IN VIVO ENTRANCE DOSE MEASURMENTS IN HEAD AND NECK CANCER TREATMENT USING THERMOLUMINESCENT DOSIMETERS

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تهدف هذه الدراسة الى التحقق من الجرعات الاشعاعية الموصوفة لمرضى سرطان الرأس والرقبة بأحد أقسام الاشعة العلاجية وذلك باستخدام مقاييس الجرع الاشعاعية (TLD) ذات التوهج الحراري. قبل استخدام هذه المقاييس تم اختبارها ومعايرتها حسب الشروط المرجعية (100cGy باستخدام Co-60 وعلى بعد 80 سم وحقل إشعاعي 10x10 سم^2) وذلك باستخدام شرائح برسبكس اضافة الى تعيين عوامل التصحيح لها. الدمية ATOM® والتي تحاكي الانسان استخدمت في تعيين توزيع الجرعات الاشعاعية في الرأس والرقبة بعد تشعيع بجرعة قدرها 100 cGy. بعدها تم دراسة 35 حقل اشعاعي لعدد 25 حالة مرضية ومقارنة النتائج المتحصل عليها بقيم الجرعات المتوقعة حسابياً حيث وجد أن التفاوت بين الجرعات الاشعاعية المقاسة والمتوقعة أكبر من 5% فقط لثلاث حقول اشعاعية.

ABSTRACT

For performing in vivo entrance dose measurements in external photon beam radiotherapy, characteristics of thermoluminescent dosimeters (LiF: Mg; Ti), known as Harshow TLD-100, studies were carried out. The TLD system (reader and dosimeters) stability and reproducibility were investigated and the calibration of the TLD's was performed. The reference TLD was calibrated under a reference condition (100 cGy with Co-60; SSD 80cm; 10×10 cm^2), using 30×30 cm^2 Perspex slices. ATOM® female phantom studies for head and neck were performed. A dose of 100 cGy was delivered to the isocenter at the center of one sit of the phantom slices. The dose values "dose distribution" at different points were obtained. Entrance dose for 25 patients with 35 treatments for head and neck cancer were performed. The results were compared with the expected Dose values, only three treatments with discrepancy greater than 5% were observed.

INTRODUCTION

Thermoluminescence is a phenomenon observed in a number of materials, some of which occur naturally, in which electrons are sufficiently excited by impinging ionizing radiation to undergo transitions to certain metastable states or traps. From there they may be excited by heat energy to undergo further transitions to emitting states from which they experience optical transitions back to the ground state, emitting visible light during these latter transitions [1]. TLD materials can now be prepared in different shapes and sizes able to exhibit good reproducibility in their response to radiation dosage. Further, they may be exposed repeatedly, even hundreds of times, to radiation, each radiation exposure being quantitatively impressed upon the material and they may be quantitatively read out upon heating between each exposure. Despite extensive reuse, the response of such samples of TLD materials to ionizing radiation remains unchanged [1].

The success of radiotherapy depends upon an adequately high dose of radiation being delivered to the intended target volume, the latter being selected to provide adequate coverage of the tumor volume and any relevant surrounding margins. To achieve good results in the treatment the accuracy in each part of the whole treatment planning and dose delivery process must be significantly high. Therefore, a quality assurance program is necessary to ensure accuracy of the prescribed dose. In vivo dosimetry is an important step of such quality assurance program, which aid in an overall and ultimate check of the whole dosimetric process. Thermoluminescence dosimeters (TLDs) are commonly used in assessing the dose from ionizing radiation. The introduction of TL dosemetry in radiotherapy has already a long history. TLD's measurements have gained considerable popularity, mainly for *in vivo* dosimetry [1]. This work reports studies about TLD's characteristics which performed before the dose measurement with a female ATOM® human phantom and patients.

MATERIAL AND METHOD

In this study, a group of 41 thermoluminescence dosimeters was used. The thermoluminescent dosimeters are LiF: Mg; Ti (TLD-100) in the form of extruded square ribbons (3x3x0.9mm^3) manufactured by Harshaw. The readout conditions depend on the construction of a particular reader, the heating method and mass of a detector. Rados DOSACUS reader was used and the optimum and recommended annealing is 1 hour at 400^{o}C in an oven, followed by a fast cooling down to room temperature. This may be still followed by 2 hour annealing at 100^{o}C in order to reduce low-temperature peaks. Before the readout, a pre-heat at 100^{o}C for 10 minutes may be also applied. For chip factor determination, the BICRON Model 2210 Sr^{90}/y^{90} Irradiator was used to irradiate the dosimeters. The irradiation for other tests for the TLD's as well as the measurement using the human phantom was performed using the CIRUS cobalt-60 unit (Activity 233.3 TBq). A 5 mm thick of wax as a buildup material was used for Co-60 measurements. The reference standard system consists of a cylindrical ionization chamber (Farmer type) model IC-70 welhofer S-N353 (0.6 cm^3) and an electrometer model Dose 1welhofer S-N 7047.

RESULTS AND DICCUSSION

Thermoluminescence detectors response

Before using the TLD's for In vivo Dose entrance measurements, the following tests are performed to select these TLD's.

Reproducibility test

The group of 41 was irradiated two times for the same dose using BICRON model 2210 Sr^{90}/Y-90 Irradiator. The Irradiator uses a rotating disk to irradiate a number of TLD's, (Activity 33MBq, 72.0578 μSv/ revolution). The detector is exposed to a dose of 21.617 mSv (300 revolution). Table (1.a) and (1.b) present the results obtained from the RA'94 Reader. On an average reproducibility with a discrepancy of less than 2% was obtained.

Table 1a: The results obtained from the RA'94 Reader at first irradiation.

	A	B	C	D	E
1	5360	5255	5508	5228	5589
2	5195	5164	5319	5203	
3	5297	5564	5452	5389	
4	5175	5402	5398	4956	
5	5589	5298	5488	5365	
6	5165	5864	5604	5585	
7	5369	5367	5127	5056	
8	2950	5425	5557	5109	
9	5394	5212	4856	4923	
10	5259	5044	5624	5270	

Table 1b: The results obtained from the RA'94 Reader at second irradiation.

	A'	B'	C'	D'	E'
1	5417	5532	5448	5347	5520
2	362	5316	5788	5292	
3	5285	5527	5282	5481	
4	5138	5409	5269	5491	
5	5114	5260	5224	5162	
6	4960	5217	4931	5442	
7	5458	5214	5074	5415	
8	5639	5513	5376	5528	
9	5382	5265	5054	5122	
10	4086	5135	5250	5067	

Readings shaded with different colors have been excluded from the calculations.

Chip factor

The individual chip sensitivity factor (K_{chip}) for each of the 41 TLD's was determined. To calculate these individual factor, the average reading of all chips is calculated and then, divided by the reading of each chip [2].

$$K_{chip,i} = \frac{R_i}{\bar{R}} \quad (1)$$

Where $\bar{R}$ and R_i are the average reading and i^{th}chip reading respectively.
Figure 1 shows the variation of sensitivity factor K_{chip} from unity for the 39 chips. From the 41 TLD's analyzed, 5 of them were chosen according to criterion of maximum variation in the sensitivity factor to be used for calibration factor determination.

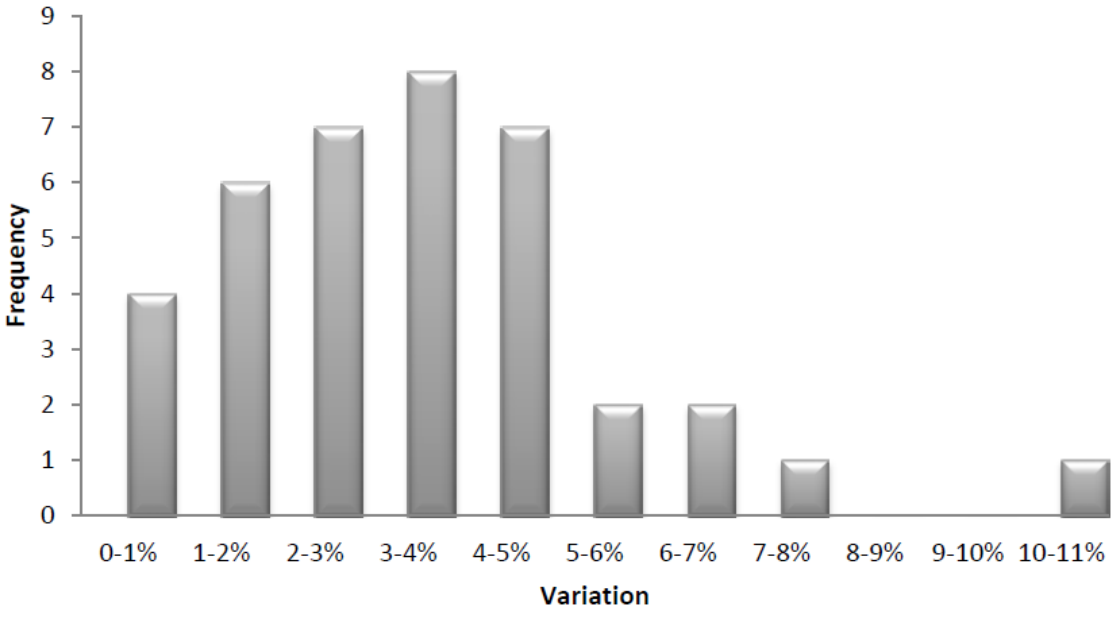

Figure 1: Frequency distribution for the chip factor

Calibration factor

The calibration factor was determined using Perspex slabs (30 cm × 30 cm × 0.5 cm) in the Co^{60} beam. The calibration was performed under a reference condition (100 cGy with Co^{60}; SSD 80 cm; 10×10 cm^2 field size) [3]. The average calibration factor can be approximated by the following relation:

$$\bar{k}_{cal} = \frac{D}{\bar{R}} \tag{2}$$

Where, D is the maximum delivered dose (100 cGy) and $\bar{R}$ is the average reference dosimeters reading for 5 TLD's. The average calibration factor result is 33.0858 $\times 10^{-5}$ cGy/TL signal.

Linearity dose response

The TLD response with dose was plotted versus the dose for the reference dosimeters under the reference condition. The data are plotted in Figure (2). The data shows a linear region up to about 150 cGy, from which the TLD response becomes supraliner.

Field size correction

The field size correction is defined as [3]:

$$k_{field} = \frac{R_{X\times X}}{R_{10\times 10}} \tag{3}$$

Where $R_{10\times 10}$ and $R_{X\times X}$ are the TLD response at field size of 10×10 and X×X respectively. Figure (3) shows an increase in k_{field}as the field size increases.

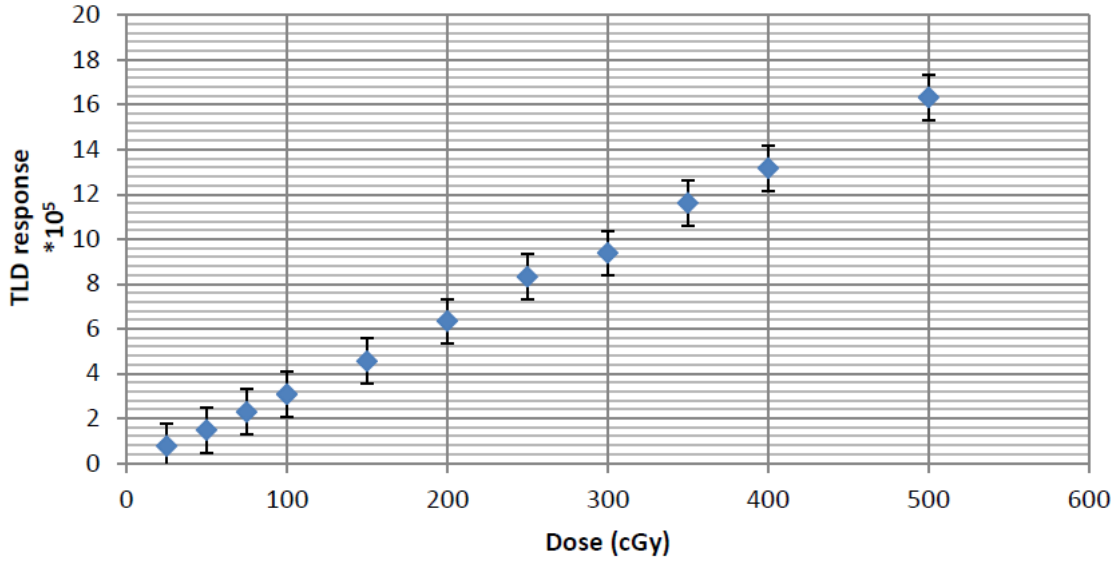

Figure 2: Variation of TLD response

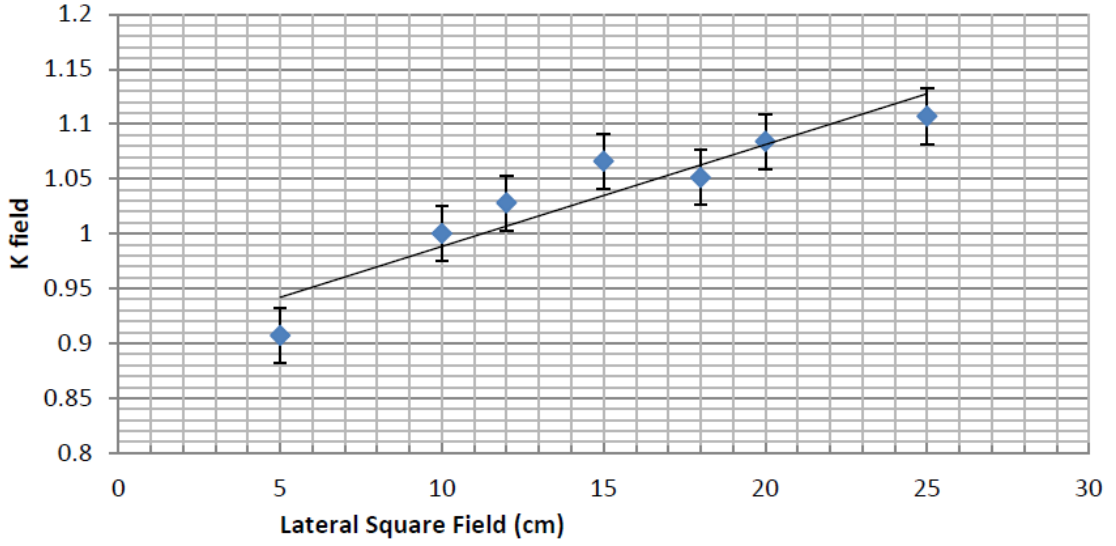

Figure 3: Correction for field size dependence

SSD correction

The SSD (Source to Surface Distance) correction measurements were performed for the calibration set up at different SSD's namely: 70, 75, 85, 90, 95 cm, in reference conditions (10×10 cm^2). The following relation can express the correction factor:

$$k_{SSD} = \frac{R_X}{R_{80}} \quad (4)$$

Where R_{80} is the TLD response of SSD of 80cm while R_X is the SSD of X cm. Figure (4) represents the results of the different measured field sizes. The results show a decrease in k_{SSD} values with respect to SSD.

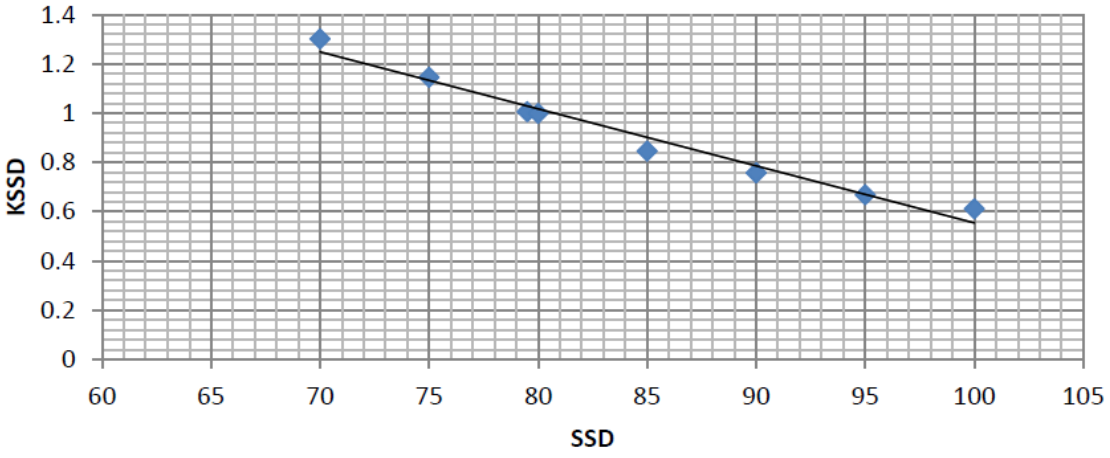

Figure 4: Correction for SSD dependence

Phantom Measurements

In these measurements a female ATOM® phantom (see Fig.5) was used. For head and neck treatments a parallel field of $10\times10cm^2$ without wedges with SSD of 80cm was considered. It has been assumed that the tumor of the head, at which a dose of 100cGy is planned to be delivered, is in the center. Figure (6) presents the contour which defines the points at which the doses were measured.

Figure (5): A female ATOM® phantom

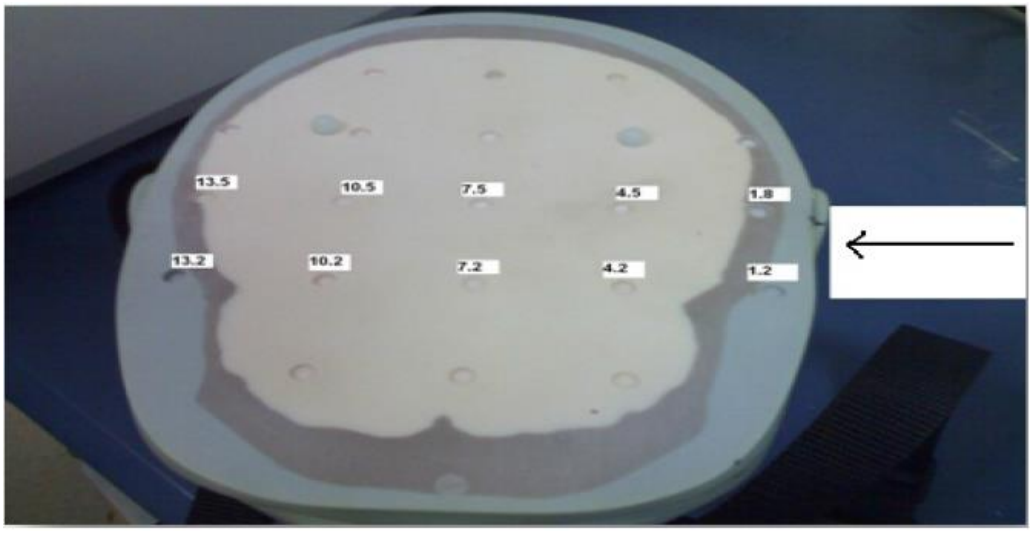

Figure 6: Irradiated points inside the head of the phantom

After the head treatment the detectors were read out and the doses were obtained using the following relation:

$$D = k_{chip}.k_{cal}.R \quad (5)$$

Table (2) presents the dose values obtained for the head and neck treatment. It can be noticed that the dose decreases as the depth increases due to attenuations of gamma rays. The overall discrepancy between measured and expected dose does not exceed 5%.The expected dose, the dose at the depth of dose maximum, was calculated manually from prescribed tumor dose [2].

Table 2: Dose measurement for human phantom

TLD #	K chip	Depth (cm)	Count	Measured Dose (cGy)	Expected Dose (cGy)	Mea/Exp
12	0.9818	0.50	467602	149.14	147.10	1.01
31	0.9824	1.20	422725	134.91	143.10	0.94
28	0.9553	4.20	396370	123.00	122.50	1.00
37	1.0437	4.50	350574	118.86	120.40	0.99
38	1.0220	7.50	305967	101.57	100.00	1.02
41	1.0409	7.50	293423	99.21	100.00	0.99
30	0.9942	10.20	245700	79.35	83.60	0.95
39	1.0130	10.50	242142	79.68	81.90	0.97
40	1.0337	13.50	187362	62.91	66.60	0.94

In vivo Measurements

A total of 35 treatment fields involving 25patients randomly selected were included in this study. The patients were treated for head and neck cancers. The goal was to discover discrepancies larger than 5% between the expected dose and measured dose [4] to be reviewed. Each patient was treated with an immobilization mask with reference marks to the entrance points in each field. TLDs with 0.5 cm wax thick were positioned on these reference marks in the center of every treatment field. The obtained results are presented in Table (3). Only three treatments had to be reviewed. The In vivo entrance dose measurements frequency distribution is demonstrated in Figure (8). The distribution shows a mean percentile deviation of measured dose from expected dose of 98% with standard deviation of 2.6%.

Table 3: Measured and expected dose for 35 treatment fields.

N	Measured Dose(cGy)	Expected Dose(cGy)	(Mea. D/Expec. D)%
1	119	123	97
2	222	217	103
3	220	217	101
4	212	218	97
5	212	218	97
6	236	226	104
7	216	226	96
8	213	217	98
9	299	296	101
10	134	135	99
11	133	135	99
12	214	225	95
13	125	127	99
14	123	127	97
15	152	151	101
16	139	143	97
17	134	143	94
18	146	146	100
19	213	220	97
20	219	220	100
21	134	132	102
22	164	176	93
23	84	88	96
24	206	219	94
25	306	318	96
26	149	151	99
27	146	151	97
28	135	134	100
29	139	142	98
30	138	142	97
31	166	164	102
32	183	182	101
33	89	89	100
34	144	142	101
35	141	142	99

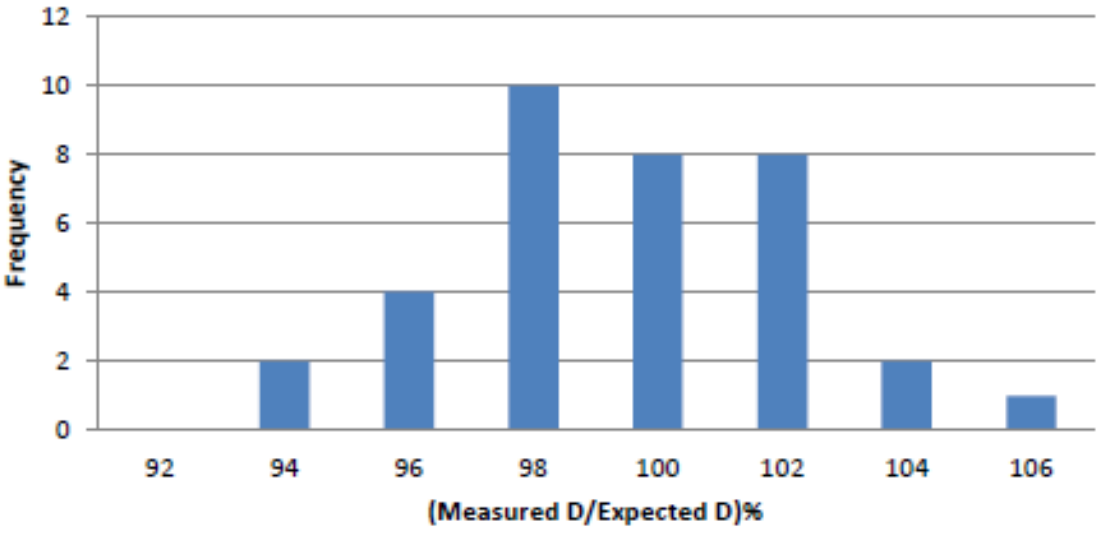

Figure 8: In vivo frequency distribution.

CONCLUSION

- The physical characteristics of thermoluminescent dosimeters (TLD-100) were investigated in the first part of the work.
- The system (dosimeters and reader) stability and reproducibility were investigated and the calibration of TLD performed.
- Non-linearity, SSD and field size factors were determined.
- The measurements with ATOM® female human phantom were performed in Co-60 CIRUS unit. The results were compared with the expected values and a good agreement was obtained.
- In vivo entrance dose measurements showed only three treatments with a discrepancy of greater than 5% with respect to the expected values. In these cases the prescribed and the delivered doses should be reviewed according to the adapted protocols used in the treatment center.

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