Romanian Reports in Physics, Vol. 63, No. 3, P. 700–706, 2011

DOSE MEASUREMENTS IN TELETHERAPY USING THERMOLUMINESCENT DOSIMETERS

ZOE GHITULESCU[1], ANA STOCHIOIU [2], MIHAI DUMITRACHE [3],

[1]CNCAN- National Commission for Nuclear Activities Control, Bucharest, E-mail:ghitulescuzoe@yahoo.com
[2]IFIN-HH - IFIN-HH (Horia Hulubei National Institute of Physics and Nuclear Engineering, Bucharest, E-mail:stoc@ifin.nipne.ro
[3]Research and Developing Army Centre, Bucharest, E-mail: mihai149@yahoo.com

Received April 27, 2010

Abstract. The tissue equivalence (LiF) of the thermoluminescent dosimeters enables their use within teletherapy in measuring the absorbed dose on phantoms.

In order to set up and compare treatment doses of the inner skull tumors using a photon beam, a number of 22 thermally pretreated and calibrated TLD–100 was used and the measurements were made using the small water phantom type 4322 PTW and the antropomorphical phantom Rando Alderson.

The two phantoms are exposed at the isocenter (accelerator axis intersection) and respectively to a lateral 6 MeV (6 MV) photon beam under the reference conditions from the Varian's medical accelerator type Clinac 2300 C/D. We choose a low value of 15 MU in order to avoid an overexposure of the TLDs. The corresponding dose values for 15 MU established with the aid of the Farmer ionization chamber and of the TLD's average dose value are very close.

The absorbed dose values measured for the z_3 depth (in Rando phantom) obtained with the TLD's method, analytically and by simulation are comparable with the considered reference value measured with the Farmer ionization chamber. Thus, their relative deviations against the value measured with the Farmer chamber are less than 0.45% and the TLD's response is good in assessing the prescribed treatment dose.

Key words: thermoluminescent detectors, absorbed dose, medical accelerator, isocenter, reference conditions, Rando-Alderson head phantom.

1. INTRODUCTION

A good method for assessing and monitoring the absorbed dose to patient and also for the personal dosimetry is to use the thermoluminescent dosimeters.

The thermoluminescent dosimeters are usually used for patient doses estimation within clinical dosimetry and furthermore can be useful tools in establishing the own national Diagnostic Reference Levels (DRLs), according to the actual nuclear legislation. It is well known that the thermoluminescent intensity is proportional to the irradiation dose.

The aim of this study is to use the TL dosimetry within teletherapy in measuring the absorbed dose on phantoms exposed to 6 MeV (6 MV) photon beam under the reference conditions from a medical accelerator. The TLD-100 components and the tissue have also close values of mass energy-absobtion coefficients for 6 MeV energy according to NIST tables.

Due to their small size and to their linear response the TL dosimeters can be placed easily into the antropomorphic phantom and thus widely used in the quality assurance procedure for the treatment planning systems. The TL dosimeters can be used in checking the absorbed dose inside the target volume.

In teletherapy using a medical accelerator, it is necessary to establish the prescribed dose for the clinical target volume inside the patient, while reducing to a minimum the exposure of other organs within its vicinity.

The check of the absorbed dose using TL dosimeters and a phantom head exposed to a photon beam was not performed before in Romania but the measurements uncertainty obtained less than 5% could express a good response of the TLDs [1, 6]. It is also considered acceptable a deviation of ±3% between the stated dose and the TLD measured dose [2, 7].

2. MATERIALS AND METHOD

The TL dosimeters used in the following experiments described below are LiF: Mg, Ti detectors also known as TLD-100. There were also used two phantoms and the medical accelerator type Clinac 2300 C/D produced by Varian.

In order to be used in clinical dosimetry TL dosimeters have to be thermally pretreated at 100^{o} C for 10 minutes. The measurement of the TL detectors was performed at the Laboratory for Environment and Personnel Dosimetry from IFIN-HH, Bucharest. A TLD Reader-Analyser Model 770A was used. It works at up to temperatures of 240 ^{o}C. A reading factor expressed in impulses was found by taking readings from each TLD on the 800 V scale, taking into account the reading factor for which the device was calibrated, the background value of the tray holder as well as the TLD calibration dose.

For the TLD calibration a source of ^{137}Cs was used. The TLD were panoramically irradiated. According to the IFIN-HH calibration certificate the source had the dose rate of 4.765 mGy/h ± 3% at a distance of one meter on 20.11.2006.

It was found at a distance of 0.5 m from the source, the value of the dose rate are of 18 mGy/h ± 3% including the tissue (water) correction corresponding to the calibration procedure. Thereby to get the three TLD lots calibrated at 10 mSv dose it was necessary their iradiation twice for 27’47” and for 27’ 50”.

Usually the individual dosimeters are calibrated using a ^{137}Cs source and the TLD’s under-response is 5% less than that obtained from their calibration at the ^{60}Co source [3].

In order to set up and compare treatment doses of the brain tumors using a photon beam, a lot of TLD–100 was used and two types of measurements were made. The first one was made with the small water phantom type 4322 PTW, and the second one with the antropomorphical phantom Rando Alderson.

2.1. REFERENCE MEASUREMENTS WITH FARMER IC AND UNIDOSE PTW

First the absorbed dose was checked with a Farmer ionization chamber of 0.6 cm^3 type 30001 and a Universal dosimeter PTW Unidos which were previously calibrated by a Secondary Standard Laboratory of Institute of Public Health in Bucharest. The beam parameters were verified thus corresponding to the acceptance certificate.

The water phantom mentioned above was positioned at the isocenter using a Laser system and checked with the mechanical pointer. Measurements on the water phantom were made at the isocenter under the reference conditions set out by IAEA–TRS 398/2004. The reference conditions used for finding the absorbed dose in the water consist of a 10cm × 10cm isocenter field and 100 cm source to ionization chamber distance at a depth of 10 cm [4, 5]. The pressure was $p = 0.1005$ MPa and the temperature $t = 21.8\ ^{o}C$ inside the room where the measurements were carried out. While this was taking place the background radiation measured with the ratemeter type FH 40 was in the range of 150–200 nSv/h.

The value read with the PTW Unidos was 81.13 cGy for 100 MU (Monitor Units) according to the acceptance tests, and an average of 12.17 cGy for 15 MU was found after three readings. The average value of the dose (according to TRS 398) has to be corrected by the energy correction factor K_Q for the Farmer chamber [8]:

$$D_F = D_{read} \times K_Q = 12.17 \times 0.9913 = 12.064 \text{ cGy}, \quad (1)$$

where: D_F is the value of corrected dose in water measured with Farmer IC at 10 cm; D_{read} is the value of uncorrected dose in water measured with Farmer IC.
The PTW dosimeter reading error is ± 0.001cGy and it is provided by Manufacturer.

2.2. TLD MEASUREMENTS

The first set of measurements with a number of 22 TLD-100 were used for two kinds of measurements on the antropomorphic phantom Rando Alderson and on the previously mentioned water phantom. When the ionization chamber was placed at 10 cm depth, source to skin distance (SSD) being of 90 cm, the TLDs were inserted at the same depth of 10 cm and the beam data were inputted into the accelerator console (field size, energy, monitor units).

The two exposures at the isocenter were made each time using 5 TLDs placed inside the Farmer chamber holder under a photon beam with an energy of 6 MeV (the displayed value being 6 MV). After the TLD's readings were taken, the resulting absorbed doses in water at a distance d = 10 cm are shown in Table 1.

Table 1

Comparison of TLD measurements with the reference absorbed doses, determined with the Farmer IC

TLD No.	D_{TLD} [cGy]	$\overline{D}$ [cGy]	D_F [cGy]	σ_n [cGy]	$\frac{D_F - \overline{D}}{D_F} \cdot 100$ [%]	$u_A = \frac{\sigma}{\overline{D}_{TLD}\sqrt{n}} * 100$ [%]
1	2	3	4	5	6	7
1 2 3 4 5	13.213 11.788 12.281 10.832 12.627	12.148	12.064	0.805	- 0.69	2.9
1 2 3 4 5	10.804 11.571 14.051 12.031 11.482	11.987	12.064	1.103	+ 0.64	4.1

For the second set of measurements, four TLDs were placed inside the second head slice of the Rando phantom, in the first row from the parallel bars (Fig. 1).

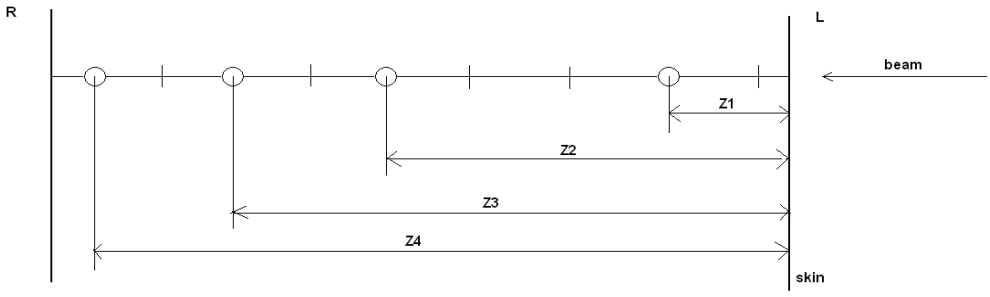

Fig. 1 – TLD's positions inside the Rando phantom on the central photons beam. z_i represent the distances between the patient skin and the TLD positions.

The phantom head is irradiated three times with 15 MU under a lateral photon beam of 6 MV, keeping SSD = 90 cm and using 12 TLDs. The TLD's read values are in Table 2.

Using the following specified values the calculation of the dose at the depth z_3 =10 cm gives [4,5]:

$$D_{z_3} = \text{MU} \times F_{\text{cal}} \times F_{\text{OUTPUT}} \times \eta = 15 \times 1.025 \times 1 \times 0.784 = 12.054 \text{ cGy}, \quad (2)$$

where: F_{cal} represents the value of colimator factor measured in water and F_{OUTPUT} is the ratio of MU/cGy and η is the 6 MeV efficiency. These values are taken from Clinacs acceptance measurements.

The calculated dose value at the depth z_4 = 12.8 cm can be obtained as follows:

$$D_{z_4} = D_{z_3} \times (f_R / f)^2 \times \text{TMR}\ (z_4, A\ z_4, t) / \text{TMR}\ (z_3, A\ z_3, t) \quad (3)$$

TMR (z_4, A z_4, t) and TMR (z_3, A z_3, t) represent the values for tissue maxim ratio for the z_4 z_3 and were measured during the acceptance procedures [4, 5]. The f_R and f are the distances from the tungsten target to the isocenter, respectively to the fourth TLD. We can obtain the dose for a point outside the isocenter using the equation (3).

In order to estimate TMR (z_4, A z_4, t) = 0.709 and TMR (z_3, A z_3, t) = 0.784 the software Mephysto was used to trace the required curves thus enabling the linear interpolation method. Using the independent calculation program of the monitor units, MUCalc 1.2.7 created by Melvin A. Abraham we found that the 15 MU for a 10cm × 10cm field at the depth z_3 = 10 cm corresponded to a dose D_{z_3} = 12.01cGy.

Table 2

The absorbed dose values inside the planning target volume

TLD No.	D_{TLD} [cGy]	z_i [mm] $_{i=1,2,3,4}$	$\overline{D}_{i\,TLD}$ [cGy]	D_{calc} [cGy]	$D_{MUC\ calc}$ [cGy]	σ_n [cGy]	$\frac{D_{calc} - \overline{D}_{iTLD}}{D_{calc}} \cdot 100$ [%]	$u_{A=} \frac{\sigma}{\overline{D}_{iTLD}\sqrt{n}} \cdot 100$ [%]
1	2	3	4	5	6	7	8	9
1 5 9	18.104 18.213 17.863	z_1 = 23	18.060	18.031	17.94	0.146	-0.16	0.4
2 6 10	14.510 14.745 15.020	z_2 = 70	14.758	14.350	14.21	0.208	-2.76	0.8
3 7 11	12.151 12.281 11.788	z_3 = 100	12.073	12.053	12.01	0.208	-0.17	0.9
4 8 12	10.040 10.530 10.217	z_4 = 128	10.262	10.322	10.28	0.203	0.58	1.1

Table 2 enables us the comparison between the average TLD doses (the fourth column) for the established depths and the calculated dose values (the fifth column). The sixth column represents the dose values calculated with an independent software. The measured dose values inside Rando phantom and the calculated dose values using ionising chamber measurements in water phantom are close related.

The displayed results (Fig. 2), taking into account the beam parameters (TMR, $F_{OUT,}$ F_{calc}) consists of isodoses graphs and the dose values calculated on the central axis for several depths.

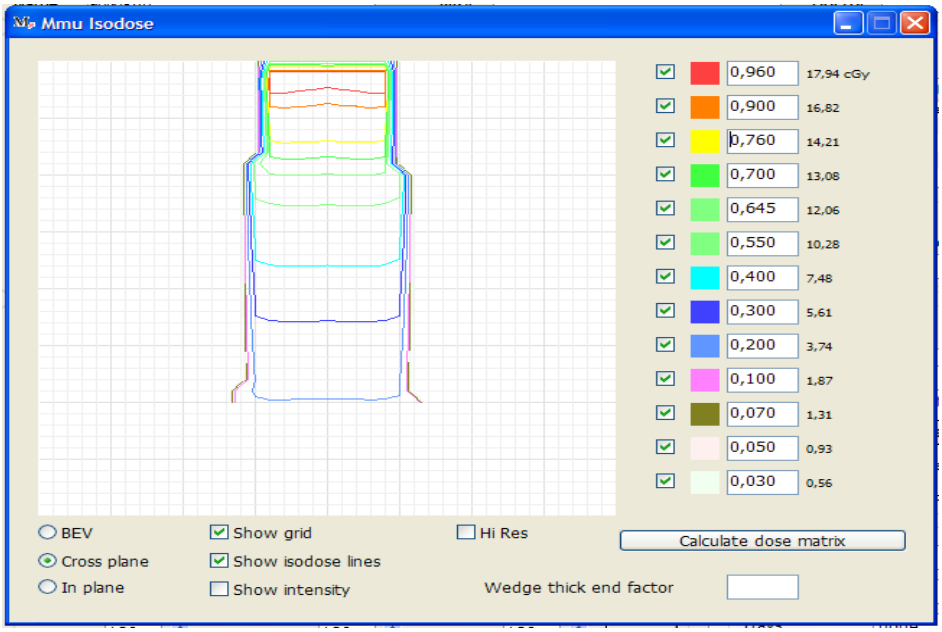

Fig. 2 – The isodose graphs and their values for Rando phantom exposure at 6 MeV photon beam and for 10 cm ×10 cm field.

3. DISCUSSION

The absorbed dose values taken from TLDs placed on the Rando phantom for the depths z_1, z_2, z_3, z_4 are close to the analytical dose values and to those obtained through MUCalc program simulation.

The absorbed dose values of 12.07 cGy, 12.05 cGy, 12.01cGy for the z_3 depth obtained with the TLD method, analytically and by simulation are comparable with the value of 12.06 cGy measured with the Farmer ionization chamber. Thus, their relative deviations against the considered reference value measured with the Farmer chamber are less than 0.45%.

Therefore the use of TLDs for checking the absorbed dose calculated with the Treatment Planing Systems (TPS) is proved to be a very convenient tool in the begining of the treatment session for each patient.

The relative deviations of the TLD dose values determined for the depth z_3 in the water phantom, against the value of 12.073 cGy measured with the help of Rando phantom are not greater than 0.7% [1]. This is due to the placing of 5 TLDs

in each of the two different plastic capsules and their handling with ordinary tweezers when positioning them into the Farmer chamber's holder.

According to the percentage relative deviations from Tables 1 and 2, the values of the ratios $\overline{D}_{i,\mathrm{TLD}} / D_F$ and $\overline{D}_{i,\mathrm{TLD}} / D_{\mathrm{calc}}$ are greater than the calculated value of 0.9936 and less than the calculated value of 1.028 showing acceptable results. The uncertainties values u_A which estimate the standard deviation of the mean value are less than 5% [5].

The deviations are in the range of +/– 3% and are smaller than the acceptance limit of 5% adopted by most TLD networks [1, 2].

The SDs (standard deviations) of the doses against their average values are small showing that TLD's response is good in assessing the prescribed treatment dose.

Acknowledgements. We express our gratitude for the given assistance in the TLDs calibration to physicist Adrian Leordeanu, Quality Management Director at Nuclear &Vacuum and lecturer at Nuclear Training Center of IFIN-HH "Horia Hulubei" National Institute of Physics and Nuclear Engineering, Magurele-Bucharest.

Our warmest thanks for the scientific talks, practical advices and also for providing of some TL dosimeters are due to PhD physicist Constantin Milu, president of the Romanian Society of Radioprotection, to Professor Alexandru Jipa, Dean of Physics Faculty of the Bucharest University, and to medical physicist Teodor Sandulescu from the Oncological Institute "Alexandru Trestioreanu", Bucharest.

REFERENCES

1. *** *IAEA/WHO TLD audit service Vienna,* IAEA-SSDL Newsletter, No. 46*,* January, 9–14, (2002).
2. D. Kroutilíková and H. Zácková, *Radiation Protection Dosimetry-TLD audit in radiotherapy*, **85**, 393–396 (1999).
3. M.L. Maiello**,** J.F. Gulbin, G. de Planque and H.T. Heaton, *International Mini-Intercomparison Investigating an Under-Response of TLDs Calibration with ^{137}Cs,* Radiation Protection Journal, 1990.
4. Subramaria Jayaraman, Lawrence H. Lanzl, *Clinical Radiotherapy Physics,* Springer, pp. 190–191, 205–206, 2002.
5. E.B. Podgorsak, *Radiation Oncology Physics*, A Handbook for Teachers and Students Vienna, pp. 78, 86–88, 171–172, 192, 212 (2005).
6. *** *Physical aspects of quality assurance in radiation therapy*, AAPM Report No.13, New York, Vol. 1& 2, 25–28 November 1994.
7. Ans Swinnen, *Quality assurance in radiotherapy: Development and validation of mailed dosimetry procedure for external audits using a multipurpose phantom and in vivo dosimetry***,** Leuven, 2005.
8. IAEA -TRS 398, *Absorbed Dose Determination in External Beam Radiotherapy: An International Code of Practice for Dosimetry based on Standards of Absorbed Dose to Water,* Vienna, 2004.