Energy dependence of TL response of $CaSO_4$:Dy, LiF:Mg,Ti e microLiF:Mg,Ti dosimeters in clinical electron beams using different phantoms

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Abstract. The application of electron beams in therapy requires great accuracy in the absorbed dose to the tumor, a variation of ± 5% is decisive in the risk of recurrence or sequelae. Thus, several organizations recommend checking the dose to the patient for quality improvement in radiotherapy. In radiotherapy dosimetry are currently used thermoluminescent detectors (TLD) of lithium fluoride doped with magnesium and titanium (LiF: Mg, Ti/TLD-100) because the dependence of their response to energy is considered small in the range of doses used in radiotherapy . Not much explored in radiotherapy yet, calcium sulphate doped with dysprosium ($CaSO_4$: Dy) is already used in radiation protection and studies have shown its great potential for dosimetry in radiotherapy. This study aims to evaluate the energy dependence of TL response of $CaSO_4$:Dy, LiF:Mg,Ti (TLD-100) and microLiF:Mg,Ti dosimeters in clinical electron beams using water, PMMA and solid water phantoms.

1 Introduction

With the advancements in the use of nuclear technology for medical purpose, there was a major concern related to the detection and assessment of radiation dose to control environmental and personnel evaluation [1]. According to Portaria 453 of June 1, 1998 of the Health Ministry, the exposure for health purposes is the main source of population exposure to artificial sources of ionizing radiation. The electron beams of high energy have wide application in medicine mainly to treat various types of cancers. The application of electron in therapy requires great accuracy in the absorbed dose to the tumor, because a small variation is highly determinant in the risk of recurrence or sequelae [2].

The main objectives of clinical dosimetry are to promote the radiation protection of individuals (patients and staff) and establish a quality control of the radiation beam [1]. The dose verification of the patient has been recommended for quality improvement in radiotherapy for several organizations like the American Association of Physicists in Medicine (AAPM) and the European Society of Therapeutic Radiology and Oncology (ESTRO) [3] [4] [5]. The International Commission on Radiation Units and Measurements (ICRU) established in 1976 that "all procedures involved in planning and execution of radiotherapy may contribute to a significant uncertainty in the dose administered to the patient." The recommended maximum values for the uncertainty in the dose range of ± 5% [2].

The high sensitivity of thermoluminescent materials allows the construction of resistant detectors and in all shapes and sizes, which makes them a useful tool, particularly for measurements in regions of sharp dose gradients [6] [7]. The TL dosimeters have a long history in ionizing radiation dosimetry in radiotherapy. In this area most of the measurements have been made with lithium fluoride (LiF) due to its tissue equivalence and the fact that the dependence of the response to the energy, dose rate and temperature of use are small in the range of doses used in radiotherapy . It has also been consistently characterized and used the microdosimeter of LiF that due to its minimal dimensions, can be used in in vivo dosimetry [8] [9] [10] [11] [12].

Another TL material, the $CaSO_4$: Dy, is already used in measurements of dose in radiation protection due to its high sensitivity [13] [14]. Although this material presents good linearity of response to beta radiation and photon beams for a wide range of doses, and preliminary studies show the viability of its application in electron beam, it has not been sufficiently explored in radiotherapy [13] [15] [16] [17] [18]. The different materials that make up the phantoms also change the response of TL dosimeters to radiation of electron beams, so these factors should be considered in dosimetry. It is essential to ensure the principle of optimization of radiation doses applied to patients in treatment, in order to control risks associated with exposure [19]. This study aims to evaluate the energy dependence TL response of $CaSO_4$:Dy, LiF:Mg,Ti (TLD-100) and microLiF:Mg,Ti dosimeters in clinical electron beams using different phantoms.

2 Materials and Methods

2.1 Dosimetric Materials:

- 100 TL dosimeters of $CaSO_4$:Dy produced by IPEN;
- 100 TL dosimeters of LiF:Mg,Ti produced by Harshaw;
- 85 TL microdosimeters of LiF:Mg,Ti produced by Harshaw.

2.2 Phantoms:

- Plates of solid water (RMI-457) with dimensions 30 x 30 cm^2;
- Plates of PMMA with dimensions 30 x 30 cm^2;
- Cubic PMMA phantom with dimensions 40.0 x 40.0 x 40.0 cm^3 filled with distilled water.

2.3 Irradiation System:

- ^{60}Co gamma source (activity 0,953 GBq in 11/11/2009);
- Linear acelerator Varian model Clinac 2100C of *Hospital Israelita Albert Einstein*.

2.4 Equipments:

- Furnace VULCAN model 3-550 PD;
- TL reader Harshaw model QS 3500.

The dosimeters were submitted initially to their respective pre-irradiation heat treatments: $CaSO_4$:Dy – 300ºC/1h; LiF:Mg,Ti and microLiF:Mg,Ti – 400ºC/1h + 100ºC/2h; irradiated with ^{60}Co gamma source in the air under electronic equilibrium conditions and, after evaluation of their TL responses, were separated into groups according to their individual sensitivity (limit ±5%).
For clinical electron beams irradiation with 4, 6, 9, 12 and 16 MeV using the linear accelerator Varian model Clinac 2100C, the selected dosimeters were placed in their depth of maximum dose (Tabel 1) in water, PMMA and water solid phantoms and always irradiated with a dose of 1 Gy. To ensure the backscatter of the beam were used 5 cm of the same phantom material under the dosimeters. The specifications followed for irradiation were recommended by the Technical Reports Series Nº. 398 (TRS 398) of IAEA (International Atomic Energy Agency): radiation field size – 10x10 cm^2; distance source- dosimeters – 100 cm [20].

Table 1 –Depths of maximum dose of dosimeters irradiation for the three different phantoms.

Irradiation	Nominal Energy [MeV]	Depth [cm]
electron	4	1,0
	6	1,2
	9	2,0
	12	2,4
	16	1,7

For each irradiation were used 5 dosimeters and the analysis of the energy dependence was based on average TL responses of dosimeters for each energy studied.

3 Results and Discussion

In Figures 1, 2 and 3 are presented the TL response relative to the dose of the $CaSO_4$:Dy, LiF:Mg,Ti and microLiF:Mg,Ti dosimeters in function of the electron beam energy for water, solid water and PMMA phantoms respectively.

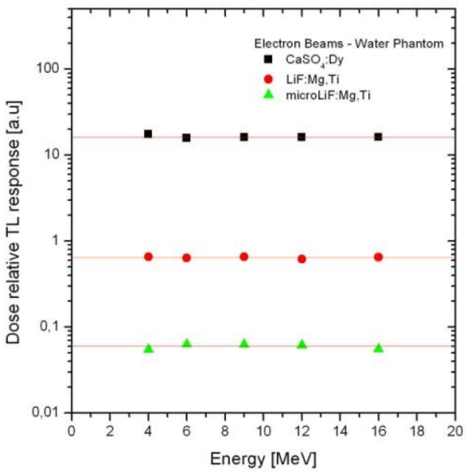

Fig. 1. Dose relative TL response of $CaSO_4$:Dy, LiF:Mg,Ti and microLiF:Mg,Ti dosimeters in function of the electron beam energy using water phantom.

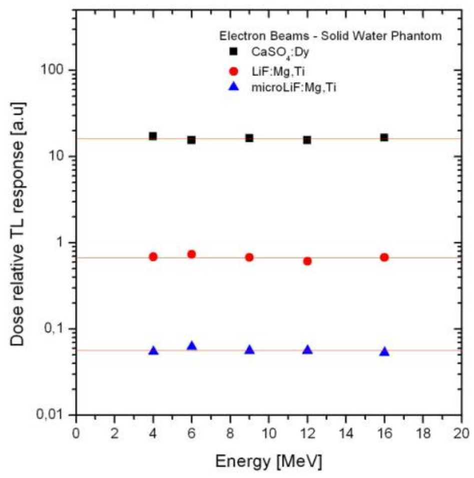

Fig. 2. Dose relative TL response of $CaSO_4$:Dy, LiF:Mg,Ti and microLiF:Mg,Ti dosimeters in function of the electron beam energy using solid water phantom.

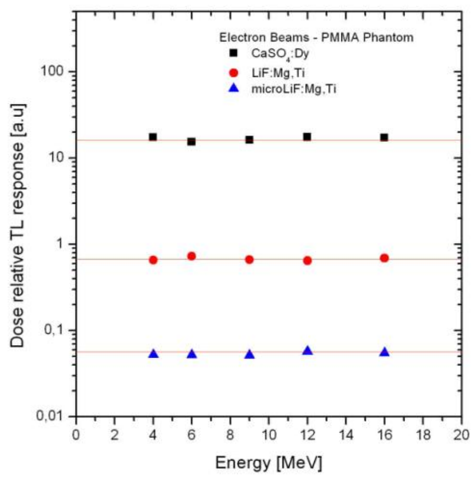

Fig. 3. Dose relative TL response of $CaSO_4$:Dy, LiF:Mg,Ti and microLiF:Mg,Ti dosimeters in function of the energy electron beam using PMMA phantom.

For the three different used phantoms, $CaSO_4$:Dy, LiF:Mg,Ti and microLiF:Mg,Ti showed no significant differences in their TL responses. For $CaSO_4$:Dy dosimeters TL response varied by 6,6%, 5,6% and 8,6% for the water, solid water and PMMA phantom respectively. TL responses to the LiF:Mg,Ti dosimeters varied by 4,7%, 10% and 7,3% using water, solid water and PMMA phantom respectively. For the micro-LiF:Mg,Ti dosimeters TL responses varied by 8,2%, 4,3% and 6,4% for the water, solid water and PMMA phantom respectively.

4 Conclusion

Through the results obtained, it can be concluded that the TL response of the three types of detectors used and different phantoms employed didn't show dependence in function of electron beam energy. It can be observed that the $CaSO_4$:Dy dosimeters produced by IPEN showed the same behavior that the LiF:Mg,Ti and microLiF:Mg,Ti dosimeters produced and marketed by Harshaw regarding the energy dependence of TL response. So, with this analysis and others already done, can be conclude that the $CaSO_4$:Dy dosimeters is a new alternative for the dosimetry of clinical electron beam applied to radiotherapy, with advantages in terms of sensitivity and acquisition cost of the detectors.

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