Preliminary Study in In Vivo CT Dosimetry Using Optically Stimulated Luminescence Detector (OSLD)

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Abstract. Optically stimulated luminescence nanoDot dosimeters (OSLD) have been used to measure single point dose distribution along the superior-inferior position at the surface (skin) and in depths, analogous to organ depths. A customized acrylic phantom of 46 cm length, 20 cm diameter was fabricated, and used for the experimental measurements using CT (Computed Tomography) beam. The CT dose profile along the surface and the centre of the phantom, as a function of scan field, were measured. The measured dose due to the primary radiation was quantified and compared with the theoretical dose profile using conventional 100 mm pencil CT ionization chamber. The OSLD responses at the center axial and the surface were found to be similar with the dose profile from CT ionization chamber. In this study, the dose at the center axial was found to be higher than the surface dose up to 28.13%. The dose at the diagonal center was found to be the highest compared to the surface dose up to 61.13%. The result of this work has revalidated the potential use of OSLD in CT dosimetry as an alternative to TL-dosimetry.

Keywords: Computed tomography, Dose profile, in vivo CTdosimetry, Optically stimulated luminescence detector (OSLD).

1. Introduction

There is a number of dosimeters available for measuring the dose to the patient or object. Mainly two types of dosimeters are in use, active and passive dosimeters. The active dosimeters are used for in-situ dosimetry, capable of measuring dose and dose rate, and displaying the output simultaneously at the time of measurements. Examples of this type include the diodes, MOSFETs, optical fibre coupled organic scintillators, and doped silica glass. They are expensive and mostly one time use. The other type is the passive dosimeter which record absorbed radiation doses
over the period of exposure time. Thereafter, the irradiated dosimeters are read out with a calibrated reader, and the net dosimeter-response is converted to dose. This is a time consuming process but they are widely used. Examples of this type of dosimeter are a variety of thermoluminescent dosimeter (TLD), and recently introduced optically stimulated luminescence dosimeter (OSLD).

Passive dosimeters are more popular than the active dosimeters because they are inexpensive, easier to use, and require no cable and battery. Before OSLD was introduced, TLDs played the leading role for measuring radiation dose, and most of the people preferred to use TLD mainly in personnel dosimetry and in vivo medical dosimetry. Recently OSL nanoDot dosimeters are being considered as a potential candidate compared to thermoluminescent dosimeters (TLDs) and MOSFETs. TL-dosimetry is tedious and time consuming. Like other dosimeters, characterization of OSL nanoDot is required before using as radiation monitors in diagnostic imaging as well as in personnel dosimetry.

The OSLDs used in this work is made of powder aluminium oxide doped with carbon (Al₂O₃:C) enclosed in 10 mm x 10 mm x 2 mm light-tight plastic case. It works in similar principles as thermo-luminescent detectors (TLDs). The only difference is the induced luminescence. OSLDs use optical stimulus rather than thermal stimulus, which is the case for TLD[1–3]. The signal, released from light-emitting diodes (LEDs) is directly proportional to the dose absorbed by the OSLD. In some works, the standard deviations of OSLD are found to be 3-10% less than TLD[1-4]. Determination of CT dose profile on the surface (representing skin) and at the center (representing internal organ) are of primary importance in CT dosimetry. As such, careful studies are required for characterization and optimization of OSL nanoDots detectors before using as radiation monitor alternative to TLDs in diagnostic imaging, particularly in in vivo CT dosmetry. Previous works using OSLD in CT dosimetry indicated its potentiality for monitoring radiation dose in diagnostic radiology[4]. In this work, attention has been focused for further validation of the applicability of OSL technique in in-vivo CT dosimetry.

2. Experimental

2.1 Axial Length of Surface and Internal Dose Profile

OSL dosimeters used in the experiments were calibrated at 120 kVp and 140 kVp beam energies using SSDL level 100 mm pencil CT
ionization chamber (RadCal Corporation) under identical geometry and exposure situation. Two sets of selected OSLDs and a cylindrical water phantom with 46 cm length and 20 cm diameter were in use. One set of OSLDs was placed along 35 cm length on the phantom surface, to represent skin dose, and the other set was placed inside, to represent internal organ dose. The placements of the OSL dosimeters are shown in Fig. 1. The distance from the beam source to the centre of OSLD was 100 cm.

Then OSLDs were irradiated with 120 kVp and 150 mAs beams with 10 cm scan length. The OSL dosimeters placed beyond the scan length up to 35 cm both on the surface and inside with a view to measure the contribution from scattered radiation in the dose profiles. Figure 2 shows the locations of the OSLDs both inside and on the surface of the phantom. After irradiations all the OSL detectors were readout using Landauer MicroStar® Inlight reader, and converted to dose in mGy.

2.2 Depth Dose Distribution

A set of OSLD was placed along the center of cylindrical water phantom with 46 cm length and 32 cm diameter (refers to Fig. 3.) at the
middle of the primary scan. Two clinical parameters that had been used for exposures were 120 kVp, 350 mAs and 140 kVP, 350 mAs beam respectively, for head and body. 10 cm scan length and helical scan were used during exposure. After the exposures, all the OSL dosimeters were read out and their responses, in mGy, were compared with each other to get a correlation between the skin dose and internal dose in CT scanning.

![Fig. 3. OSLD placements during depth dose distribution.](image)

3. Results

3.1 Axial Length of Surface and Internal Dose Profile

The dose profiles for each placement, representative skin and inside organ, are shown in Fig. 4.

![Fig. 4. The dose profile during internal and surface axial.](image)
The dose profiles at the surface and internal were similar with the dose profile from the 100 mm pencil CT ionization chamber. During the experiment, the average standard deviation was found ±8.77% which was still acceptable for dose profile measurement. The dose profiles demonstrate that the surface and internal doses in the active scan field are steady, because of the helical CT scan. The measured doses outside the primary scan length (10 cm) represent contribution from the scattered radiation. Similar tail is observed in the dose profile measured with the aid of reference class SSDL level CT ionization chamber and TLDs. The relative internal and surface dose at each point during axial scan or horizontal scan has been observed to be 28.15% higher than the surface dose.

3.2 Depth Dose Distribution

The dose distribution along the center of cylindrical solid water phantom was measured by using a set of OSLDs, placed along the center of cylindrical solid water phantom. The dose distributions during CT imaging are shown in Fig. 5 & 6, respectively, for 120 kVp and 140 kVp beam.

![Fig. 5. The dose profile at 120 kVP and 140 kVP.](image)

From Fig. 4, the internal dose is higher than the surface dose due to electronic equilibrium law, where the more secondary ions produced by primary ionizing particles continuously increase until a maximum is reached. The maximum dose occurs at certain depth as internal dose[^3^-^6].
4. Discussion

The relative doses from the surface and internal start decreasing to 5 cm distance, thereafter, start to become stable until the rest. During this experiment, the dose saturation on the surface was found to be higher than in the internal locations. This is due to attenuation of radiation beam in the medium. More scattered energetic photons from the attenuation of the medium contributed to the total absorbed dose. Since the attenuation of solid water inside is higher than the attenuation of air on surface, the scattered photons available internally is higher than those on the surface\textsuperscript{[7–10]}.

In the depth dose distribution, as shown in Fig. 5, the dose to the center of the phantom was the highest compared to other locations up to 61.13\% at 120 kVp and 55.34\% at 140 kVp beam. The increase of absorbed dose continues until certain depth. The dose maxima reached at the maximum range of primary ionizing particle where the electronic equilibrium is attained. Then the absorbed dose decreases with increasing depth because of the continuous decrease in the flux of indirectly ionizing radiation\textsuperscript{[11]}.

Based on Fig. 6, the dose from OSLD was higher than the dose from ion chamber readings. The average relative dose from OSLD to ionization chamber reading was ±7.81\% at 120 kVp and ±5.75\% at 140 kVp. The average standard deviation for OSLD at 120 kVp and 140 kVp were ±8.97\% and ±6.64\% respectively, while for ionization chamber at 120 kVp and 140 kVp were ±5.42\% and ±4.04\% respectively. To
analyze the variation, and association between each device, statistical calculation analysis of variance (ANOVA) was used. Based on one way ANOVA for different detectors, using Fisher method, the p value was 0.30. It means that there was no association between each detector during the measurement of CT dose. The difference between the average dose from OSLD and the ion chamber could be due to the variation of batch sensitivity of OSLD and the statistical error propagated from ion chamber readings due to its automatically average dose calculation[12,13].

5. Conclusions

During in vivo CT dosimetry, the OSLDs response showed good similarity to the dose profile using ionization chamber. Within the active scan field, the internal dose was higher than the surface dose. The variation of OSLDs response during depth dose profile measurement was similar to theoretical dose profile from ionization chamber, demonstrating the potentiality of using OSLDs as an alternative detector in CT dosimetry, particularly for the assessment of CT doses in the internal organs.

References


دراسة تمهيدية لحساب الجرعة الإشعاعية داخل جسم الإنسان الصادرة من جهاز التصوير المقطعي باستخدام مقياس الجرعة الإشعاعية بتقنية الحث الضوئي الوضيع

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المستخلص. تم استخدام مقياس الجرعة الإشعاعية بتقنية الحث الضوئي الوضيع لحساب توزيع الجرعة الإشعاعية لعدة نقاط على طول الجسم من سطح الجسم إلى العمق. وتم تصميم هيكل محاكي لجسم الإنسان من مادة الأكريليك على شكل أسطوانة بطول 62 سم وقطر 20 سم، وتم استخدامه في القياسات التجريبية بواسطة التصوير المقطعي. تم قياس الجرعة الإشعاعية على طول السطح ومركز الهيكل المحاكي كعامل في الحقل الإشعاعي. تم قياس الجرعة الإشعاعية الأولية المقاسة بواسطة غرفة إشعاعية مرسمية خاصة بالتصوير المقطعي بطول 100 ملم ومقارنتها بالجرعة الإشعاعية النظرية. كانت استجابة الجرعة الإشعاعية المقاسة بتقنية الحث الضوئي الوضيع مماثلة للجرعة الإشعاعية المقاسة بواسطة الغرفة الإشعاعية الخاصة للتصوير الإشعاعي. في هذه الدراسة، كانت الجرعة الإشعاعية الداخلية في مركز الهيكل المحاكي أعلى من الجرعة الإشعاعية السطحية بمقدار 18.05%. أيضاً، كانت الجرعة الإشعاعية الداخلية على طول الهيكل المحاكي أعلى من الجرعة الإشعاعية السطحية بمقدار 11.03%. أكدت نتائج هذه الدراسة على أهمية استخدام مقياس الجرعة الإشعاعية بتقنية الحث
الضوئي الوميضي كبديل لمقاس الجرعة الإشعاعية بتقنية الحث الحراري الوميضي.

كلمات مفتاحية: التصوير المقطعي، التوزيع الإشعاعي، حساب الجرعة الإشعاعية داخل جسم الإنسان من جهاز التصوير المقطعي، مقياس الجرعة الإشعاعية بتقنية الحث الضوئي الوميضي.