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TECHNICAL NOTES

First application of total skin electron beam irradiation in Greece: Setup, measurements and dosimetry

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Abstract Total Skin Electron Beam (TSEB) irradiation is considered as the treatment of choice for cutaneous T-cell lymphoma internationally, for either curative purposes or palliative care. An attempt for the first application of this external radiation therapy technique in Greece took place at the Radiation Therapy Unit of 2nd Department of Radiology of University of Athens at University General Hospital "Attikon". TSEB modality was developed on a linear accelerator VARIAN Clinac 2100C. To create a uniform and sufficiently large field ($\approx$200 cm $\times$ 80 cm) at SSD = 380 cm, two symmetrical 6 MeV electron beams are combined with 17.5° tilts concerning the horizontal direction. An immobilization system was constructed to support patient during treatment and to modulate the composite electron field. Irradiation procedure demands a standing patient that takes, in total, six treatment positions. For the confirmation of treatment suitability and the determination of physical features of the clinical electron field, specific measurements were carried out using a parallel-plate ionization chamber and TLDs at water equivalent plastic and anthropomorphic phantoms. Measurements at the referred conditions showed a homogeneous total field with intensity variation of $\pm$2% in the longitudinal axis and $\pm$4% at horizontal axis. The mean energy of the composite field ($\bar{E}_o$) is 3.4 MeV, the most probable energy ($E_{p,0}$) is 4.4 MeV and the half-value depth in water (R_{50}) is 1.5 g/cm^2. The maximum X-ray background of the TSEB field is 2.1% at head and feet. The above results lead us to conclude that TSEB treatment using "Six-dual-field" technique can be applied in our department safely.

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Introduction

Cutaneous T-Cell lymphoma and its derivative forms (Mycosis Fungoides-MF, Sézary Syndrome-SS) are rare skin malignancies which are usually treated with Total Skin Electron Beam (TSEB) Therapy [1]. This kind of external radiotherapy treatment aims at delivering the prescribed dose to the skin of the patient, either to cure or palliate disease's symptoms [2,3]. Its main prerequisites are a linear accelerator capable of producing large electron fields at an extended SSD and a large treatment room.

Despite of its existence in medical service since the 50's [4], TSEB therapy had never been implemented by any radiotherapeutic clinic or institute in Greece. The lack of this modality can be attributed to the low prevalence of that kind of skin malignancies in the population ($2-3:10^6$ for MF) [5] and the complexity in equipment and application of every existing TSEB technique.

In the Radiation Therapy Unit of University Hospital "Attikon", a total skin electron beam treatment technique was designed, following the guidance of the literature and adapting physical parameters to clinic's features. After several trials and measurements, "six-dual-field" or as commonly mentioned "Stanford" TSEB technique [5] was proven most suitable for the Unit. In this report, technical features of this modality are described along with experimental procedure, measurements, and dosimetric checks.

Material and methods

Equipment

All measurements were carried out at the linear accelerator Varian 2100C (Varian Medical Systems, Inc., Palo Alto, California) of the Radiotherapy Unit of our hospital. For TSEB therapy, High Dose Rate Total Skin electron mode (HDTSe$^-$) was selected from the control console of the accelerator. This mode has an interlock to ensure that the collimator jaws are opened to a pre-configured width, in our case the manufacturer default of 36 cm by 36 cm after the insertion of a specific tray dedicated for this practice. No electron applicator is used. The nominal energy of the produced electron beam is 6 MeV. Dose is delivered at the isocenter with a high rate of 2500 MU/min (although 888 MU/min are displayed in the control screen, HDTSe-MUs are calibrated to provide roughly 3 times more dose).

Preliminary measurements of TSEB technique selection

Total skin electron beam treatment is a quite demanding procedure concerning equipment needed and dosimetric checks due to the incompatible manner of irradiation. A clinical acceptable technique should meet some standards.

Firstly, as far as field characteristics are concerned, the deposition of the maximum dose should be at a few millimeters underneath skin surface (5–15 mm). Field should have dimensions that can cover a patient of maximum dimensions of $\approx$200 cm in height by 80 cm in width, in conjunction with limited inhomogeneity (vertical uniformity of $\pm$8% and horizontal uniformity of $\pm$4% over the central 160 $\times$ 60 cm area of the treatment plane). X-ray background should be kept at a low percentage (1–4%), relative to the total mean dose delivered from the electron beams at d_{max} [5].

Additionally, the positioning of the patient should be repetitive in a manner that ensures immobilization as well as dose uniformity throughout the skin. For example, lying TSEB techniques permit better immobilization and better dose uniformity, as in reclined position, the folds of the body are more exposed to the primary beam. Moreover, the main problem that usually arises during standing TSEB treatment techniques is the patient's fatigue due to long treatment time. Especially for elder patients, a motionless posture for a period of at least 20 min could be intolerable.

For these reasons, after a thorough investigation of the relevant literature and before the final adoption of "six-dual-field" technique from our department, the applicability of "modified Christie hospital" technique [6] and

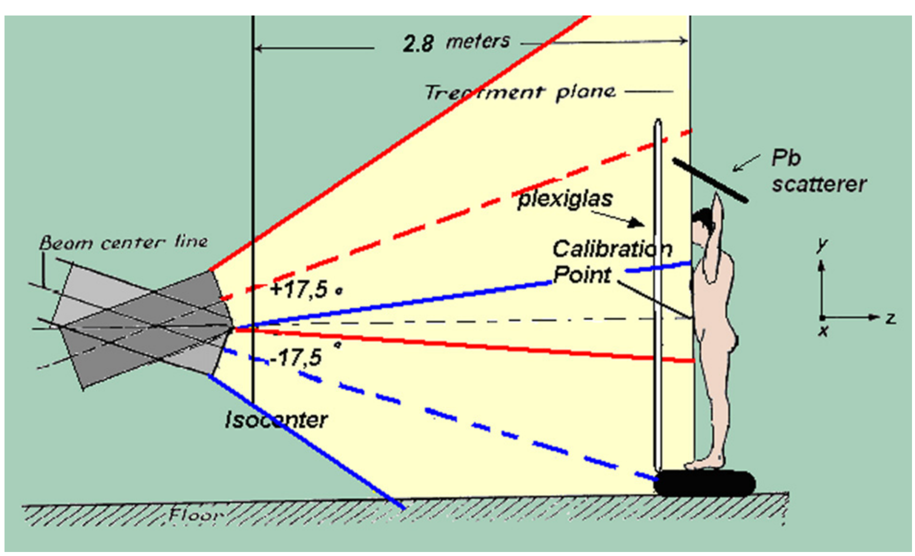

Figure 1 "Six-dual-field" technique at Radiation Therapy Unit of University General Hospital "Attikon".

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Figure 2 TSEB immobilization system.

"lying-on" technique [7], that seemed to fulfill both clinical demands and patient's comfort, was examined experimentally. These two irradiation setups were finally abandoned in our department, just for practical reasons.

"Six-dual-field" technique

Finally, "six-dual-field" technique as described in AAPM Report No 23 [5] was implemented. The nominal source-skin distance was set at 380 cm, taking into account available space in the treatment room. Figure 1 [5] shows the exact irradiation technique implemented in our Unit.

Immobilization system

For the six-dual-field irradiation technique, an immobilization system was designed and constructed at our department (Fig. 2). In spite of the fact that there are some commercial solutions available for patient supporting during total body irradiation procedures, the construction of this system enables freedom in the choice of the technique's characteristics in combination with a reduced cost.

It was designed in order to serve a dual purpose: to reduce electron beam's initial energy and to support the patient during treatment. This system has dimensions of 250 cm $\times$ 111 cm $\times$ 82 cm. On its front side, a large (203 cm $\times$ 111 cm) Plexiglas (PMMA) sheet of 0.5 cm thickness was placed. Its presence reduces energy and broadens the beam. The quality of this PMMA layer was tested before use in comparison to other available acrylic plates in the clinic.

This construction has also two supporting straps for the proper positioning of the patient and a removable shelf for the accomplishment of all needed dosimetric checks. On top of patient's head, there is a lead sheet (50 cm $\times$ 40 cm) of 0.4 cm thickness. The lead-vertex distance and angle can be adjusted for the right dose distribution to the vertex of the scalp [8]. The whole construction is portable and stands on five wheels with brakes, for displacement avoidance during treatment and for patient's stability. In this system, patient can take six postures of treatment: 240°, 0°, 120°, 300°, 180° and 60° (Fig. 3).

Gantry angle

For the proper coverage of patient's total surface, the head of the linac should take two positions of irradiation per patient position (Fig. 1). A Markus® parallel-plate ionization chamber-Type 23343 (PTW, Freiburg, Germany) was fitted in its adaptor plate and was placed on top of 7 acrylic plates (30 cm $\times$ 30 cm $\times$ 1 cm). This setup was put vertical on the measurement self, 30 cm away from the inner surface of the Plexiglas® layer and connected to a PTW UNIDOS® electrometer (PTW, Freiburg, Germany). For each angle from a range of angles (16°–25° from the horizontal direction), a pair of measurements was retrieved. One measurement was taken on the imaginary central axis of the horizontal beam and another at 90 cm distance from this point by moving the shelf upwards for 90 cm.

Percentage depth-dose curves

Electron beam's features at treatment plane were determined by measuring dose variation versus depth in PMMA. To obtain this data, a parallel-plate ionization chamber PTW Markus®, connected to the PTW Unidos® electrometer, was embedded into its adaptor plate and was placed on top of the water equivalent plastic phantom. A 0.4 cm thickness lead pipe shielded chamber's cable, for the avoidance of "cable effect". The chamber was moved gradually deeper in the phantom by interposing acrylic plates of different thickness in front of it. The recorded values of electrical charge were processed and were converted to percent dose per depth in water, according to TRS-398 dosimetry protocol [9].

PDD curves were calculated for the single horizontal beam, single dual-field, and the six-dual-field irradiation technique. For the later, directional dependence of the Marcus chamber was taken into account. When the Markus® ionization chamber is turned at 60° from the vertical position concerning the central axis of beam, an overestimation of dose exists of the order of 5%. This falsification was included for the recuperation of real values of measured electrical charge.

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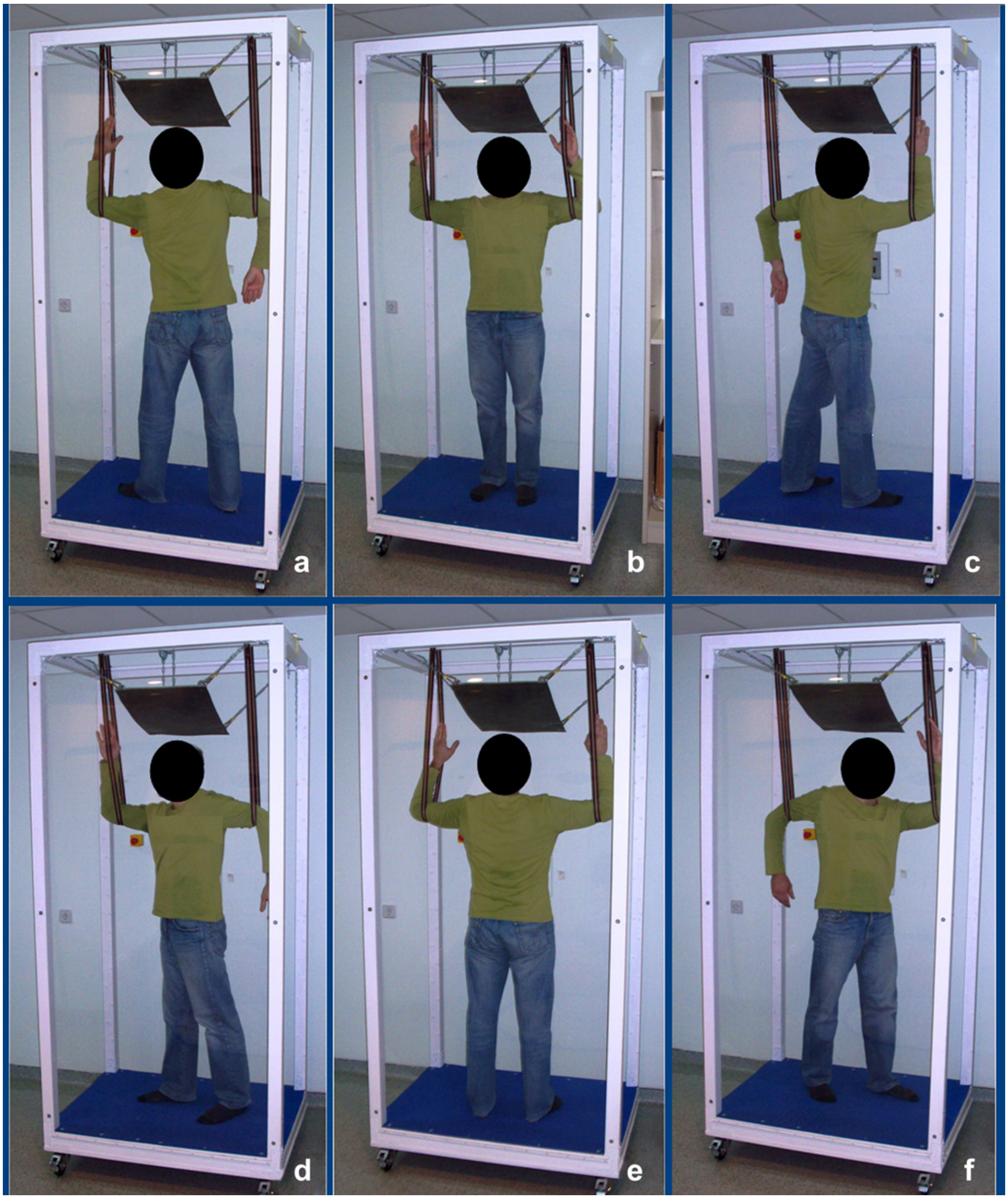

Figure 3 Patient treatment position TSEB at: (a) 240° (b) 0° (c) 120° (d) 300° (e) 180° (f) 60°.

Electron beam energies at treatment plane

The Most Probable energy and The Mean energy were calculated by the following equations [10]. The values of R_p andR_{50} were obtained from the PDD curves:

$$E_{p,0} = 0.22 + 1.98 \cdot R_p + 0.0025 \cdot R_p^2 \quad (1)$$

$$\bar{E}_0 = C \cdot R_{50} \quad (2)$$

where: C = 2.33 MeV/cm

Electron beam homogeneity

All measurements for beam flatness verification were performed with the Markus® chamber and the acrylic phantom. The longitudinal profile of the composite field was measured

Table 1 Measurements for determination of proper gantry angle.

φ (degrees)	Q_o (pC)	Q_{90} (pC)	c_{angle}
16	155.0	255.0	1.65
17	139.5	209.5	1.50
17.5	134.0	260.5	1.94
18	126.5	260.0	2.06
19	110.5	263.0	2.38
20	101.0	263.5	2.61
21	88.0	263.5	2.99

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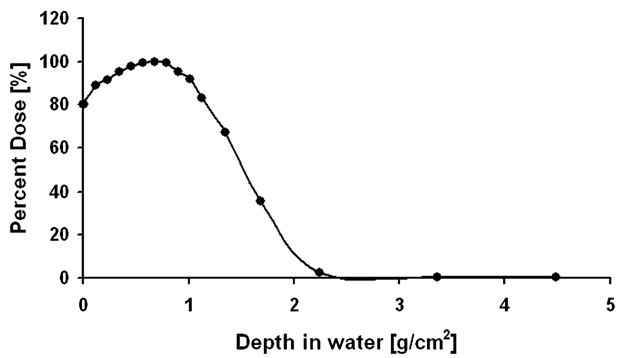

Figure 4 PDD of single field.

by Markus® chamber. The device chamber-phantom was put perpendicular on the shelf of the immobilization system. The phantom was moving in the longitudinal direction along with the shelf, and being irradiated every 10 cm by both angled beams. The horizontal profile was measured utilizing the same setup, by the chamber that was being moved every 10 cm horizontally at the central position of the shelf. Measurements were taken at treatment plane (patient surface) and at $z_{max} = 0.7\ g/cm^2$ in water or at 0.6 cm in the water equivalent plastic phantom [9].

Absorbed dose measurements

Absorbed dose measurements were carried out at reference depth (0.8 cm in the water equivalent plastic phantom) for a single horizontal beam, a dual field, and the complete treatment. The cable of Markus® chamber was shielded to prevent "cable effect". The recorded values were processed according to TRS-398 dosimetry protocol [9].

Monitor unit calculation

For Monitor Unit calculation, the following equation [11,12] was used:

$$M_h = \frac{D_{6df(pr)}}{D_{w,Q(z_{ref})} \cdot C_{(df/hb)} \cdot C_{(6df/df)}} \quad (3)$$

where:

M_h: Monitor Units set for a single horizontal beam or for an angled beam

$D_{6df(pr)}$: Prescribed Dose to z_{ref}

$D_{w,Q(z_{ref})}$: Dose delivered to z_{ref} by a single horizontal beam per Monitor Unit

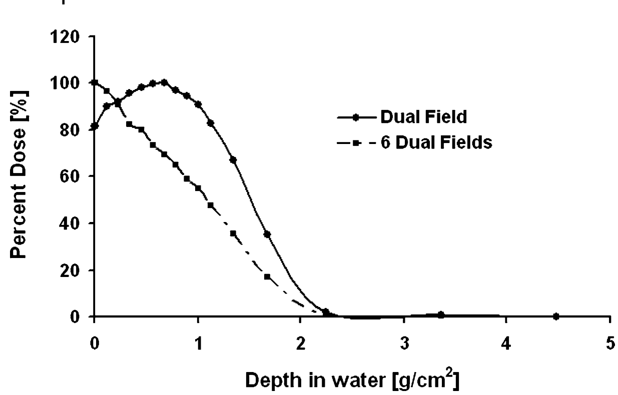

Figure 5 Comparison of single dual and six-dual-fields PDD curves.

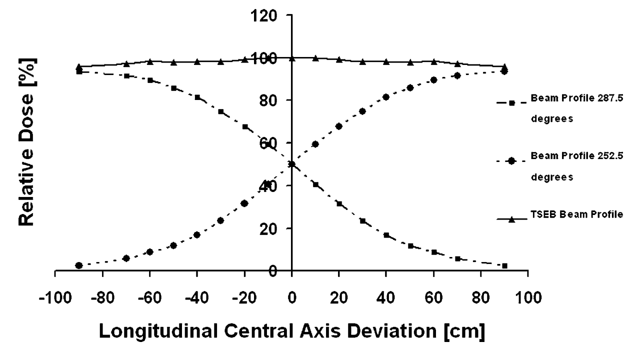

Figure 6 Composite longitudinal TSEB profile at treatment plane.

$C_{(df/hb)}$: Correction factor. Ratio of the dose $D_{df(z_{ref})}$ delivered to z_{ref} by a single dual field to $D_{w,Q(z_{ref})}$

$C_{(6df/df)}$: Correction factor. Ratio of the dose $D_{6df(z_{ref})}$ delivered to z_{ref} from the six-dual-field treatment to$D_{df(z_{ref})}$

To determine all the essential parameters, data from absorbed dose measurement were utilized along with results of measurements on an anthropomorphic phantom (Rando-Alderson phantom). Specifically, for the absorbed dose measurements to patient's skin by six-dual-field treatment, TLD rods (GR-200A, LiF:Mg,Cu,P), calibrated in our department with the use of an LTM Manual TLD reader System (Fimel, Velizy, France) and a Fimel ETT oven (Fimel, Velizy, France), were put on phantom's umbilicus and irradiated with 100 cGy, as in actual treatment procedure. Data were processed according to TRS-398 dosimetry protocol [9].

Dose uniformity on an anthropomorphic phantom

The distribution of the dose on the entire skin was measured by setting the anthropomorphic phantom on the shelf of the immobilization system and pasting on it at isodistance intervals TL dosimeters [13,14]. The irradiation procedure imitated real conditions of treatment (irradiation at 60° steps counter-clockwise until a complete rotation).

Scatterer positioning

The proper positioning of the lead scatterer was determined by putting TLDs at six positions on the vertex of the

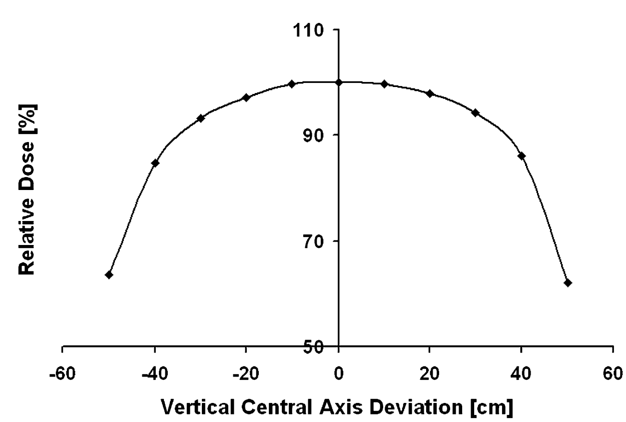

Figure 7 Composite horizontal TSEB profile at treatment plane.

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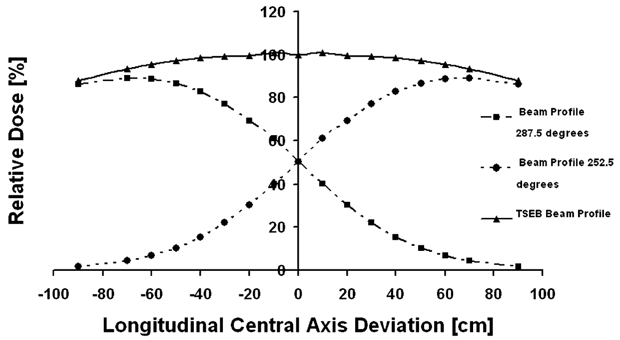

Figure 8 Composite longitudinal TSEB profile at $z_{max} = 0.7$ g/cm^2.

anthropomorphic phantom and by changing scatterer's distance and slope in respect to the vertex. Measurements were carried out without and with the scatterer. Head TLD values were normalized to a reference TLD value, pasted on phantom's umbilicus.

Results

Gantry angle calculation

The fraction of the collected charge at 90 cm vertically off axis to the charge on axis named "angle factor, c_{angle} ". This factor should be approximately 2 in order to have a uniform field at treatment distance. The angle that served this requirement was 17.5° (Table 1). Therefore, during all measurements, gantry took two angles of irradiation ($\theta_1 = 270° + 17.5°$ and $\theta_2 = 270° - 17.5°$) to form a homogeneous electron field.

PDD curves

Fig 4 shows the Percentage Depth-Dose curve for a single horizontal electron beam with field dimensions of 36 cm × 36 cm at source-skin distance of 380 cm. The percentage of the entrance skin dose is 80% and the maximum dose deposition point lies at 0.7 g/cm^2 underneath skin. After this peak, dose percentage falls rapidly to 0.7%, which is attributed to background from X-rays, which are produced from electron interactions with matter. The practical range of the beam is $R_p = 2.1$ g/cm^2 and the half-value depth is $R_{50} = 1.5$ g/cm^2.

Fig 5 displays PDD curves of the dual-field and the six-dual-field TSEB treatment. Although PDD of the dual-field appears to have almost the same physical features with the single horizontal beam curve, six-dual-field curve has a complete different shape. The maximum dose is deposited to the surface due to the contribution of the six fields [5]. After this point dose falls dramatically.

According to Eqs. (1) and (2) and data derived from the above curves, dual-field of total skin electron beam at treatment plane has $E_{p0} = 4.4$ MeV and $\overline{E}_0 = 3.4$ MeV.

X-ray background

The contaminating contribution from X-rays to absorbed dose quantified from the PDD curves and their "bremsstrahlung tail". Therefore, for a single dual field, the X-ray background varies from 0.7% of the maximum dose at the center of the patient on the central axis and 1.1% at head and feet. For the complete treatment, these percentages raise to 1.4–2.2% of the maximum dose respectively.

Electron beam profile

The homogeneity of the field was ±2% at the surface for the longitudinal axis (Fig. 6) and ±4% for the horizontal axis (Fig. 7) while at z_{max} the nominal field showed a longitudinal uniformity of ±4% (Fig. 8) and a horizontal uniformity of ±4% (Fig. 9).

Absorbed dose at z_{ref}

From Table 2 it is evident that the complete treatment delivers 53.4% more dose to z_{ref} than a single dual field,

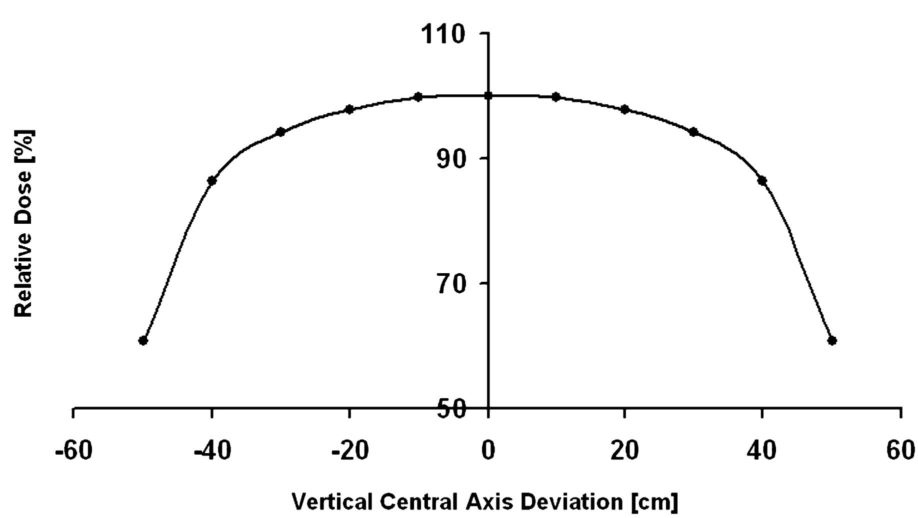

Figure 9 Composite horizontal TSEB profile at $z_{max} = 0.7$ g/cm^2.

Table 2 Values of Dose per MU at z_{ref} and related correction factors

$D_{w,Q(z_{ref})}$ (cGy/MU)	$D_{df(z_{ref})}$ (cGy/MU)	$D_{6df(z_{ref})}$ (cGy/MU)	$C_{(df/hb)}$	$C_{(6df/df)}$
0.179	0.180	0.338	1.008	2.457

while horizontal and dual field deliver almost the same amount of dose.

MU calculation

Using the Eq. (3) and data recorded in Table 2, it was calculated that if 100 cGy ($D_{6df(pr)} = 100$ cGy) are to be delivered to z_{ref}, 224 monitor units per field should be set at accelerator's control console.

Dose distribution

Dose distribution measurements revealed a satisfactory dose delivery to phantom's "skin" (Fig. 10(a) and (b)). Dose percentages varied from 112% to 35% on phantom's surface with a standard deviation of 7%. Underdosed areas are observed at areas of the body that there is "self-shielding" from other anatomical structures.

The position at which the vertex of the scalp receives the total amount of the prescribed dose is 20 cm away from the vertex with the scatterer at a slope of 10° (Table 3). Areas that are peripheral to vertex, such as occipital area, received an excess amount of radiation both from the primary and from the scattered beam. With this scatterer position, it was also feasible to reduce overdose percentages at these anatomical areas (Table 4). Figure 11(a) and (b) display percent dose to the vertex in respect to the prescribed dose without and with the presence of the lead scatterer respectively.

Table 3 Percent dose at the vertex normalized to the dose delivered to phantom's umbilicus.

Scatterer Angle (degrees)	Distance from Vertex (cm)		
	10	15	20
	Percent Dose (%)		
10	113	99	98
20	117	101	92
30	118	103	89
40	120	105	88

Discussion

Composite beam profiles were measured both at treatment plane and at z_{max}. In this way, field suitability could be confirmed according to AAPM report No 23 (acceptable variation of dose distribution: ±8% vertically and ±4% horizontally within the central 160 cm × 60 cm field area) and IAEA's suggestions (dose delivery of ±5% at z_{max} in a phantom on the central ray for at least 80% of the nominal field area). In both cases, the composite field meets these requirements.

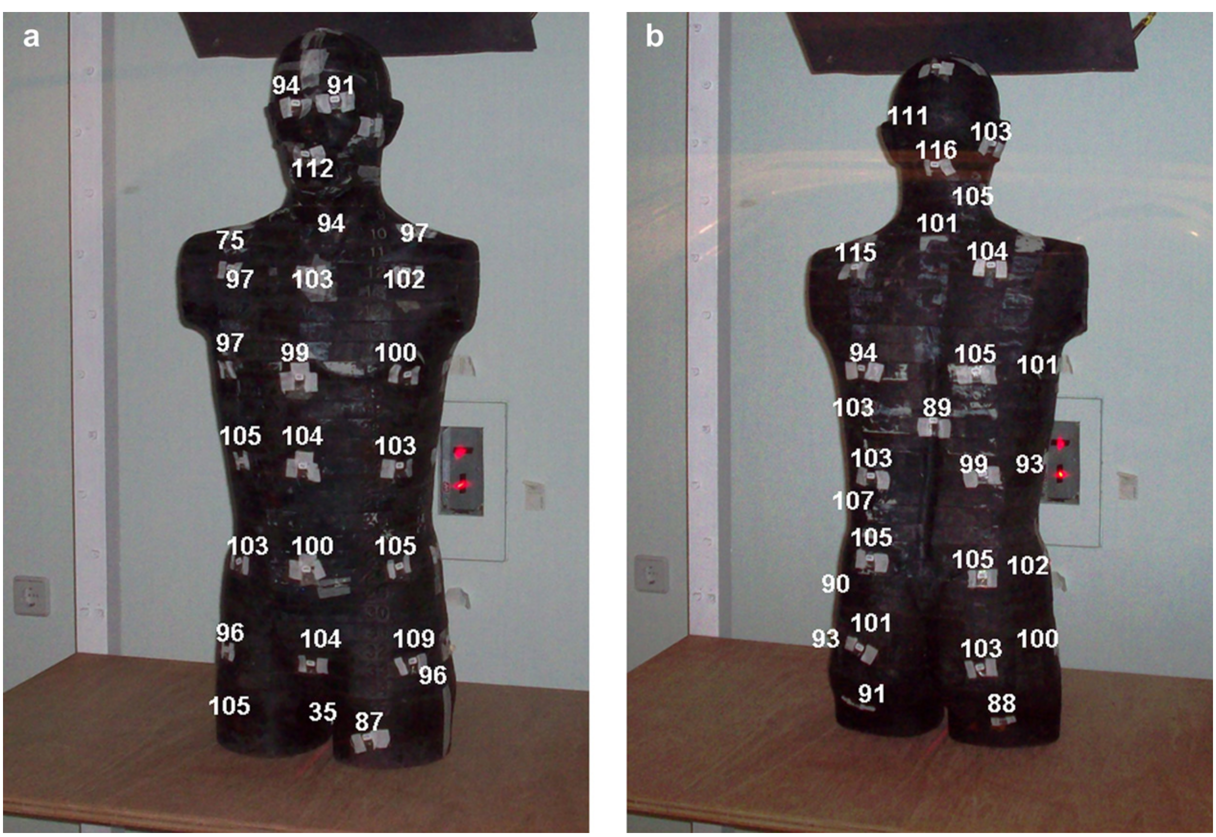

Figure 10 Dose distribution (%) on phantom's surface (a) anterior side (b) posterior side.

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Table 4 Percent dose at the occipital area normalized to the dose delivered to phantom's umbilicus.

Scatterer Angle (degrees)	Distance from Vertex (cm)		
	10	15	20
	Percent Dose (%)		
10	142	130	116
20	141	129	123
30	139	126	127
40	137	125	131

All dosimetric results are in agreement with AAPM report No. 23 [5] and IAEA's guidelines [15]. Patient will be irradiated at a 3.8 m SSD by two angled and degraded electron beams (±17.5°), in order to compose a large and homogeneous electron field with dimensions of 200 cm × 80 cm.

The extended SSD (and thus large volume of interlaying air) in combination with the large Plexiglas® sheet, achieved a satisfactory energy reduction. Consequently, maximum dose is deposited at a shallower depth into tissue. The contamination from photon production managed to be kept as low as 1.4% at central axis from the complete treatment. The clinical beam is quite "clean" from produced X-rays. This comes as a result of the irradiation geometry and the "Bremsstrahlung phenomenon" features. As the two central axes of each beam point outwards patient's body, X-ray contribution in total absorbed dose becomes less significant at central axis even than photon contamination from the single horizontal beam (0.7%) as its main concentration is about the central axis of the beam [5]. For anatomical regions closer to the central axis of the angled beams (head and feet) this percentage is more significant (1.1%). As in total treatment, three dual fields contribute to electron dose and six to X-ray dose at any point [5], these percentages are doubled.

The initial field dissimilarity along treatment plane (±4%) turned out to be dose heterogeneity on phantom's surface of average ± 7% with overdosed areas (maximum dose percentage 118% in respect to reference point at umbilicus) and underdosed areas (minimum dose percentage 35%). This is a result of human's body curvature.

The absence of the lead sheet above the scalp leads to irradiation of the vertex with 65% of the prescribed dose. With the import of the scatterer, dose percentage on this area raised to 98%.

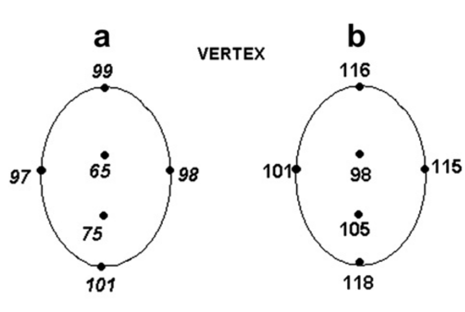

Figure 11 Dose distribution (%) at phantom's vertex (a) without scatterer (b) with scatterer. Normalization point: Umbilicus.

All six irradiation positions of the patient in order to cover evenly his entire surface are displayed in Fig. 3. In a typical treatment schedule, a two-day cycle will be followed for total skin irradiation. The choice of the exact schedule is a decision of each clinic. For example, the first day patient will be irradiated at 0°, 240° and 120° and the second day at 180°, 60° and 300°. The treatment will be over in 20 complete cycles.

Selected high dose rate ensures less treatment time. This rate turns TSEB into a faster and more comfortable procedure. Moreover, high dose rate minimizes heterogeneity in dose distribution to patient's skin caused by movements, as it provides a "snapshot" kind of irradiation [16].

For regions of the body that do not need to be irradiated, the construction of proper shielding was necessary. For the safety of patients' eyes, a pair of goggles was filled with Pb of 1.5 cm thickness. For toenails and fingernails, a lead layer of 0.4 cm thickness was employed. Genital area is going to be protected by a shield made of a 2 cm water bag, which is pasted on top of a 0.4 cm Pb layer. The first layer of this double shield will stop electrons and the lead layer will attenuate produced photons by the water bag.

Underdosed areas will be in vivo mapped with TL dosimetry [14] and additionally irradiated with a supplementary boost-field session [17].

Conclusions

Total skin electron beam therapy is the treatment of choice for cutaneous T-cell lymphoma, especially in early stages of the disease. In our radiotherapy unit, for the first time in Greece, that kind of treatment developed after various dosimetric checks and measurements. "Six-dual-field" or "Stanford" technique, as it is described by AAPM TG 30 [5], was modified to meet our clinic's demands. Using the HDTSe^{-} mode of a Varian Clinac 2100C linear accelerator, two electron beams with angulations of ±17.5°, form a uniform field of 200 cm × 80 cm at treatment plane (SSD = 3.8 m). A large PMMA sheet, attached to an originally designed and constructed immobilization system, modulates the combined beams. High dose rate was preferred to a conventional dose rate to reduce treatment time and patient's discomfort.

Beam quality indexes and dosimetry aspects were defined with precision in order to provide an effective treatment. Every physical parameter was in agreement with suggested values of the international guidelines. In conclusion, total skin electron beam therapy can be implemented with safety in the Radiation Therapy Unit of University's General Hospital "Attikon".

Conflict of interest statement

No conflict of interest, financial or other, exists.

References

[1] Strohl RA. The role of total skin electron beam radiation therapy in the management of mycosis fungoides. Dermatol Nurs 1994;6(3):191—4. 6, 220.

[2] Jones GW, Rosenthal D, Wilson LD. Total skin electron radiation for patients with erythrodermic cutaneous T-cell lymphoma (mycosis fungoides and the Sezary syndrome). Cancer 1999;85(9):1985—95.
[3] Funk A, Hensley F, Krempien R, Neuhof D, Van Kampen M, Treiber M, et al. Palliative total skin electron beam therapy (TSEBT) for advanced cutaneous T-cell lymphoma. Eur J Dermatol 2008;18(3):308—12.
[4] Shouman T, El-Taher Z. Total skin electron therapy: a modified technique for small room linear accelerator. J Egypt Natl Canc Inst 2004;16(4):202—9.
[5] Karzmack CJ, Anderson J, Fessenden P, Svensson G, Buffa A, Khan F, et al. AAPM report No.23, total skin electron therapy: technique and dosimetry. Report of Group 30. Radiation therapy Committee AAPM; 1987.
[6] Anacak Y, Arican Z, Drumea K, Rosenblatt E, Tamir A, Chetver L, et al. Total skin electron irradiation in mycosis fungoides: comparison between a modified Christie Hospital translational technique and the Stanford technique. Leuk Lymphoma 2002;43(11):2093—7.
[7] Wu JM, Leung SW, Wang CJ, Chui CS. Lying-on position of total skin electron therapy. Int J Radiat Oncol Biol Phys 1997;39(2): 521—8.
[8] Peters VG. Use of an electron reflector to improve dose uniformity at the vertex during total skin electron therapy. Int J Radiat Oncol Biol Phys 2000;46(4):1065—9.
[9] Andreo P, Burns DT, Hohlfeld K, Huq MS, Kanai T, Laitano F, et al. *IAEA* TRS-398: absorbed dose determination in external beam radiotherapy: an international code of practice for dosimetry based on standards of absorbed dose to water, vol. 10. I.A.E. Agency-IAEA; 2000.
[10] ICRU Report 71. Prescribing, recording and reporting electron beam therapy. In: Journal of the ICRU, vol. 4. Oxford University Press; 2004.
[11] Cox RS, Heck RJ, Fessenden P, Karzmark CJ, Rust DC. Development of total-skin electron therapy at two energies. Int J Radiat Oncol Biol Phys 1990;18(3):659—69.
[12] Poli MER, Todo AS, Campos LL. Dose measurements in the treatment of mycosis fungoides with total skin irradiation using a 4 MeV electron beam.
[13] Weaver RD, Gerbi BJ, Dusenbery KE. Evaluation of dose variation during total skin electron irradiation using thermoluminescent dosimeters. Int J Radiat Oncol Biol Phys 1995;33(2):475—8.
[14] Antolak JA, Cundiff JH, Ha CS. Utilization of thermoluminescent dosimetry in total skin electron beam radiotherapy of mycosis fungoides. Int J Radiat Oncol Biol Phys 1998;40(1):101—8.
[15] Podgorsak EB. Review of radiaton oncology physics: a handbook for teachers and students. Vienna, Austria: I.A.E. Agency; 2003.
[16] Reynard EP, Evans MD, Devic S, Parker W, Freeman CR, Roberge D, et al. Rotational total skin electron irradiation with a linear accelerator. J Appl Clin Med Phys 2008;9(4): 2793.
[17] Wilson LD, Quiros PA, Kolenik SA, Heald PW, Braverman IM, Edelson RL, et al. Additional courses of total skin electron beam therapy in the treatment of patients with recurrent cutaneous T-cell lymphoma. J Am Acad Dermatol 1996;35(1): 69—73.

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