelial tumors. Then, the values have been compared with tolerance dose (TD5/5) for each intended organs.

2. Materials and Methods

In this research, the dose received by the mentioned critical organs was measured using Thermoluminescent Dosimeter in form of TLD-100 chips (LiF:Mg,Ti), manufactured in Harshaw, on the tissue-equivalent phantom (Anthropomorphic), and 20 patients afflicted with head and neck epithelial tumors participated in.

The utilized phantom is anthropomorphic and consists of head, upper extremities, abdomen and pelvis. Its geometrical dimensions are similar to human body; its height is 95 cm; the thickness of upper extremities is 22 cm; and its density and atomic number are equivalent to the smooth tissue.

Its skeleton is natural and its internal organs consist of a combination of wax and NaCl whose atomic number is medium and its electronic density is similar to the smooth tissue. A porous wood with 0.3 gr/cm³ density being close to lung tissue density has been used for the lung tissue. [3] The following images relate to upper extremities, abdomen, and pelvis of phantom (Figure 1).

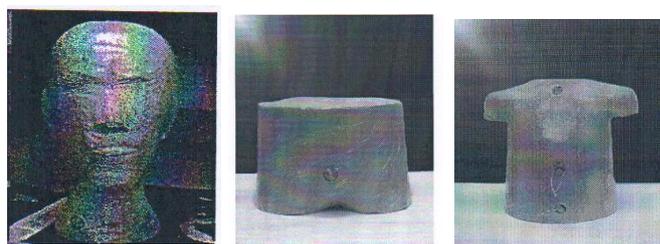


Figure 1. The Phantom Used in This Research

To design the treatment, the technique of two parallel-opposed posterior fields and one anterior field were utilized through ALFARD[®] Software. The measurements were conducted for treatment fields of nasopharynx, tongue and larynx which have similar treatment plan in radiotherapy. To measure the absorbed dose at various depths of phantom, special places were used for locating TLD chips in Anterior-Posterior (AP) direction in the head and neck area. By using 30 TLD-100 chips, calibration and calculation steps were conducted on Cobalt-60 Device to determine the element correction coefficients of dosimeters.

The chips were divided into ten groups, each containing three chips. Nine groups measure the absorbed dose and one group measures the background signal. Then, the chips were used in the pre-determined points on phantom in the thyroid, parathyroid, eye lens and gonads (ovaries and testicles). To compensate the distance between eye surface and lens, a 3 mm peesplex at eye surface of phantom was used. In each treatment session, the chips were radiated by 400 cGy dose (200 cGy for two parallel-opposed posterior fields and 200 cGy for one anterior field). The experiments were repeated three times to reduce the statistical errors for

each treatment field. Overall, the phantom was radiated in 18 steps.

The values of absorbed dose at the intended depths were achieved by reading in TLD-Reader 3500 Device, manufactured in Harshaw/Bicorn USA. Then, the results were analyzed by Excel[®]. By means of a t-test, a comparison was conducted between the mean values related to the absorbed dose on surface of and at depth of thyroid, parathyroid, eye lens and testicles.

3. Results

The results of measurements of absorbed dose on phantom have been given in Table 1, regarding three treatment fields by TLD chips after 3 replications and acquiring means.

Table 1. Means of absorbed dose for intended organs in three treatment areas

Area of Absorbed Dose Mean (cGy)	Nasopharynx Treatment Field	Tongue Treatment Field	Larynx Treatment Field
Thyroid and Parathyroid	197.50±27.00	180.60±12.30	151.30±12.60
Eye Lens	12.70±0.30	3.80±0.10	2.15±0.03
Ovaries	0.41±0.07	0.37±0.08	0.34±0.07
Testicles	0.11±0.08	0.12±0.08	0.12±0.08

Table 2 includes the results of measurements of absorbed dose in the intended areas among patients.

Table 2. Mean of Values for Absorbed Dose for Intended Organs in Three Treatment Areas

Area of Absorbed Dose Mean among Patients	Absorbed Dose Mean (cGy)
Thyroid and Parathyroid	145.40±12.70
Eye Lens	7.97±0.36
Ovaries	0.26±0.03
Testicles	0.18±0.08

Based on Table 1 and Table 2, the measurements on phantom and results of mean for absorbed dose of intended organs in three treatment fields are 176.5±17.3 cGy, 6.22±0.14 cGy, 0.37±0.07 cGy, and 0.12±0.08 cGy for the thyroid and parathyroid, eye lens, ovaries, and testicles, respectively.

Furthermore, the values of average absorbed dose as the results of measurements on patients are 145.4±12.7 cGy, 7.97±0.36 cGy, 0.26±0.03 cGy, and 0.18±0.08 cGy for the thyroid and parathyroid, eye lens, ovaries, and testicles, respectively. The results in both categories did not show any significant differences.

4. Discussion

Among the patients under treatment, the average absorbed dose were 145.4±12.7 cGy, 7.79±0.36 cGy, 0.26±0.03 cGy and 0.18±0.08 cGy for thyroid-parathyroid, eye lens, ovaries, and testicles, respectively.

In other studies, the mean thyroid dose and volume of the thyroid gland spread from 10, 20, 30, 40, 50 doses and 60 Gy (VS10, 20, 30, 40, 50 and 60, respectively) were calculated from DVH based on the 3D radiotherapy planning system. According to this study, a mean thyroid dose of 30 Gy may be a useful threshold for predicting the development of hypothyroidism after radiation therapy for head and neck cancers (2015) [4].

The similar study, which was conducted to evaluate the function of thyroid and parathyroid gland after head and neck radiotherapy showed significant effect of radiation on the parathyroid gland functions but not as much on the thyroid function (2017) [5].

Measurements for treatment fields of nasopharynx, tongue and larynx show that the thyroid and parathyroid areas have been exposed considerably to the radiation field, but the eye lens, and gonads just received sporadic radiation. On average, the absorbed dose in the mentioned treatment fields is about 45% prescribed dose for thyroid and parathyroid area in one session of single radiation on phantom. The absorbed dose for eye lens and gonads with sporadic radiation received is 1.6%, 0.1%, and 0.03 for eye lens, ovaries and testicles, respectively, in one session of sporadic radiation on phantom. In addition, the mean values of absorbed dose among patients had not significant differences in comparison with the mean values of absorbed dose in phantom (P-Value<0.05).

On the other hand, the measurements on the phantom in thyroid and parathyroid areas for various depths and

analysis of results determine the fact that the absorbed dose of intended areas did not have considerable differences with each other (P-Value<0.05). In other words, the surface dose is equal with the depth dose and TLD chips can be located on surface of patient's skin to measure the dose in this area. The equality of depth and surface doses in the area of above organs can be attributed to the present of thyroid and parathyroid glands in the radiation field. In other words, due to the low depth (surface to 3cm depth for neck sides) and exposure of organs to the major radiation field, it seems that there is not a statistically striking difference between the absorbed dose in thyroid and parathyroid areas at surface and depth.

However, the results of measurements on phantom in testicles area for different depths and analysis of results showed statistically significant differences at absorbed dose in the intended areas at various depths (P-Value<0.05). As the depth increases, the absorbed dose reduces in the area of testicles. Due to a considerable distance of this organ from the radiation field, the share of absorbed dose can be pertained to the sporadic rays. The studies conducted in determining the absorbed dose in the outer points of radiation field in phantom represent that the absorbed dose is decreased exponentially as the distance of intended point is increased from the radiation field. It occurred because the body-resulted sporadic rays are weakened. On the other hand, the share of rays leaked from the head of device is higher [6, 7, 8]. Thus, the presence of a significant difference between the absorbed dose on surface and in depths of ovaries area relates to the increased share of leakage rays from the head of device in the more surface layers of ovaries area in contrast to the depth.

5. Conclusion

According to the measurements on phantom at various depths and analysis of the results of this study, it is determined that the absorbed dose in the thyroid and parathyroid area at different depth does not differ significantly in radiotherapy of head and neck epithelial tumors, and for the treatment fields of nasopharynx, tongue and larynx (P-Value<0.05). However, significant

differences were observed in the absorbed dose of various depths in the ovaries area (P-Value<0.05).

The average absorbed dose in thyroid-parathyroid, eye lens, ovaries, and testicles organs are lower than their amount of tolerance dose (TD5/5). It is worth mentioning that special considerations should be followed in relation to the measurements of absorbed dose in ovaries area; due to absorbed dose limit (2 msv) for radiotherapy in these fields, especially in the pregnant women [9].

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