DETERMINATION OF THE RADIATION DOSE SCATTERED OUTSIDE THE TARGET VOLUME TREATED WITH IMRT TECHNIQUE

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Abstract

IMRT is an advanced mode of high precision radiation therapy that uses computer controlled linear accelerators to deliver precise radiation doses to a malignant tumor or specific areas within the tumor, conforming more precisely to the three dimensional shape of the tumor by modulating or controlling the intensity of the radiation beam in multiple small volumes. IMRT also allows higher radiation doses to be focused to regions within the tumor while minimizing the dose to surrounding normal critical structures. An assessment of clinical requirements in radiation therapy shows that a high accuracy is necessary to produce the desired result of tumor control rates that are as high as possible, consistent with maintaining complication rates within acceptable levels. This work aimed to determine the radiation dose in two target volumes (tumors) treated at same time and the scattered dose distribution in organs at risk using thermoluminescent dosimeters of LiF:Mg,Ti for IMRT treatment technique.

Keywords: thermoluminescent dosimetry; LiF:Mg,Ti; photon beam; IMRT

Introduction

The optimisation of the external beam radiation therapy technique consists of selectively delivering a high dose to specified target volumes, while maintaining as low a dose as possible to surrounding healthy tissues and organs at risk. At any rate, a more or less significant dose is received in the patient’s whole body, including sites where second cancers may occur [Diallo et al., 2006]. The use of multileaf collimators (MLCs) in radiation therapy requires the use of computers to control leaf positions and speed of travel. With many components involved in the process of treatment planning and delivery, quality assurance (QA) practices are essential in ensuring that all components are working correctly and effectively. Phantoms have proven to be a useful tool in QA for dosimetric parameters [McNiven et al., 2004]. The assessment of the doses in radiotherapy is extremely important, the outcome of treatment depends upon tumor doses that do not vary by more than ± 5% about the optimum [AAPM, 1983].

This work aimed to determine the radiation dose distribution using lithium fluoride doped with magnesium and titanium (LiF:Mg,Ti) dosimeters in five cavities of a PMMA phantom specially designed for these measurements. Two cavities were considered target volumes (tumors) to be treated by IMRT technique and other three cavities were considered organs at risk and surrounding healthy tissues. The doses calculated for the planning system (isodose curves) were compared to the doses evaluated by the thermoluminescent dosimeters (TLDs).

Materials and methods

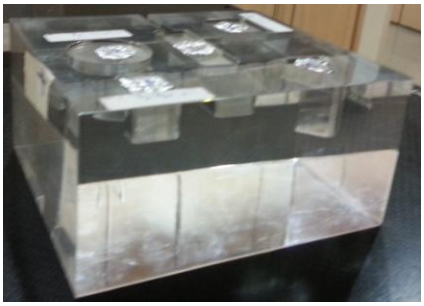
A batch of fifty LiF:Mg,Ti (TLD-100) dosimeters produced by Harshaw Chemical Company previously selected with repeatability better than ±5% and calibrated using ^{60}Co gamma radiation were used to doses evaluation. The pre-irradiation heat treatment adopted was one hour for 400ºC in the furnace Vulcan model 3-550 PD and two hours for 100ºC in the surgical heater Fanem model 315-IEA 11200.

A dose response curve to 6 MV photons from a linear accelerator Clinac Varian 6EX of the Sociedade Beneficente Israelita Brasileira-Hospital Albert Einstein was obtained using a polymethylmethacrylate (PMMA) phantom for the following absorbed doses: 0.05; 0.5; 1; 3.5 and 7 Gy corrected to the maximum dose depth by planning system.

For the scattered dose assessment the LiF:Mg,Ti dosimeters were irradiated with photon beams (6 MV) positioned in a PMMA phantom specially designed and constructed to perform this measurement, containing five cavities (Fig. 1-a). Two cavities were considered the tumors to be treated (cavities 1 and 2, Fig. 4); the other cavities (3, 4 and 5, Fig. 4) considered organs at risk. A group of ten TLDs individually identified were positioned inside each of the five cavities. The IMRT irradiations were performed in the target volumes with MLCs modulated synchronously with the fluence of the radiation beam. A PMMA block of 10 cm thickness positioned on the top of the PMMA phantom was used to ensure the backscattered radiation (Fig. 1-b).

Two target volumes were treated simultaneously (cavities 1 and 2) and the scattered radiation dose distribution in the surrounding areas near to the tumors (cavities 3, 4 and 5) was evaluated. The obtained results were compared with the isodose curves provided by the planning system of Hospital Albert Einstein (Fig.4).

The thermoluminescent responses were obtained using a reader TL Harshaw model 4500. Each presented value represents the average of 10 TL responses and the error bars the standard deviation of the mean (1σ) with a confidence interval of 95%.


(a)


(b)

Fig. 1: (a) PMMA phantom containing five cavities; (b) Dosimeters positioned inside the phantom's cavities and PMMA block positioned on top of the phantom to ensure backscattering.

Results and Discussion

The repeatability of TL responses obtained to 6 MV photons is better than 4.12%, lower than 5% acceptable for radiation therapy [AAPM, 1983; Podgorsak, 2005].

Figure 2 presents the TL dose-response curve of the LiF:Mg,Ti TLDs to 6 MV photon beam radiation. It can be observed the linear behaviour in the dose range studied, from 0.05 to 7 Gy.

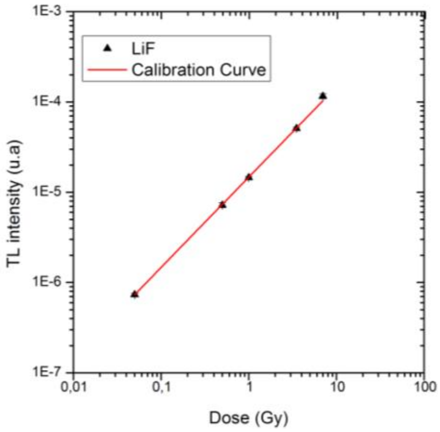
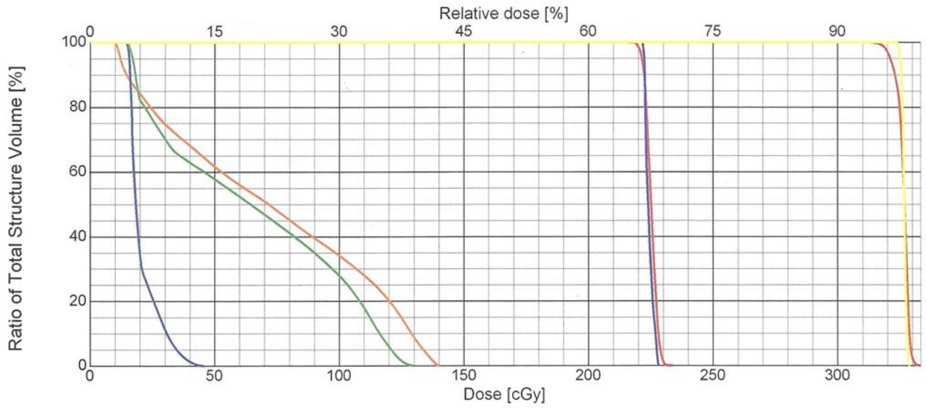


Fig. 2: TL dose-response curve of LiF:Mg, Ti to 6 MV photon beam from linear accelerator VARIAN 6EX.

Figure 3 presents the cumulative dose volume histogram showing the mean doses calculated by the planning system related to the structure numbers: the doses calculated by the planning system to the cavities 1 and 2 were 326.7 $\pm$ 0.9 and 224.2 $\pm$ 1.6 cGy, respectively.



Some structures are unapproved or rejected

Structure	Structure Status	Coverage [%/%]	Volume	Min Dose	Max Dose	Mean Dose	Modal Dose	Median Dose	Std Dev
4	Unapproved	100.0 / 94.5	0.3 cm³	14.9 cGy	129.7 cGy	65.3 cGy	18.4 cGy	64.3 cGy	38.0 cGy
5	Unapproved	100.0 / 108.1	0.4 cm³	14.1 cGy	45.8 cGy	20.9 cGy	16.8 cGy	18.3 cGy	6.2 cGy
3	Unapproved	100.0 / 97.6	0.7 cm³	9.6 cGy	140.5 cGy	72.0 cGy	11.9 cGy	71.7 cGy	42.7 cGy
1	Unapproved	100.0 / 105.3	0.8 cm³	323.7 cGy	329.0 cGy	326.7 cGy	326.9 cGy	326.8 cGy	0.9 cGy
2	Unapproved	100.0 / 98.1	1.0 cm³	221.5 cGy	228.2 cGy	224.2 cGy	222.7 cGy	223.9 cGy	1.6 cGy
PTV	Approved	100.0 / 99.3	30.2 cm³	302.8 cGy	333.3 cGy	326.4 cGy	327.5 cGy	326.9 cGy	2.5 cGy
PTV2	Approved	100.0 / 100.1	34.6 cm³	203.9 cGy	233.9 cGy	225.1 cGy	225.6 cGy	225.1 cGy	2.3 cGy

Fig. 3: Cumulative Dose Volume Histogram calculated by planning system of Hospital Albert Einstein.

The isodose curves provided by planning system are presented in Fig. 4.

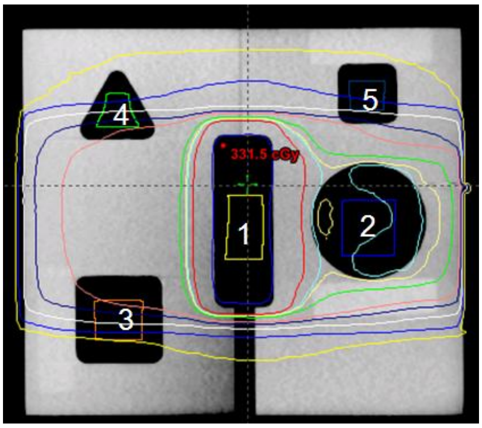


Fig. 4: Isodose curves given by planning system showing the dose distribution in the five phantom cavities.

The data provided by the planning system and the measured for the LiF:Mg,Ti dosimeters to the five cavities are presented in Tables 1 and 2, respectively and summarized in Fig. 5.

Table 1: Dose distribution provided by the planning system

Structure	Min Dose (cGy)	Max Dose cGy)	Mean Dose (cGy)	Std Dev (cGy)
1	323.7	329.0	326.7	0.9
2	221.5	228.2	224.2	1.6
3	9.6	140.5	72.0	42.7
4	14.9	129.7	65.3	38.0
5	14.1	45.8	20.9	6.2

Table 2: Dose distribution measured by LiF:Mg,Ti dosimeters

Structure	Min Dose (cGy)	Inter Dose (cGy)	Max Dose (cGy)	Mean Dose (cGy)	Std Dev (cGy)
1	324.71 ± 6.29	---	346.33 ± 6.81	337.07	13.03
2	215.87 ± 1.86	---	228.07 ± 2.32	221.10	6.79
3	24.90 ± 0.51	55.75 ± 2.52	99.35 ± 5.16	65.25	29.85
4	20.48 ± 2.40	40.04 ± 4.12 [(a)] 85.22 ± 0.19 [(b)]	104.86 ± 13.27	60.14	35.06
5	19.72 ± 2.37	---	29.46 ± 2.37	22.64	5.21

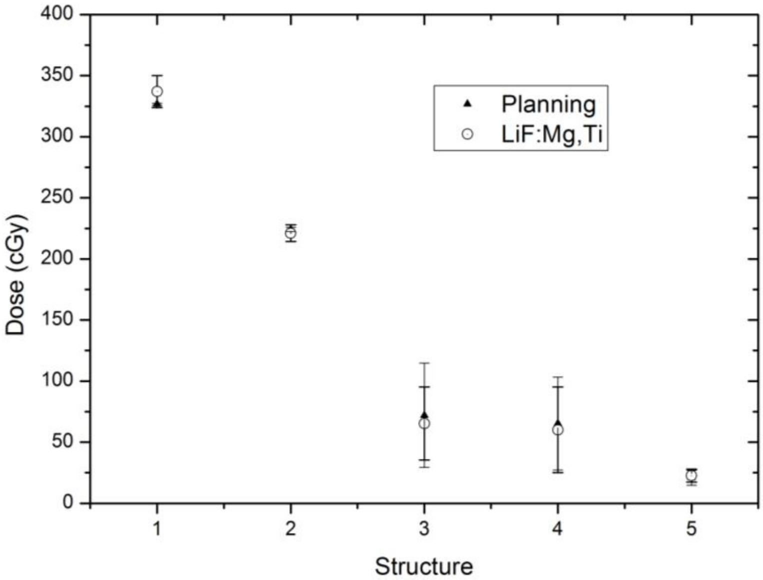


Fig. 5: Mean doses given by the planning system and measured by LiF:Mg,Ti.

The mean doses measured in the cavities 1 and 2, target volumes, were 339.59 ± 14.02 cGy and 221.10 ± 6.80 cGy, respectively. The TL results agree, considering the standard deviations, with the espected by the planning system.

Regarding the doses evaluated by the LiF:Mg,Ti dosimeters for the structure 3 the minimum dose was 24.90 ± 0.51 cGy, the maximum dose 99.35 ± 5.17 cGy, can be observed an intermediate isodose line of 55.75 ± 2.52 cGy and mean dose of 65.25 ± 29.85 cGy. For structure 4 the minimum dose was 20.48 ± 2.40 cGy, the maximum dose 104.86 ± 13.27 cGy, can be observed two intermediate isodoses lines of 40.04 ± 4.12 cGy (a) and 85.22 ± 0.19 cGy (b) and mean dose 60.14 ± 35.06 cGy. For structure 5 the minimum dose was 19.72 ± 2.37 cGy, the maximum dose 29.46 ± 2.37 cGy and mean dose 22.64 ± 5.21 cGy. In all cases the experimental results agree with the isodose curves provided by the planning system. In the case of scattered radiation the experimental doses evaluated presents standard deviations lower than the calculated.

Conclusion

The doses evaluated to the tumor simulators using LiF:Mg,Ti dosimeters corresponding to the estimated doses given by IMRT planning and the repeatabilities of TL responses is better than 4.12%, lower than 5% acceptable for radiation therapy [AAPM, 1983; Podgorsak, 2005]. The scattered radiation doses received by structures 3, 4 and 5 corresponded on average to 16.14% of the highest dose received by the structure 1, according to the planning.

This study can contribute to an accurate mapping of the doses received at any point in the PMMA phantom and further studies will analyze the isodose curves according to the delimitation of its areas. Therefore the evaluation of the IMRT technique with the use of dosimetric methods can be used for assuring the quality control for the absorbed doses in whole planning.

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