Dosimetric evaluation using the diode measurements for total skin electron therapy technique

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Received: 12 September 2013 / Revised: 29 April 2014 / Accepted: 25 May 2014
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Abstract  Objective: The purpose of this study was to present the dosimetric study and evaluation the dose delivered to the skin tumor by using diode detector with total skin electron therapy (TSET). Methods: The total skin electron irradiation (TSEI) technique was used to treat ten patients with histological confirmed mycosis fungoides according to the Stanford staging system at the Radiotherapy Department, National Cancer Institute, Cairo University, Egypt. High dose rate electron beams with low electron energy 5 MeV from a Siemens linear accelerator were used for treatment. Diodes were calibrated at TSET distance 300 cm and field size (35 x 35) cm2. Results: The result of diodes measurements showed the dose to flat surface of the body was within ±10 % from the prescribed dose. Special areas of the body such as the perineum & eyelid showed large deviation up to 30% variation from the prescription dose. Conclusion: The diode results of this study will be used as a quality assurance check for all new patients treated with TSET and to compare it to the prescribed dose delivered to the patients. It is recommends to evaluate the diodes measurements for all patients throughout the full treatment cycle and to identify individually the boost dose areas.

Key words  total skin electron therapy (TSET); in vivo dosimetry; diode detector; mycosis fungoides (MF)

Total skin electron therapy (TSET) is a special radiotherapy technique which aims to deliver a uniform dose to the entire skin of a patient while sparing all other organs from a significant amount of radiation. TSET has historically been used for the treatment of cutaneous T cell lymphoma (mycosis fungoides, MF), but has also been extended for the treatment of other cutaneous diseases such as Kaposi’s sarcoma and scleromyxoedema [1–3]. Due to the ability to achieve therapeutic dose levels to the skin with a rapid fall-off in dose beyond a shallow depth to avoid bone marrow toxicity. Occurrence of MF increases with age and it occurs more frequently in men than in women, it is approximately twice as common in men as in women and it is more common in blacks than in Caucasians, where blacks have twice the incidence of Whites, regardless of sex and age [4, 5]. MF presents in early stages with patches and plaques that affect any area of the skin which then evolve into palpable plaques [6]. Later stages are characterized by the onset of tumors and erythroderma eventually with blood, lymph node and/or systemic involvement which then lead to infection as the skin turns into ulcerating and necrotic tumors [7, 8].
The treatment distance was an extended source to skin distance (SSD) of 300 cm with field-size (25 × 25) cm² electron cone which was replaced by a high dose rate insert to collimator opened to the largest field size (35 × 35) cm² insert by the physics mode on the console computer of the linear accelerator. Lucite panel (scatter plate) was used in front of the patient about 20 cm apart to degrade the electron beam energy as shown in Fig. 1a. A custom-built rotating platform with a circular standing area 60 cm in diameter was built in the departmental machine shop for this technique. The top surface of the rotating platform was 30 cm above floor level, and for shorter patients shown in Fig. 1c and 1d.

The collimator angle was 45° where the gantry angles were one set 20 degrees above horizontal, and the other angled 20 degrees below horizontal, so that the dose distribution was uniform vertically from head to toe and that beam points above patient’s head and below patient’s feet, respectively, in order to minimize contaminant X-ray dose. Scatter plate degrader X-ray was used in front of the patient. We have used a normal dose rate of 900 Mu/min on Siemens (primus) linear accelerator. Shields were used for eyes, nails, and toes as prescribed in the Stanford technique.

**TSET technique**

TSET is the treatment method based on Stanford technique. It is based on delivering twelve fields technique where the patients were irradiated from six directions on the first day of the treatment, anterior and two posterior oblique fields were applied, while on the second day, posterior and two anterior oblique fields were applied to cover the whole length of the patient as shown in Fig. 1b. The total prescribed dose was 3500 cGy delivered in 20 fractions over a period of 5 weeks. The patient has been received 175 cGy per fraction were given along 4 days per week.

The whole treatment session may last 20 to 30 minutes; including time to set up of the patient in each position, and the cumulative diode reading from multiple fields was used during monitoring.

**Diode measurements**

Sun nuclear electron diodes were used to verify the dose prescribed to the dose measured during the treatment. The diodes were calibrated at the same condition of the total skin electron irradiation (TSEI) treatment. A simple QA check of output constancy could be done before each treatment by using parallel-plate ion chamber which connected with a UNIDOS electrometer at the treatment condition [300 cm SSD, (35 × 35) cm² field size with gantry 270°] at dmax depth of energy 5 MeV on the horizontal central axis.

**Diode calibration**

At the same phantom the diodes were fasten to the entrance surface of slap phantom at the center of the field as in Fig. 2. Diodes were connected with multiple channel electrometers with special requirements according to the
Both diodes and ion chamber have been exposed to the same monitor unit (Mu) from the linear accelerator. The measurements of calibration factor for each diode $F_{cal}$ was calculated according to the equation No. (1).

$$F_{cal} = M \left( \frac{D}{Mu} / R \right)$$

Where $D/Mu$ was the dose rate measured with the ionization chamber at $d_{max}$ of energy according to TRS No. 398, $R$ was the reading of diode and $M$ was the monitor unit exposure by the linear accelerator. After diodes were calibrated, the diodes have been put on the skin to obtain the measured dose calculated from equation No. (2).

$$\text{Dose} / \text{Fr} = R \times F_{cal}$$

Where Dose/Fr were the measured dose/fraction, $R$ was the diode signal and $F_{cal}$ was the calibration factor for diode.

### Results and discussion

#### Calibration factor for diodes

Diodes were placed on each of four locations around the surface of the phantom and uniformity irradiated to nominal dose of 175 cGy each diode was irradiated three times and the average of the readings were shown in Table 1. And dose rate by parallel plate was 0.0549 cGy/Mu at SSD 300 cm.

### Patient in-vivo dosimetry

During the first two treatment days (first cycle) of the first TSEI patient, the diodes detectors were performed for different locations on the body surface to verify dose calculations (Fig. 3). The resulting dose measurements were summarized in Tables 2–4.

Table 2 showed the measured skin doses (means ± SD, and range of % prescribed dose, $n = 10$) for selected points in patients with diodes during TSET treatment with linear accelerator. The skin dose was measured for the first three fractions for each patient.

At the umbilicus the average of diode measurements were 104% of the prescribed doses. With a standard deviation of 3% because this value very close to 100% of the prescribed dose so there was high confidence that the treatment was delivered accurately and that the accelerator was applied properly. All locations considered as flat surfaces on the body gave values very close to 100% of the prescribed dose as in Table 2. Tangentially irradiated regions of the body were often found to be more variation in dose than other locations as indicated as in Table 3.

### Tables

**Table 1** The single and calibration factor for each diode under total skin electron treatment conditions for 5 MeV

<table>
<thead>
<tr>
<th>Serial No. of diode</th>
<th>Diode reading</th>
<th>Calibration factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1608133</td>
<td>174.3 nC</td>
<td>0.0315</td>
</tr>
<tr>
<td>1608131</td>
<td>173.4 nC</td>
<td>0.0317</td>
</tr>
<tr>
<td>1608132</td>
<td>173.5 nC</td>
<td>0.0316</td>
</tr>
<tr>
<td>1608130</td>
<td>173.9 nC</td>
<td>0.03157</td>
</tr>
</tbody>
</table>

**Table 2** Variation in dose for flat surfaces of the body

<table>
<thead>
<tr>
<th>Location</th>
<th>Average % of prescription dose</th>
<th>% Difference from prescription</th>
</tr>
</thead>
<tbody>
<tr>
<td>Umbilicus</td>
<td>104</td>
<td>± 3.0%</td>
</tr>
<tr>
<td>Forehead</td>
<td>105</td>
<td>± 4.3%</td>
</tr>
<tr>
<td>Mid chest</td>
<td>103</td>
<td>± 3.0%</td>
</tr>
<tr>
<td>Mid back</td>
<td>105</td>
<td>± 2.4%</td>
</tr>
</tbody>
</table>

**Table 3** Variation in dose for tangential surface of the body

<table>
<thead>
<tr>
<th>Location</th>
<th>Average % of prescription dose</th>
<th>% Difference from prescription</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right lateral hip</td>
<td>103</td>
<td>± 7.0%</td>
</tr>
<tr>
<td>Inner thigh</td>
<td>107</td>
<td>± 14.0%</td>
</tr>
<tr>
<td>Left outer ankle</td>
<td>104</td>
<td>± 8.0%</td>
</tr>
<tr>
<td>Foot</td>
<td>111</td>
<td>± 11.5%</td>
</tr>
</tbody>
</table>

**Table 4** Variation in dose for special areas of the body

<table>
<thead>
<tr>
<th>Location</th>
<th>Average % of prescription dose</th>
<th>% Difference from prescription</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perineum</td>
<td>52</td>
<td>± 20%</td>
</tr>
<tr>
<td>Axilla</td>
<td>60</td>
<td>± 13%</td>
</tr>
<tr>
<td>Under breast women</td>
<td>45</td>
<td>± 15%</td>
</tr>
</tbody>
</table>

**Fig. 3** The anatomical sites for single used diode
Clinical application of K during the treatment of TSET. The detector’s results 5% for all surface point’s measurements of all patients found very well with a standard deviation within ± (2.4–dual-field TSET system. The reproducibility of diode was at the “tangential” body surfaces when commissioning a 25%. Special attention should be paid to the dosimetry in almost all patients receiving a scalp boost greater than to 30% under dose. Permanent loss of scalp hair noticed to the tissue under the breast. Conclusion boost to the tissue and required no boost but women with large breasts. Women with smaller breasts had adequate dose of under breast area showed a few dose. Variation in di diodes reading is directly related to the size of the women’s breasts. Women with smaller breasts had adequate dose to the tissue and required no boost but women with large pendulous breasts had a lower reading and required a boost to the tissue under the breast.

Table 4 showed the reading for special area for the body. Perineum and axilla were showed wide variation in readings, in the perineum most of the readings were only 52% of the prescription dose with standard deviation ± 10%. The variability in the perineum doses, inner thigh also depends on the patient’s inguinal and gluteal fold affecting the degree of self-shielding however, another component of continues due to dosimeter position variability from patient to another. A large variation in dose from 40%–80% of the prescribed dose was documented for the axilla. The dose variation received depends mainly on the patient’s ability to hold his or her arms up during treatment and next on the patient’s axillary skin folds. Areas such as inner thighs and axillae which are obstructed by adjacent body structures require supplementary irradiation. For women who undergo total skin electron treatment the measurement of under breast area showed a few dose. Variation in diodes reading is directly related to the size of the women’s breasts. Women with smaller breasts had adequate dose to the tissue and required no boost but women with large pendulous breasts had a lower reading and required a boost to the tissue under the breast.

Conclusion
Thin areas of the body showed large deviations up to 22% of the prescription dose other special areas, such as the perineum and scalp vertex, that showed variations up to 30% under dose. Permanent loss of scalp hair noticed in almost all patients receiving a scalp boost greater than 25%. Special attention should be paid to the dosimetry at the “tangential” body surfaces when commissioning a dual-field TSET system. The reproducibility of diode was found very well with a standard deviation within ± (2.4–5)% for all surface point’s measurements of all patients during the treatment of TSET. The detector’s results showed a reasonable agreement with prescribed doses with no significant different in surface area. Surface cavities can receive fewer doses than flat or convex surfaces, while higher doses may occur in areas with body protrusions. With the patient setup described in this work, in-vivo dosimetry demonstrated that under dose regions can occur when the skin is shielded by other body parts (inner thigh and leg regions), when the skin is shielded by patient vital sign monitoring equipment (beneath the blood pressure cuff). The inner thigh region under dose may be improved with the use of additional straps to separate the legs; however, a boost to the perineum and axilla region may still be needed at the discretion of the physician. When performing in-vivo dosimetry measurements to verify that the prescribed dose is delivered correctly and confirm dose uniformity, the choice of detector is important to consider.

References