

Original Article

Evaluation of clinical use of OneDose™ metal oxide semiconductor field-effect transistor detectors compared to thermoluminescent dosimeters to measure skin dose for adult patients with acute lymphoblastic leukemia

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Abstract

Background: Total body irradiation is a protocol used to treat acute lymphoblastic leukemia in patients prior to their bone marrow transplant. It involves the treatment of the whole body using a large radiation field with extended source-skin distance. Therefore, it is important to measure and monitor the skin dose during the treatment. Thermoluminescent dosimeters (TLDs) and the OneDose™ metal oxide semiconductor field effect transistor (MOSFET) detectors are used during treatment delivery to measure the radiation dose and compare it with the target prescribed dose. **Aims:** The primary goal of this study was to measure the variation of skin dose using OneDose MOSFET detectors and TLD detectors, and compare the results with the target prescribed dose. The secondary aim was to evaluate the simplicity of use and determine if one system was superior to the other in clinical use. **Material and Methods:** The measurements involved twelve adult patients diagnosed with acute lymphoblastic leukemia. TLD and OneDose MOSFET dosimetry were performed at ten different anatomical sites of each patient. **Results:** The results showed that there was a variation between skin dose measured with OneDose MOSFET detectors and TLD in all patients. However, the variation was not significant. Furthermore, the results showed for every anatomical site there was no significant difference between the prescribed dose and the dose measured by either TLD or OneDose MOSFET detectors. **Conclusion:** There were no significant differences between the OneDose MOSFET and TLDs in comparison to the target prescribed dose. However, OneDose MOSFET detectors give a direct read-out immediately after the treatment, and their simplicity of use to compare with TLD detectors may make them preferred for clinical use.

Keywords: Skin Dose, Total Body Irradiation, MOSFET, TLD, ALL.

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Introduction

Acute lymphoblastic leukemia (ALL) in adults accounts for 15% of acute leukemia [1]. Total body irradiation (TBI) for adult patients with ALL is a vital technique used prior to bone marrow transplant [2]. A total body irradiation regime is used in the treatment of ALL to destroy malignant cells and to suppress the immune system to allow for bone marrow transplant by preventing rejection

of the donor bone marrow [2]. Since the treatment is delivered at an extended source-to-skin distance (SSD) of 400 cm, the treatment planning system (TPS) cannot perform the calculation for the target prescribed dose. In this case the dose has to be calculated by a point-dose determination at the dose prescription point which is typically at the mid-plane of the patient. It is important to monitor the skin dose to ensure the precision of the dose

delivered to patients. The aim of the present work was to compare the target prescribed dose to the dose that measured by two dosimetry systems: the newer OneDose™ metal oxide semiconductor field effect transistor (MOSFET) detectors and traditional dosimetry thermoluminescent dosimeters (TLDs).

TLDs have been widely used for radiation monitoring, for monitoring staff dealing with radiation, and to monitor patient exposure to radiation during radiation therapy treatments [2]. The widespread use of TLDs may be due to these advantages: their small size; that they can operate under any conditions; and that they do not rely on any external power supply [3]. When a TLD is exposed to radiation, it absorbs radiation energy and then emits luminescence light, and the light emitted is proportional to the X-ray energy absorbed [3, 4].

Recently, the OneDose MOSFET detector verification system has been marketed. These are a solid-state detector used in radiation therapy treatment applications to measure the entrance and exit dose during the treatment [4]. MOSFET detectors are characterized by their energy response [4, 5]; however, the variation in the energy dependence is beyond the scope of the present study.

The OneDose system is small, with a measured area of 3 mm in diameter and 25 mm in length. The detectors are factory calibrated with a Co-60 beam with full build-up conditions. The detectors are wireless, which make them easier to use. The accuracy of the detectors as specified by the manufacturer is ± 1 cGy for a dose that is less than 20 cGy and $\pm 5\%$ for a dose of 20 cGy to 500 cGy (Sicel Technologies Inc). They are normalized to a 6-MV photon beam [5]. Each detector is valid for one use only [6]. OneDose MOSFET detectors are considered a safe, non-invasive dose verification system that could be used with all types of radiation therapy treatments. It has been suggested that MOSFET has a high input impedance, is voltage controlled, and produces real-time dose measurements [5]. Its superiority over TLD is in producing the result of the exposure immediately, whereas the TLD needs hours to process and obtain the reading [7].

The primary aim of this study was to compare the two dosimetry systems. The secondary aim of the study was to evaluate the simplicity of use of the detectors and determine if one system was superior to the other in clinical use for monitoring and measuring the skin doses during TBI treatment for ALL.

Materials and Methods

Detectors

The thermoluminescent detectors used were the LiF chip type (TLD-100, $3 \times 3 \times 0.9$ mm) (Harshaw, Bicon-NE Solon, OH, US). The metal oxide semiconductor field-effect transistors were OneDose MOSFET detectors (Sicel Technologies, Inc, Morrisville, NC; distributed by MedTec, Orange City, USA. Fig. 1).



Fig. 1 The OneDose system with the detector (Left), and close-up of the detector (Right).

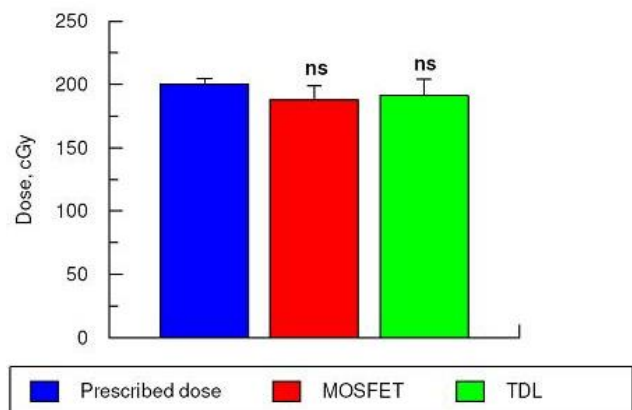


Fig. 2 Means \pm SD, n=12 patients of the prescribed dose and measured doses using One Dose MOSFET (n=6 patients) and TLDs (n=6 patients). Ns: Not significantly different as compared the target prescribed dose with either One-Dose MOSFET or TLDs (ANOVA analysis, Turkey's test for multiple companion tests).

Patient selection

Twelve adult patients, all diagnosed with acute lymphoblastic leukemia (ALL) participated in this study. All patients signed an informed consent for the study prior to treatment. The patients were selected on the basis of having the same prescribed dose and a similar pathology report to our other ALL patients. Six patients were measured with each detector.

Prior to their bone marrow transplantation, the patients were treated with TBI. The total target prescribed dose was 1200 cGy delivered in six fractions as recommended by the AAPM Task Group 29 [8]. Through greater understanding of bone marrow recovery, the total dose of 1200 cGy has been determined to be effective and less toxic. Less toxicity occurs with this dose even when large amounts of bone marrow are exposed.

Treatment protocol

Monitoring the skin dose during TBI treatment is considered an essential tool for quality assurance in radiation therapy. For TBI, it is essential to monitor the dose that is actually delivered and compare it with the target prescribed dose. The TBI technique used in the

Department of Radiation Oncology, King Faisal Specialist Hospital and Research Center, Riyadh, Saudi Arabia takes into account the recommendations of the AAPM Task Group 29 [8] by delivering two opposed bilateral fields, right lateral and left lateral, using extended source-to-skin distance (SSD). This allows sufficient field size to cover the whole body during the treatment. The patient is supine and the radiation beam is directed horizontally across the treatment room directly on the patient. The treatment is delivered at a source-to-surface distance (SSD) of 400 cm, with a radiation field size of 40 x 40 cm² at one meter and the collimator rotated through 45° using 18 MV X-ray beams generated by a Varian Clinac-2300 EX linear accelerator (Palo Alto, California, USA). The dose rate was 300 Mu/min. A Perspex™ beam spoiler with a thickness of 1.5 cm was used in front of the patient to create a uniform dose [8]. The dose was described to the midline depth of the patient. Rice bags and tissue-equivalent boluses were used to compensate for missing tissues and to create a uniform dose around the patient's body [8, 9]. The number of fractional MUs were calculated using the target prescribed dose which was in this study 200 cGy divided by the output factor of the linear accelerator (OF) in cGy per MU at a distance of 400 cm (SSD) at a depth of 10 cm in water, percentage depth dose (PDD) for the patient's separation and the tray factor for the linear accelerator.

TLD and MOSFET calibration

TLDs were calibrated with 6 MV photon beams using a 600 C machine (Palo Alto, CA, USA) with a field size of 10 cm x 10 cm² and SSD of 100 cm. The TLDs were exposed to 100 cGy, and the reading output from the chamber was recorded. The chamber used was a farmer chamber (Nuclear Enterprises 0.6 cc, model 2571, serial number 1504, Radiation Products Design, Inc, 6 MN, and USA). Ionization chamber cross calibration was done using method based on IAEA-398 [9] [9], in terms of absorbed dose to water (Dw), beam quality (Qo) and correction factor for quality beam (kQ0) in reference point of an ion chamber [8,10]. The same set of TLD, in which each set contains three TLD chips, was used with six patients out of the total number of patients, and the readings were recorded. The selected point's doses were verified by placing a set of three TLD at the entrance and exit side of body. The ten total points that were selected were the neck (right and left), lungs (right and left), midline point of the patient which is between the legs, abdominal area (right and left), umbilicus level, and right knee; the last point was the ionization chamber point which was used at the groin for absolute dose verification, placed between the thighs in the mid-perineal region to monitor the dose during treatment. The output reading from the chamber was divided by the reading when it is used with a patient and multiplied by 200cGy (which is the fractional dose for each patient) to give us the calibrations factor for the TLD. The TLDs were read after 24 hours and the average of the readings was calculated using a commercial TLD reader (TLD system 4000, Harshow, USA). OneDose MOSFET detectors (Fig 1)

were first zeroed by the handheld reader immediately before irradiation, and then were placed at the ten selected anatomical points for every patient. Following the treatment the detectors were collected from the patients and then two minutes later, each detector was placed in the handheld reader, and the result of measured doses was recorded. Measured doses from the MOSFET and TLD were then compared with the target prescribed dose for each point.

Statistical analysis

Data from each sample were run in duplicate and expressed as means ± SD (cGy, n = 12 patients). The results were compared using one-way ANOVA analysis followed by Turkey's test for multiple comparisons. Means were considered significantly if $P < 0.05$. Statistical analysis was performed using a GraphPad Prism™ package for personal computers (GraphPad Software, Inc., San Diego, USA) and figures were drawn using a GraFit™ package for personal computers (Erithacus Software Limited, Surrey, UK).

Results

The 12 patients in this study were between 18-34 years old with a mean age of 22 years. Eight men and four women participated in the study. Patient characteristics are summarized in Table 1.

Table 1 Patient's characteristics

Patient	Age (y)	Gender	Measurement modalities
1	19	Male	MOSFET
2	31	Male	MOSFET
3	18	Female	MOSFET
4	25	Female	MOSFET
5	19	Female	MOSFET
6	18	Male	MOSFET
7	34	Female	TLD
8	23	Male	TLD
9	18	Male	TLD
10	19	Male	TLD
11	21	Male	TLD
12	24	Male	TLD

Table 2 . Measured skin doses means and ± SD, (n = 12 patients) for selected points in adult patients with MOSFET (n = 6) and TLD (n = 6) during TBI treatment with Linac 2300 EX. The skin dose was measured for a single fraction from parallel opposed field for each patient.

Selected Point	Prescribed Dose	MOSFET	TLD
Right Neck	200.02 ± 1.22	198.02 ± 1.82 ^{ns}	197.13 ± 10.71 ⁿ
Left Neck	200.01 ± 0.55	198.10 ± 3.60 ^{ns}	200.12 ± 6.70 ^{ns}
Right Lung	200.02 ± 2.20	198.12 ± 3.95 ^{ns}	195.11 ± 2.26 ^{ns}
Left Lung	200.01 ± 1.42	196.11 ± 2.50 ^{ns}	194.02 ± 6.23 ^{ns}
Chamber	200.02 ± 2.12	196.01 ± 2.21 ^{ns}	193.21 ± 3.23 ^{ns}
Right Abdomen	200.08 ± 1.11	196.10 ± 3.36 ^{ns}	190.13 ± 2.94 ^{ns}
Left Abdomen	199.98 ± 2.62	193.12 ± 3.41 ^{ns}	191.12 ± 4.17 ^{ns}
Umbilicus	200.02 ± 2.02	195.21 ± 2.55 ^{ns}	192.20 ± 2.66 ^{ns}
Right Knee	200.04 ± 0.12	196.11 ± 2.35 ^{ns}	197.10 ± 5.96 ^{ns}
Right Eye	200.10 ± 0.10	194.12 ± 2.37 ^{ns}	187.02 ± 4.13 ^{ns}

Table 2 shows the means ± SD of the measured skin doses

for the selected ten anatomical sites in each patient measured either by OneDose MOSFET or TLDs. The results indicated that the dosimeter measurements using the OneDose MOSFET or TLDs gave precise measurements compared to the prescribed dose. There was agreement between the detectors and the target prescribed doses especially in the flat surfaces of the body.

Figure 2 shows the means and \pm SD of the prescribed dose and the doses measured by OneDose MOSFET detectors and TLDs for all ten sites measured. There was no significant difference between the measured dose by using either MOSFET or TLD in comparison with and the target prescribed dose.

Discussion

For TBI it is vital to measure and monitor the skin dose using patient's dosimetry such as MOSFETs or TLD. The present study was designed to measure variation between skin dose measurements using OneDose MOSFET detectors and TLD in TBI. Precise dose measurement is important because clinical decisions are currently made with respect to skin dose. It is necessary to monitor the skin reaction while ensuring accurate dose delivery to patients [8, 11].

Our data showed no significant difference between the measured doses using either MOSFET or TLD in comparison with the target prescribed dose. There were small variations in the results for the OneDose MOSFET and TLD. These variations could be a result of additional buildup from the rice bag and/or the bolus placed on the patient's anatomical sites, since the use of a 1.5-cm acrylic spoiler plate, the bolus, and the large field size should have been in a relatively flat dose region close to depth of the maximum dose [12, 13]. Furthermore, although the OneDose MOSFET has an inherent buildup of 0.88 mm, we expected that the dose absorbed by the MOSFET detectors and TLD should have been nearly the same at most of the selected points. Rice bags have an approximate thickness of 2 cm; we put detectors beyond the depth of the maximum dose, where the additional inherent buildup of the MOSFET should have led to a negligible decrease in the percent difference of 3% compared to the measurements close to depth of the maximum dose. The quality control of the TLD reading and calibration procedures for the OneDose detectors may have added to differences between the readings. On other hand, the discrepancies could result from errors made in the TLD determination or evaluation, such as placement errors of the TLD chips, insufficient shielding, or inadequate patient immobilization. However, the difference between the neck and umbilicus is larger than expected; therefore, we suspected the difference to be the result of statistical uncertainty of both the TLDs and the MOSFETs. Our results are consistent with previous studies that found a small variation between the measured doses using MOSFET as compared to the ones measured by TLD [12-14].

Conclusion

No significant difference between the OneDose MOSFET detectors and TLDs compared to the target prescribed dose during the treatment of TBI for ALL were found in this study. However, the OneDose MOSFET detectors are easier to use than the TLDs with wireless set-up and factory calibration. The OneDose MOSFET dosimeters, due to reliable and fast real time monitoring, were preferred to measurements using TLDs. MOSFET is therefore, a suitable option when measuring skin dose for total body irradiation treatment.

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