Dose Distribution in Solid Phantom by TLD with a Metal Plate of Various Thicknesses

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Purpose: TLD experiments were set up to measure the dose distribution and to analyze the influence on dose measurement of thin metal plate and solid water phantom. The aim of the present study was to investigate the build-up effect of metal plate loaded on TLD chip and depth dose in the controlled environment of phantom measurements.

Materials and Methods: Measurements were done by using LiF TLD-100 loaded by a thin metal plate with the same surface area (3.2×3.2 ㎟) as TLD chip. TLD chips loaded with one metal plate from three different metal plate (Tin, Copper, Gold) of different thicknesses (0.1, 0.15, 0.2, 0.3 ㎜) were used respectively to measure radiation dose. Using the TLD loaded with one metal plate, surface dose and the depth dose at the build-up maximum region were investigated.

Results: Using a metal plate on TLD chip increased the surface dose. Surface dose curve shows the dose build-up against equivalent thickness of metal to water. The values of TL reading obtained by using metal plate at depth of build-up maximum are about 8% to 13% lower than those obtained by normal TLD chip.

Conclusion: The metal technique used for TLD dosimetry could provide clinicals information about the build-up of dose up to 4.2mm depth in addition to a depth dose distribution. The results of TLD with a metal plate measurements may help with decisions to boost or bolus certain areas of the skin.

Key Words: TLD, metal plate, depth dose, equivalent thickness

Introduction

Skin complications due to radiation used in radiotherapy treatment of cancer have always interested oncologists. Modern radiotherapy treatment machines reduce the skin dose by making use of the build-up effect in mega voltage radiation beams. In general, it would be interest for the radiation oncologist to know the dose close to the skin surface as well as the degree of buildup behind it. This can be of importance to minimize unwanted skin reactions.[1)]

The absorbed dose in the surface region varies rapidly with depth in the tissue. The relevant depth of a measurement depends on which biological effect one is interested in. For skin erythema the basal cell layer is of interest. With higher doses the damage is related to deeper components of the skin. The layer recommended for practical dose assessments is situated at 0.07 ㎜ depth, according to ICRP publication 60 and ICRU Report 39 but the real depth varies considerably. For the purpose of radiation protection the effective depth is assumed to be located at 3 mm depth. The dosemeters used should give and estimate of the absorbed doses at the relevant depth.[2)]

Various detector types can be used for in vivo dosimetry; however, semiconductors and thermoluminescent dosimeters(TLD) are the ones most commonly employed. Most commercially available semiconductors are designed to measure the dose at a certain depth in tissue and entrance dose measurement. They are usually covered by a cap which takes the active point of measurement to a depth of typically between 0.5 and 2.0 cm allowing for the build-up effect in megavoltage x-ray beams.

The aim of the present study was to investigate the build-up effect of metal plate loaded on TLD chip in the controlled environment of phantom measurements. This was done by using LiF TLD-100 loaded by a thin metal plate with the same surface area as TLD chip. Tin and Gold plate of thicknesses of 0.1, 0.2 and 0.3 mm and Copper plate of thicknesses of 0.15 and 0.3 mm were used respectively. The results of the study can help to interpret TLD results in strong dose gradients such as at the surface and in the build-up maximum dose region for megavoltage x-ray beams.[3]

Materials and Methods

1. TLD surface dose with various metal plate

TLD-100 Harshaw chips of dimensions of 3.2mm× 3.2mm×0.9mm for normal TLD chips and several metal plates(Tin, Copper and Gold plate) were used. All the metal plates with various thicknesses (0.1, 0.2, and 0.3 mm for Tin and Gold plate and 0.15, 0.3 mm for Copper plate) have the same area as TLD-100. TL dosimeter without any thin metal plate (nc: normal chips) and TL dosimeter loaded with one of the metal plates (mc: metal loaded TLD chip, tc: Tin loaded TLD chip, cc: Copper loaded TLD chip and gc: Gold loaded TLD chip) were investigated as dosimeter. TLD was embedded in 1mm depth and 3.2×3.2 mm² square hole of solid water phantom which just accommodate one chip. Then, only one of the metal plates was simply loaded on TLD-100 respectively on the TLD with vacuum tweezer. The TLD reader used was a Harshaw TLD reader 5500. Additional reader software which allowed access to the full time, temperature and counts profile of the glow curve was obtained from the manufacturer. It was recorded as charge collected by the photomultiplier in nano-coulomb(nC). Annealing was carried out using a programmable TLD annealing oven (PTW,TLDO).

The experiment was carried out irradiating with Varian Clinac 600c accelerator. For calibration, the TLD chip was placed inside a polystyrene phantom at a depth of 15mm. The exposure of nc and mc chips were made in the 6MV photon beams on the surface of a 20 cm thick solid water phantom at a field size of 10×10 cm² and 100 cmSSD. Surface dose response of TLD measurements of nc and mc chips were made following exposure to photon beam at dose level 100 cGy. The whole experiment was carried out using a group of five TLD chips always employed together. For each chip, an individual sensitivity factor was determined with respect to the mean value of the five readings of the group.

2. TLD depth dose against various thickness of metal

The nc and mc dosimeters were investigated as dosimeter for evaluations of photon absorbed depth dose in solid phantom. TLD was embedded in 1mm depth and 3.2×3.2 mm² square hole of solid water phantom which just accommodate one chip. Then, One of the thin metal plates was simply mounted on the TLD with vacuum tweezer. After that, 15mm thick polystyrene was free lying on the nc or mc dosimeter embedded in solid water phantom. So the TLD dosimeter was located in the hole at the depth of maximum dose(dmax) in solid water.[4] The nc and mc dosimeters were irradiated 15mm deep in a polystyrene phantom at a field size of 10×10 cm² and 100 cm SSD with 6 MV photon beam. Solid phantom depth dose response of TLD measurements of nc and mc chips were

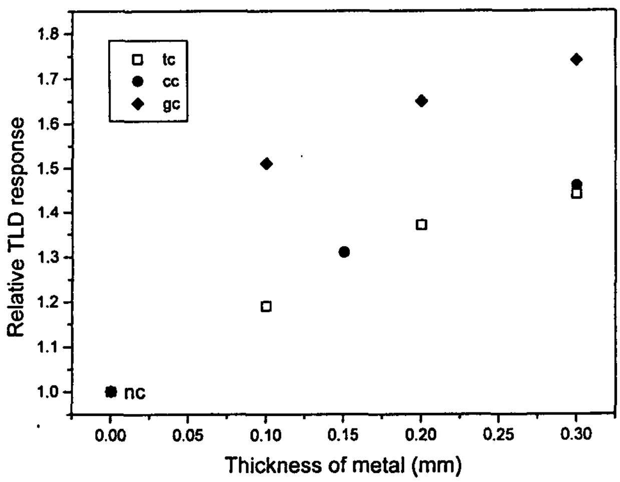

Fig. 1. The dose build-up in TLD chip loaded with one of thin metal plates was shown against various metal thicknesses. The reading of a normal chip (nc) at the surface of solid phantom was normalized as shown by a asterisk.

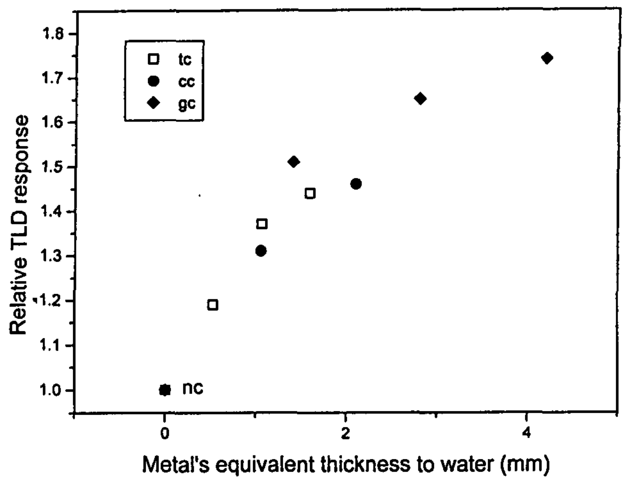

Fig. 2. The dose build-up was shown against equivalent thickness of metal to water. The increasing equivalent thickness in this arrangement leads to a steep dose build-up.

made following exposure to photon beam of 100 cGy.

By keeping each chip separately identified we were able to use the relative sensitivity of each chip; the uncertainty of reproducibility was within ±2%. Since we were only interested in sensitivity relative to other dosimeters it was not necessary therefore, to determine the variation in absolute sensitivity of the whole dosimeters.

Results and Discussion

1. Surface dose with build-up effect

One of thin metal plates was loaded on top of TLD chip (mc) to imitate and measure the dose distribution in a solid phantom. The thin metal plate with the same surface area as the TLD chip was placed free lying on the surface of TLD chip. The mc dosimeter was flush with the solid phantom surface and exposed to 100 cGy in a 10 × 10 ㎠ field of 6MV x rays at 100 ㎝ SSD. All data were measured with TLD dosimeter with metal plate at the surface of solid phantom.

Figure 1 shows the dose buildup in TLD chip loaded with one of thin metal plates against various metal thicknesses. The dose buildup curve consists of readings from the mc where relative dose readings are plotted against the thickness of metal. All dose measurements for the same kind of metal plate are joined and represent the dose increase against the thickness of metal in 6MV x-rays. The reading of a normal chip(nc) at the surface of solid phantom was normalized as shown in Fig. 1 where nc reading was shown by a asterisk. The larger electron density of metal in this arrangement leads to a higher TLD response in the mc dosimeter chip shown in Fig. 1. All mc chips have a higher reading than that of nc most probably due to increased scattered electrons from metal and build-up effect. The highest reading for all dosimeter was found for the mc with the largest equivalent thickness of metal, and the lowest at the nc chip.

To further investigate build-up effect, the measured TLD reading in each dosimeter was given as a function of metal's equivalent thickness to water. Fig. 2 shows the dose build-up against equivalent thickness of metal to water. The increasing equivalent thickness in this arrangement leads to a steep dose build-up in the

Table 1. Normal chips(nc) and metal loaded TLD chip(mc, tc: Tin loaded TLD chip, cc: Copper loaded TLD chip and gc: Gold loaded TLD chip) were investigated as dosimeter. TLD reading of mc dosimeter at 15 mm depth in polystyrene phantom, normalized to the value of nc. Equivalent thickness of material to water = thickness of material × (# el/㎤ of material ÷ # el/㎤ of water)

Type of TL dosimeter	nc	tc	cc	gc
Loaded material on TLD-100	None	Tin	Copper	Gold
Thickness of loaded material (㎜)	None	0.1	0.15	0.1
Equivalent thickness of material to water(㎜)	None	0.54	1.07	1.43
Relative TLD reading to nc at 15 ㎜ depth in phantom	1	0.92	0.9	0.87

TLD chip shown in Fig. 2. This can be attributed to the increase in scattered radiation from the loaded metal plate with a higher number of electrons per unit volume as compared to the other metals with the same thickness. In Fig. 2, even at the same equivalent thickness the different metals have shown the slightly different TL responses. This can be caused by the different mass attenuation coefficients of different metals. Mass attenuation coefficient of Tin is a little bit larger than that of Copper.[5] The reading of nc dosimeter was normalized shown in Fig. 2 where nc reading was marked by a asterisk. The dose distribution measured with the mc dosimeters shown in the Fig. 1 and 2 depicts the build-up curve of 6 MV x-rays in solid water. Besides showing the variation of dose with equivalent depth in the first depth in cm, these results could be used to estimate the response for dosimeters with different thicknesses.

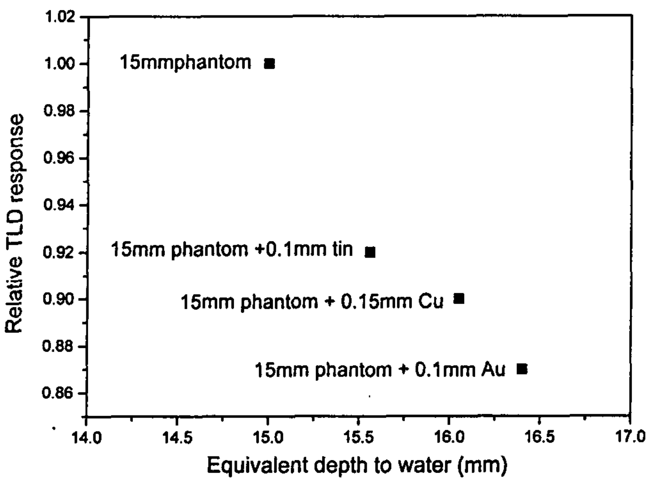

Fig. 3. The relative TLD response for metal chip (mc) dosimeter against equivalent depth to water. Equivalent depth to water means 15 ㎜ solid phantom thickness plus metal's equivalent thickness to water.

2. Equivalent depth dose in solid phantom

In order to imitate and to estimate the variation of dose with the depth in tissue, the depth dose distribution in polystyrene around the depth of build-up maximum region was measured with mc chip. A depth dose curve for a 10×10 ㎠ field of 6 MV x-rays at 100 ㎝ SSD was measured using the mc dosimeters with various equivalent thicknesses of metal plate to water. The mc was positioned at 15mm depth in solid water and irradiated to 100 cGy.

Table 1 shows the thicknesses of metal plates used for this measurement and the TL readout of nc and mc at 15 ㎜ depth in solid phantom. The TLD reading was relative to measurements of nc chip done 15mm deep which depth had been determined by earlier measurements to be the depth of the maximum dose(d_{max}). The readings are normalized to a nc chip placed at d_{max}. Fig. 3 shows the relative TLD response for mc dosimeter against metal's equivalent depth to water. Metal's equivalent depth to water means 15㎜ solid phantom thickness plus metal's equivalent thickness to water. The values of TL reading obtained by using mc chips are about 8%

to 13% lower than those obtained by nc. In the present case, the lower value for mc could be attributed to its reduced stopping power for electrons of energies below 0.5 MeV which contribute significantly in TLDs. A detailed study to look into the finer details of the response of different dosimeters is, however, necessary to explain the differences in the values measured by various dosimeters.[6]

Conclusion

The LiF TLD-100 chips are a small and free-standing dose measurement device suitable for a wide range of applications in dosimetry. In this paper the possibilities to use TLD loaded with a metal plate for surface absorbed dose measurements and in vivo dosimetry were investigated. The proposed system of TLD with the metal plate of thicknesses between 0.1 and 0.3 mm covers the dose distribution from the very surface to about 4.2 ㎜ equivalent depth in tissue. This comprises most of the depths where unwanted skin reactions originate.

Using a metal plate on TLD chip increased the surface dose. Surface dose curve shows the dose build-up against metal's equivalent thickness of metal to water. The values of TL reading obtained by using metal plate at depth of maximum dose are about 8% to 13% lower than those obtained by normal TLD chip.

The results of in vivo TLD with metal plate measurements could provide clinicians information about the build-up of dose up to 4.2mm depth in addition to a depth dose measurement.[7] And the TLD with metal plate technique used for in vivo dosimetry may be helpful with decisions to boost or bolus certain areas of the skin.

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다양한 두께의 금속판을 얹은 TLD를 이용하여 구한, 고체 팬텀 내에서의 선량분포

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목적: 금속박막과 고체 팬텀이 선량 분포와 선량 측정에 미치는 영향을 연구하기 위하여 TLD 실험을 행하였다. 본 연구의 목적은 주어진 고체 팬텀 환경 내에서 TLD 기판 위에 놓인 금속박막의 build-up 효과와 깊이선량 분포를 알아보고자 하였다.

대상 및 방법: 측정은 TLD 기판과 같은 면적(3.2 × 3.2 ㎟)의 금속박막을 LiF TLD-100 위에 얹어서 행하였다. 여러 종류(주석, 구리, 금)의 다양한 두께 (0.1, 0.15, 0.2, 0.3 ㎜)를 가진 금속박막 중에 한 개를 TLD 기판 위에는 얹어서 각 각의 흡수선량을 측정하였다. 금속박막을 얹은 TLD 기판을 사용하여 고체 팬텀에서의 표면흡수선량과 최대 build-up 영역에서 흡수선량을 측정하였다.

결과: 금속박막을 이용한 TLD 기판의 경우 표면흡수선량이 증가하였고, 물에 대한 금속의 등가 두께에 따른 표면흡수선량 곡선에는 build-up이 뚜렷이 관측되었다. 최대 build-up 영역에서 관측한 흡수선량 측정값은 금속박막을 얹지 않은 TLD의 경우보다 약 8%에서 13% 정도의 보다 작은 값을 나타내었다.

결론: TLD 선량 측정 시 금속 박막 법은 깊이에 따른 흡수선량 뿐 만 아니라 피부 표면으로부터 약 4.2mm 깊이까지의 흡수선량의 build-up 에 관련 정보를 의료진에 제공할 수 있으며, 금속박막을 얹은 TLD에 관한 실험 결과는 피부 특정 영역에서의 bolus의 결정에 도움이 될 것으로 사료됨.

중심단어: TLD, 금속박막, 깊이 선량, 등가 두께