DOSE DISTRIBUTION ASSESSMENT (COMPARISON) IN THE TARGET VOLUME TREATED WITH VMAT GIVEN BY THE PLANNING SYSTEM AND EVALUATED BY TL DOSIMETERS

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ABSTRACT

Volumetric-modulated arc therapy (VMAT) is a relatively new therapy technique in which treatment is delivered using a cone beam that rotates around the patient. The radiation is delivered in a continuous gantry rotation while the cone beam is modulated by the intertwining of dynamic multileaf collimators (MLCs). Studies of VMAT plans have shown reduction in the treatment delivery time and monitor units (MU) comparable to IMRT plans improving major comfort to the patient and reducing uncertainties associated with patient movement during treatment. The treatment using VMAT minimizes the biological effects of radiation to critical structures near to the target volumes and produces excellent dose distributions. The dosimetry of ionizing radiation is essential for the radiological protection programs for quality assurance and licensing of equipment. For radiation oncology a quality assurance program is essentially to maintain the quality of patient care. As the VMAT is a new technique of radiation therapy it is important to optimize quality assurance mechanisms to ensure that tests are performed in order to preserve the patient and the equipment. This paper aims to determinate the dose distribution in the target volume (tumor to be treated) and the scattered dose distribution in the risk organs for VMAT technique comparing data given by the planning system and thermoluminescent (TL) response.

1. INTRODUCTION

In the scenery of radiation therapy, a new method of treatment, volumetric modulated arc therapy (VMAT) has been responsible to bring benefits and to allow a lower toxicity in the

treatment of patients. This treatment minimizes the radiation dose to the healthy tissues and escalates the dose to the target volume (tumor) [1,2,3].

VMAT works simultaneously with radiation delivery in a continuous gantry rotation and modulation of the multileaf collimators (MLCs). Studies comparing VMAT and IMRT plans have presented that VMAT minimizes treatment delivery time, so reducing uncertainties associated with patient movement during treatment. VMAT uses lower MUs than IMRT being faster, safer, and more accurate technique [4,5,6,7].

The dosimetry of ionizing radiation is essential for the radiological protection programs for quality assurance and licensing of equipment. All components that are involved in the process of treatment planning and dose delivery have to be verified to guarantee the quality assurance. This process is essential to maintain the integrity of treatment and therapy equipment. Several organizations recommended maximum values range of $\pm 5\%$ for the uncertainty in the absorbed dose. This verification of patient dose certificates the quality improvement in radiation therapy [8,9].

There are few methods of quality assurance deep-seated for IMRT and as the deployment of VMAT is still at the beginning is important to optimize and facilitate quality control mechanisms. It is important to ensure that tests are performed in order to preserve above all the patient but also the equipment itself. To guarantee that the services accord the highest clinical standards, each institution should invest in a quality assurance program for treatment planning and dose absorbed [10,11].This paper aims to determinate the dose distribution in the target volume (tumor to be treated) and the scattered dose distribution in the risk organs for VMAT technique comparing data given by the planning system and thermoluminescent (TL) response.

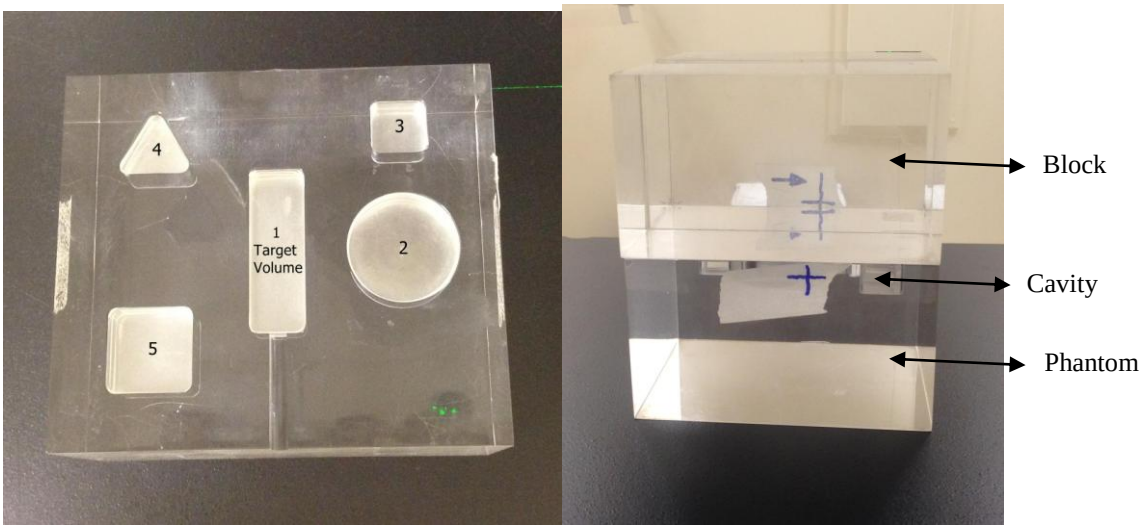
2. MATERIALS AND METHODS

The pre irradiation heat treatment used to the LiF:Mg,Ti dosimeters produced by Hashaw Chemical Company was 400ºC for one hour using a furnace VULCAN model 3-550 PD plus 100ºC for two hours using a furnace FANEN model 315-IEA 11200. The dosimeters were separated into groups of five dosimeters and selected with repeatability better than ± 5%.

The dose response curves were obtained using a linear accelerator Truebeam STx of Varian Medical Systems of the Hospital Israelita Albert Einstein (HIAE). The irradiation was done using 6 MV photons clinical beams with doses ranging from 30 up to 1400 cGy. The irradiations were carried out using a polymethacrylate (PMMA) phantom with absorbed doses corrected to the maximum dose depth by planning system of the equipment.

For the dose assessment a specific PMMA phantom containing five different geometric cavities was designed. One cavity was defined as a target volume and the other cavities as possible organs at risk. The PMMA phantom with cavities is showed in the Figure 1a. A PMMA block 10 cm thick was placed on the PMMA phantom (Figure 1b) and was used to ensure the backscattered radiation. A group of eight dosimeters were positioned inside each cavity and all cavities were irradiated with homogeneous doses in the linear accelerator Truebeam STx of Varian Medical Systems of HIAE, Figure 2. This irradiation was done three

times in three different days. The thermoluminescent responses were obtained using TL reader Harshaw model 4500.



a) **b)**

Figure 1. a) PMMA phantom containing five cavities; b) PMMA block used upon phantom with dosimeters positioned to irradiation.

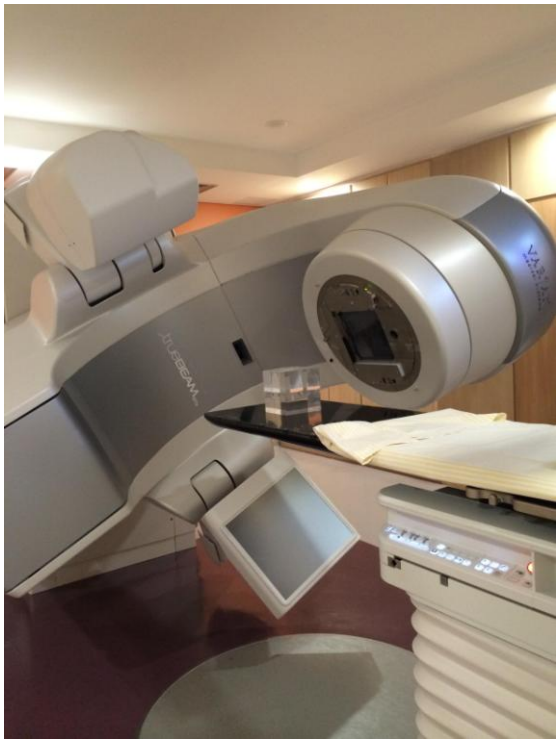


Figure 2. Set up of dosimeters irradiation using PMMA phantom with five cavities and linear accelerator Truebeam STx of Varian Medical Systems of HIAE.

The absorbed doses given by the VMAT planning system of the HIAE were 300 cGy, 150 cGy, 200 cGy, 100 cGy and 50 cGy in the cavities 1 to 5 respectively and they were compared with results obtained using the LiF:Mg,Ti dosimeters. The cavity 1 was defined as target volume. The planning has been done so that no isodose line pass through cavities providing a homogeneous dose of radiation inside each cavity. The isodose lines provided by planning system of VMAT Rapid Arc of HIAE are presented in Figure 3.This irradiation was done to verify if the results of the LiF:Mg,Ti dosimeters agree with the VMAT planning system enabling measurements simulating some tumor treatment.

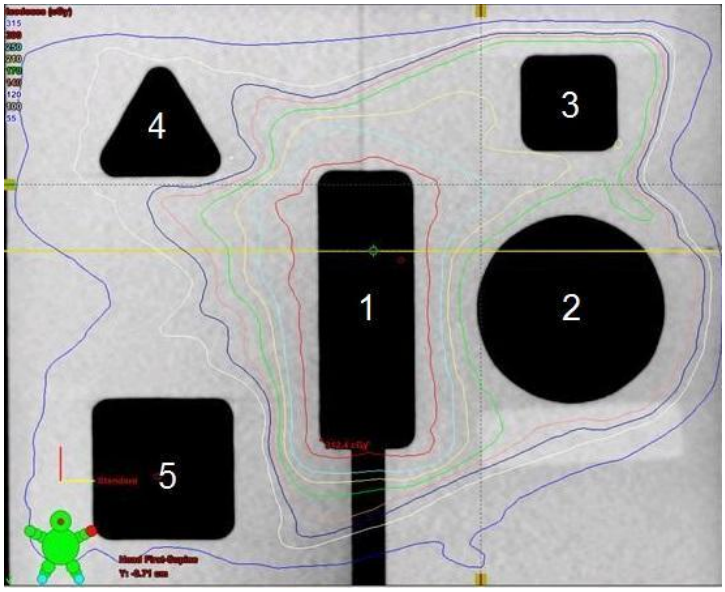


Figure 3. Dose distribution in the phantom with five cavities - isodose lines provided by planning system.

Each presented value of the dose response curves and the phantom irradiation is the average of five and eight measurements of dosimeters of the same sensitivity respectively. The error bars represent the standard deviation of the mean (1σ) with a confidence interval of 95%.

3. RESULTS AND DISCUSSION

The TL dose-response curves of LiF:Mg,Ti dosimeters to linear accelerator Truebeam STx of Varian Medical Systems to the absorbed dose range studied (30 – 1400 cGy) are presented in Figure 4.

The average dose given by the planning system of linear accelerator Truebeam STx of Varian Medical Systems of HIAE and the minimum, maximum and average absorbed doses evaluated by the LiF:Mg,Ti dosimeters are showed in the table 2.

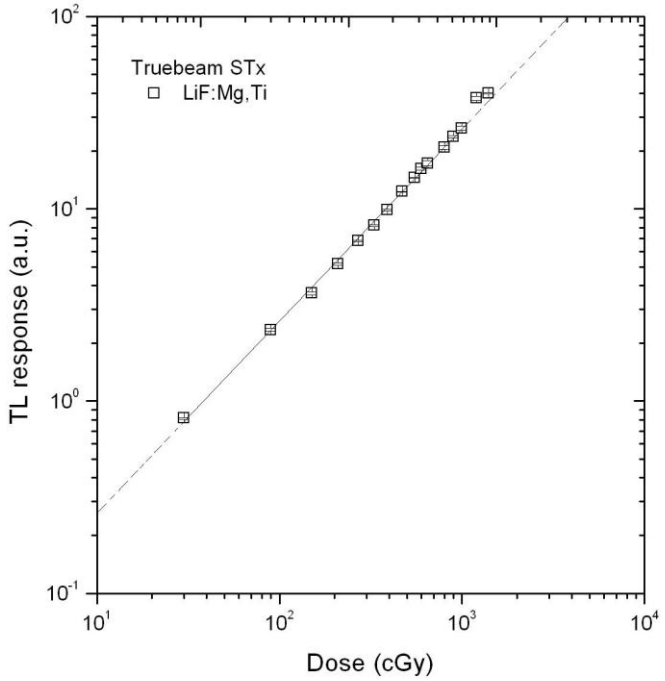


Figure 3. TL dose-response curve of LiF:Mg,Ti to linear accelerator Truebeam Stx of HIAE.

It can be observed a linear behavior from 30 up to 1000 cGy and above 1000 cGy a saturation of the TL response.

Table 2. Average doses given by the VMAT planning system of HIAE and minimum, maximum and average absorbed doses obtained by LiF:Mg,Ti dosimeters inside each cavity.

		Absorbed doses (cGy)				
		Cavities at phantom				
		1 (target)	**2**	**3**	**4**	**5**
Planning system	$\overline{D}$	300.0	150.0	200.0	100.0	50.00
1st irradiation	D_{min}	299.4	148.7	198.2	98.7	48.90
	D_{max}	301.4	151.8	201.7	101.4	51.40
	$\overline{D}$	300.4	150.5	199.5	100.4	50.00
2nd irradiation	D_{min}	298.6	149.7	199.2	99.0	49.37
	D_{max}	301.0	151.0	201.9	101.4	51.10
	$\overline{D}$	300.1	150.3	200.7	100.4	50.34
3rd irradiation	D_{min}	298.3	149,0	198.9	99.1	49.07
	D_{max}	301.0	151.7	201.3	101.8	51.32
	$\overline{D}$	299.9	149.9	200.3	100.6	50.57

The absorbed doses measured with LiF:Mg,Ti dosimeters ranged from 298.3 cGy up to 301.4 cGy for cavity 1 (target volume), from 148.7 cGy up to 151.8 cGy for cavity 2, from 198.2 cGy up to 201.9 cGy for cavity 3, from 98.7 cGy up to 101.8 cGy for cavity 4, from 48.90 cGy up to 51.40 cGy for cavity 5. The measurements obtained using TL dosimeters showed maximum variation of punctual absorbed dose of ±2.8% referring cavity 5 (50 cGy) compared to VMAT planning system.

The variation of the average absorbed dose measured with LiF:Mg,Ti dosimeters inside each cavity compared with the absorbed dose given by the VMAT planning system was ± 0.13%, ± 0.25%, ± 0.13%, ± 0.44% and ± 0.30% in the cavities 1 to 5 respectively.

The agreement between absorbed dose given by the planning system of linear accelerator Truebeam STx of Varian Medical Systems of HIAE and obtained with the LiF:Mg,Ti dosimeters is showed in the Figure 4.

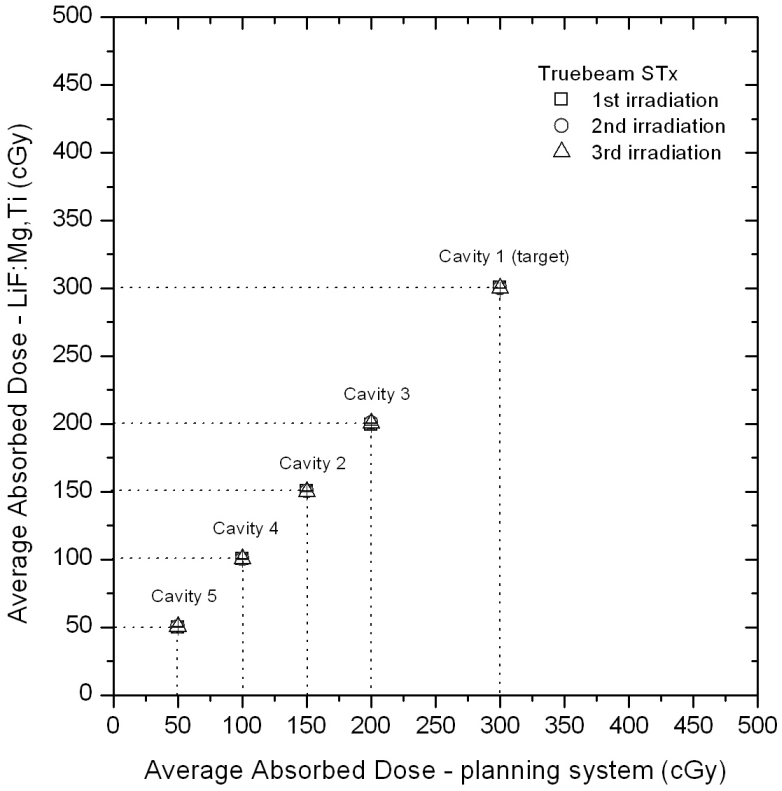


Figure 4. Average absorbed doses provided by the VMAT planning system of HIAE and measured by LiF:Mg,Ti with TL technique.

3. CONCLUSIONS

All measurements were better than ± 3%, so the repeatability of TL response was within acceptable limits for radiotherapy purposes [8,9].The variation of the average absorbed dose

measured with LiF:Mg,Ti dosimeters inside each cavity ranged from ± 0.13% to the cavity that simulated the tumor to be treated up to ± 0.44% to the cavity that simulated the risk organs (scattered radiation). It shows the great agreement between the doses measured with LiF:Mg,Ti dosimeters and the dose given by the VMAT planning system. LiF:Mg,Ti dosimeters showed great performance to evaluate the dose distribution in VMAT planning. Therefore further studies will be done to add more reliability to analyze the isodoses lines of the treatments that use the VMAT system and to establish dosimetric methods to assuring the quality control for absorbed doses of this kind of therapy.

ACKNOWLEDGMENTS

The authors are thankful to grant #2010/16437-0, São Paulo Research Foundation (FAPESP); CNPq, CAPES and INCT - Metrology of Radiation in Medicine for the partial financial support and to the Radiation Therapy staff of the Hospital Israelita Albert Einstein for the photons irradiations.

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