Evaluating the effect of energy on calibration of thermo-luminescent dosimeters 7-LiF:Mg,Cu,P (GR-207A)

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ABSTRACT

Background: 7-LiF: Mg,Cu,P (GR-207A) is one kind of thermo-luminescent dosimeters (TLD) which can be used in diagnostic radiology and radiotherapy applications. Because of having suitable properties such as good sensitivity, small size and being tissue equivalent, thermo-luminescent dosimetry has been one of the most important techniques in medicine over many years. Choosing a correct energy for TLDs' calibration is one of the most important factors in the accuracy of the absorbed dose. ***Materials and Methods:*** In order to evaluate the effect of calibration energy on the response of GR-207A TLDs, calibration of the TLDs were done with 120kVp, 200kVp, 6MV, 18MV and ^{60}Co beams. Then the responses of TLDs were normalized to ^{60}Co and energy dependence was calculated for each dose step. ***Results:*** The results confirmed that this kind of TLD dose not have the same response in different energies and reference dose affects on the amount of energy dependence. ***Discussion:*** Energy dependence of this type of TLDs is more significant at lower energies compared to megavoltage beams. Relative response to ^{60}Co illustrates that GR-207A dose not have uniform response to different steps of energies and the amount of energy dependence is totally different in various dose levels.

Keywords: *Dosimetry, thermo-luminescent dosimeters, TLD, energy dependence*

INTRODUCTION

Thermo-luminescent dosimeters (TLDs) due to having good properties such as small size, being tissue equivalent and detecting high dose gradients are one of the most important dosimetry detectors in medicine. Many efforts have been made to produce thermo-luminescent materials having properties similar to human tissue. Lithium Fluoride has been the phosphor which is used in medical applications due to its quasi-equivalence to human tissue (Z_{eff}=8.2) (1).

There are different types of thermo-luminescent dosimeters such as LiF:Mg,Ti (TLD-100), LiF:Mg,Cu,P(GR-200A), 7-LiF:Mg,Cu,P(GR-207A) and etc. among various types of TLDs, we selected GR-207A with properties such as linear response behavior for doses between 0.5 µGy-12Gy, very low rate of fading(negligible at 20°C and less than 0.1% per day at 50°C) (2). At first LiF was doped by Mg and Ti activators and more recently impurities of Mg,Cu,P were added to obtain a material having a very high sensitivity. The sensitivity of LiF:Mg,Cu,P is approximately 25 times higher than LiF:Mg,Ti. It is able to measure doses at microgray levels or even below [3].

One of the important factors in selecting an appropriate dosimeter, is the amount of variation in photon energy response of dosimeter. This matter may be significant in applications where the energy spectrum differs from that used to calibrate the absolute response of the TLD. However, there are limitations to produce different range of energies [4,5]. Therefore, by having the amount of variations in photon energy response of TLDs, calibration can be done in any energy.

The aim of this study is to measure the response of 7-LiF:Mg,Cu,P at 5 energies in the context of clinical applications and evaluating the photon energy response of this kind of TLD.

MATERIALS AND METHODS

TLD

In this study forty 7-LiF:Mg,Cu,P TLDs (commercially known as GR-207A), manufactured by Fimel company, (Fimel, Velizy, France), in the form of chip with dimension of 4.5×0.8 mm were utilized. At the onset of the study, TLDs were annealed by the procedure recommended by the manufacturer to reduce the background radiation (240°C 10 min) [6]. Each chip was positioned in specialized holes on a perspex slab at the depth of maximum dose at 6MV photon beam produced by a Varian linear accelerator. A dose of 100 cGy was irradiated to TLDs to acquire the Element Correction Coefficient (ECC). The Element Correction Coefficient was calculated from equation 1.

$$ECC_j = \frac{<TLD>}{TLD_j} \qquad (1)$$

Where <TLD> and TLD j are average of reading of the total TLDs and individual reading, respectively.

Radiation energies

In order to calibrate the TLDs over different dose steps and different energies, various radiation sources (120kVp, 200kVp, 6MV, 18MV and ^{60}Co beams) were selected. In each step of irradiation, 3 TLDs were positioned in a specialized hole on a Perspex (PMMA) slab that was sandwiched between other slabs to prepare adequate electronic equilibrium condition (figure 1) [7].

Figure 1. Using slabs for irradiation of TLDs.

Table 1 shows the conditions of the irradiations with 5 different steps of energies.

Table 1. Characteristics of the X-ray sources and the conditions of irradiations.

Potential (cm)	SSD (cm)	Field (cm²)	Depth
120kVp(0.2 mm Cu)	30	10×15	surface
200kVp(1mm Cu)	40	10×15	surface
6MV	100	10×10	1.6
18MV	100	10×10	3.3
^{60}Co(1.25Mev)	80	10×10	1

TLD Reader

After irradiation, all TLDs were read out employing a LTM reader (Fimel, Velizy, France), regarding to their ECCs. The read-out cycle included 140°C 7 s (pre-heat), 6°Cs^{-1} linear ramp to 245°C for 10 s [1].

RESULTS

Calibration Curves

Initially by using ECCs, five calibration curves (thermo-luminescent response versus absorbed dose) were obtained in radiation energies of 120kVp, 200kVp, 6MV, 18MV and ^{60}Co beams (figure 2). Dose steps varied between 5 to 200 cGy and as they were within 0.5 μGy-12Gy, the calibration curves exhibited a linear behavior. Standard deviation in the results of three tested TLDs in each dose step in all studied rang of energies varied from 0.51% to 2.04%.

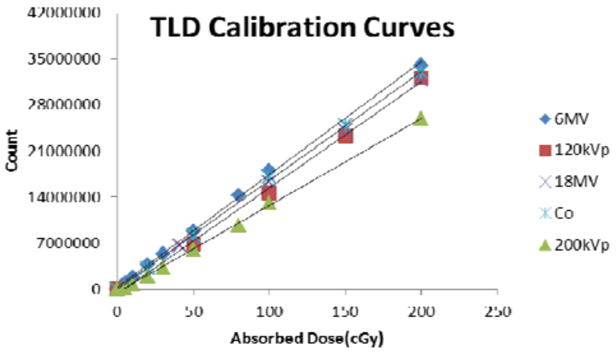

Figure 2. TLD calibration curves at 5 different energies.

Energy dependence

After obtaining calibration curves, by selecting equal dose steps from different calibration curves, energy dependence was calculated. Energy dependence is the change of the TL response at a certain dose as a function of the energy of the radiation [(3)]. According to this definition, energy dependence was obtained by irradiating the tested TLDs with absorbed doses of 50,100,200cGy under the same geometric conditions and varying only the radiation beam. Then the response was normalized to ^{60}Co.

Table 2 shows the relative response of TLDs at 4 different energies and 3 different dose steps. By using equation 2 error bars were obtained for relative responses of different energies and different dose steps.

$$\left(\frac{\sigma R}{R}\right)^2 = \left(\frac{\sigma N_1}{N_1}\right)^2 + \left(\frac{\sigma N_2}{N_2}\right)^2 \qquad (2)$$

Where σR stands for the error bar for relative response, R is the relative response, σN_1 and σN_2 represent standard deviation of the 3 tested TLDs in each dose step and N_1, N_2 are the average counts of the TLDs in each dose step.

Figures 3 illustrates the variations in energy response of 7-LiF:Mg,Cu,P (GR-207A) at different dose steps. According to the definition of energy dependence, it is calculated 30.84%, 27.36% and 24.04 % when the reference dose is 50,100,200 cGy, respectively.

Table 2. Relative response of TLDs to the result of ^{60}Co at different energies and various dose steps.

Potential	Relative Response to ^{60}Co		
	200cGy	50cGy	100cGy
120kVp	0.98±0.12	0.84±0.12	0.85± 0.11
200kVp	0.79±0.12	0.74±0.11	0.77±0.10
6MV	1.04±0.11	1.07±0.10	1.06±0.11
18MV	0.97±0.10	0.97±0.12	0.95±0.12

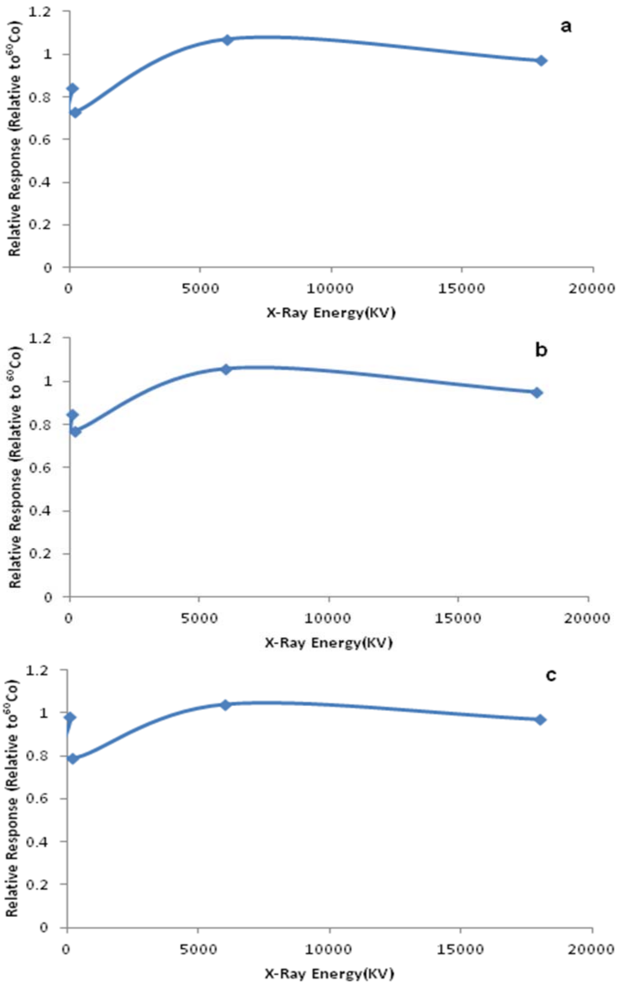

Figure3. The relative response of ^{7}LiF normalized to ^{60}Co at (a): 50cGy, (b): 100cGy, (c): 200cGy.

DISCUSSION

Figure 3 illustrates the variations in response of TLDs with energy at three different dose steps. As it was shown in figures above, 7-LiF:Mg,Cu,P has a non-uniform response at different energies. This is consistent with Krasa *et al.* who concluded that GR-200A TLDs were energy dependent [8].

With respect to the TLDs energy dependence (figure 3) and the data in table 2, it can be concluded that 7-LiF:Mg,Cu,P is a material that shows a more significant variation in lower energies compared to megavoltage beams. This result is either consistent with Edwards *et al.* and Olko *et al.* [9,10].

In each dose step the maximum relative response belongs to 6MV photon beams and the minimum relative response is for 200kVp but the amount of variation in photon energy response is quite different in various dose steps (30.84%, 27.36% and 24.04% when a dose of 50, 100 and 200 cGy absorbed by TLDs, respectively). This result demonstrates that selecting a reference dose for reporting the amount of variations in photon energy response of TLDs, can affect on the amount of energy dependence.

The maximum relative response for ortho-voltage therapy beams (120kVp and 200kVp) occurred when a dose of 200cGy irradiated to TLDs and the minimum was at a dose of 50 cGy. However, for megavoltage beams, the variations in response of TLDs are more uniform.

Our findings are not consistent with Lisa Duggan *et al.* who investigated the response of GR-200A TLDs in different energies and different annealing cycles on clinical utility. She concluded that the response of LiF:Mg,Cu,P deviated by a maximum of 15% [5]. Then the measured energy response of LiF:Mg,Cu,P TLDs was fit to a simple model devised by Kron *et al.* [11]. The reason for variability in that study and ours in the amount of variations in photon energy response of LiF:Mg,Cu,P may be due to manufacturing procedure, thermal handing or dopant concentration [5], selecting reference energy, reference dose, isotopically enrichment of Li(^{natural}Li/^{7}Li) and also because of statistical errors and experimental uncertainties.

CONCLUSION

Relative response to ^{60}Co illustrates that GR-207A dosen't have uniform response to different steps of energies and the amount of energy dependence is totally different in various dose levels. Therefore, reference dose affects on the amount of energy dependence. Energy dependence of this type of TLDs is more significant in lower energies compared to megavoltage beams. So selecting an appropriate energy, preferably similar to exam energy, for calibrating the TLDs , plays an important role in the response of TLDs and also in the accuracy of absorbed dose, particularly in kilo-voltage therapy beams.

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