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

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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) cm^2. ***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 scleromyxodema [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 lesion is superficial with depth of 1 cm which means that the treatment has to cover the major portion of the body and has to be performed with electron beams of an average energy of 3–5 MeV [9]. Diodes detectors were used routinely to document dose to various points of the body and to compare it with the electron prescribed dose from this reading we can decide if a particular set of readings fall within normal or if they indicate a problem in either the measurement technique or the dose delivered to a specific location AAPM No. 87 [10].

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Materials and methods

At the Radiation Oncology Department, National Cancer Institute, Cairo University, Egypt, the total skin electron therapy irradiation technique was used to treat ten patients with histological confirmed mycosis fungoides (MF) under the Stanford technique. The high dose rate electron beams with low electron energy 5 MeV from a Siemens (primus) linear accelerator were used. The protocol was used a standing position with Stanford using dual angled fields in order to achieve the greatest dose uniformity along the patient's longitudinal axis (the height of the patient) as suggested by AAPM report 23

[11]. The treatment distance was an ex-tended source to skin distance (SSD) of 300 cm with field-size (25 × 25) cm^2 electron cone which was replaced by a high dose rate insert to collimator opened to the largest field size (35 × 35) cm^2 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 [12]. 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 based on delivering twelve fields technique where the patients were irradiated from six directions on the first day of the treatment, anterior and two posteriors 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 [13]. 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 [10]. 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) cm^2 field size with gantry 270°] at d_{max} depth of energy 5 MeV on the horizontal central axis.

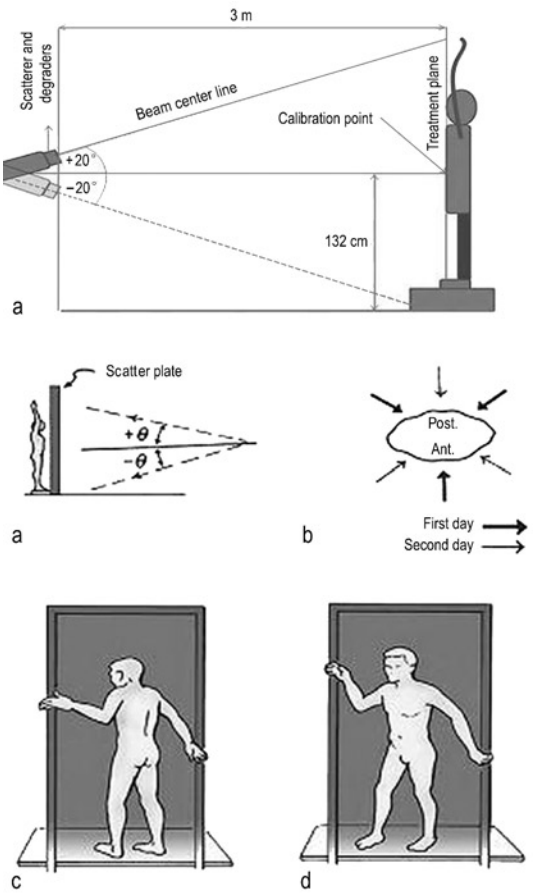

Fig. 1 (a) Patient was treated by two beams at each position, one beam directed 20 degrees below horizontal and the other 20 degrees above horizontal. (b) Exposure film from six fields at midline of the phantom (c, d) patient positions for the six-field Stanford technique

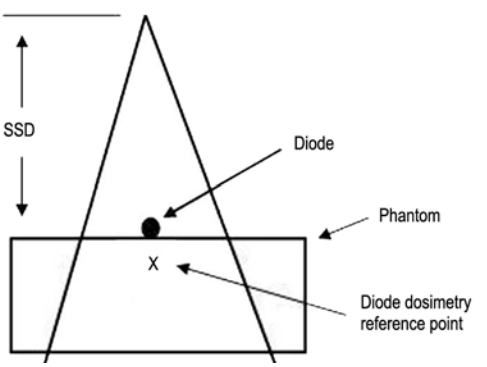

Fig. 2 The setup of diodes calibration with ion chamber

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

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

Serial No. of diode	Diode reading	Calibration factor
1608133	174.3 nC	0.0315
1608131	173.4 nC	0.0317
1608132	173.5 nC	0.0316
1608130	173.9 nC	0.03157

Table 2 Variation in dose for flat surfaces of the body

Location	Average % of prescription dose	% Difference from prescription
Umbilicus	104	± 3.0%
Forehead	105	± 4.3%
Mid chest	103	± 3.0%
Mid back	105	± 2.4%

Table 3 Variation in dose for tangential surface of the body

Location	Average % of prescription dose	% Difference from prescription
Right lateral hip	103	± 7.0%
Inner thigh	107	± 14.0%
Left outer ankle	104	± 8.0%
Foot	111	± 11.5%

Table 4 Variation in dose for special areas of the body

Location	Average % of prescription dose	% Difference from prescription
Perineum	52	± 20%
Axilla	60	± 13%
Under breast women	45	± 15%

report in AAPM No. 87. Both diodes and ion chamber have been exposed to the same monitor unite (Mu) from the linear accelerator. The measurements of calibration factor for each diode F_{cal} was calculated according the equation No. (1).

$$F_{cal} = M\,[(D / Mu) / R] \quad (1)$$

Where D/Mu was the dose rat 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 putted on the skin to obtain the measured dose calculated from equation No. (2).

$$Dose / Fr = R \times F_{Cal} \quad (2)$$

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.

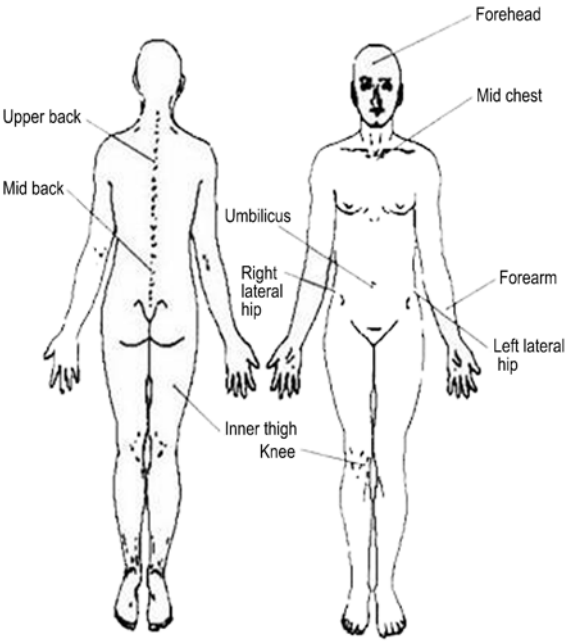

Fig. 3 The anatomical sites for single used diode

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.

Tables 2–4 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.

Measurements for the right lateral hip region were varied from 154 cGy to 201 cGy with standard deviation 10%. The left outer ankle ranged from 161 cGy to 208

cGy this indicates that there was some variation dose in patients set up; in particular, the oblique treatment dose to the inner thigh region was also quite variable ranging from 149 cGy to 208 cGy with high standard variation. This could be due to patient positioning, as well as the physical characteristics of the patients because patients with thin thigh could receive a higher dose to the inner thigh especially if their legs were position too far apart. But the patient with thick thigh some beams could be locked by the beam and, thus received lower dose. The reading of the back of the hand varied from the 148 cGy to 155 cGy with this reading. The distribution of doses for the foot and inner thigh has relatively high standard deviations of the prescribed dose. The different in distribution of dose is due to the reproducibility of organ position during treatment.

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 a 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.

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