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Dose distributions and percentage depth dose measurements for a total skin electron therapy

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HIGHLIGHTS

- Planar dose distribution and percentage depth dose measures for a Total Skin Electron Therapy delivery with a clinical linac.
- Total Skin Electron Therapy dosimetry shows a good dose distribution on treatment plane and depth in water-plastic phantom.
- A treatment simulation performed on a humanoid phantom shows an acceptable penetration on the first layers of the skin.
- Our results agree with AAPM report 23, EORTC consensus and other author's publications.

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ABSTRACT

We present the dosimetry experience of setting up the radiotherapy technique for Cutaneous T-cell Lymphoma (Mycosis Fungoide disease) at Radio-Oncology facility of Instituto Nacional de Ciencias Médicas y Nutrición Salvador Zubirán (INCMNSZ). It consists of a total skin irradiation with a high energy electron beam (6 MeV nominal) produced by a clinical linear accelerator using the modified Stanford Technique, being the most widely used variant of the Total Skin Electron Therapy (TSET) technique where the patient is placed in six positions for treating each body surface resulting in an adequate homogeneous dose distribution at the patient's surface. TSET dosimetry requires measurements in nonreference conditions. Because of the complexity of the required measurements for the commissioning process of this technique, different dosimetric systems were employed such as thermoluminescent dosimeters, radiochromic films and an ionization chamber. Dosimetric, geometric and patient positioning details are reported in AAPM report 23. Our commissioning parameters met the requirements of TSET treatments. In a treatment area of 52.5 cm × 160 cm, the dose is uniform within 5% and 3% on vertical and horizontal direction, respectively. Derived from percentage depth dose curves obtained with EBT2 films and ionization chamber it was determined the electron beam energy averaged at the phantom entrance (3.8 MeV), the electron range R_p (2.1 cm) and the depth of maximum dose (0.61 cm) in a plastic water phantom. The X-ray background measured was 1.4%, being suitable for TSET treatments. The isodose curves measured during a simulation of the actual treatment using an anthropomorphic phantom shows that the dose is adequately uniform on the first layers of the skin and the maximum dose depth is about 0.1 cm. These results agree with reference guidelines recommendations and this special technique of radiation therapy could be properly used clinically at INCMNSZ.

1. Introduction

Cutaneous T-cell lymphoma is a subtype of hematopoietic neoplasms that represents 2–3% of all lymphomas (set of neoplastic diseases that develop in the lymphatic system). It is known also as mycosis fungoid/Sézary syndrome and has an incidence rate of 0.54 per 100,000 person-years (Wang and Vose, 2013).

The main goal of Total Skin Electron Therapy (TSET) is to deliver radiation primarily to the superficial layers (epidermis and dermis) of involved skin and to spare deeper tissues and organs of any radiation effects. Technical challenges in setting up a TSET program

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Table 1
Previously published irradiation geometry conditions, beam parameters, dose uniformity and x ray contamination for TSET.

Geometry SSD/Angles	D_{max} [mm]	R_{50} [mm]	E_0 [MeV]	Dose uniformity	X-ray contamination	Reference
441 cm/252.5° and 287.5°				9.8%	<1%	(Andreozzi et al., 2016)
380 cm/270°				5% in 180 cm	2.7%	(Evans et al., 2014)
370 cm/72° and 108°			3.9	4% in 200 cm	1.2%	(Hensley et al., 2014)
380 cm/252.5° and 287.5°	7	15	3.4	4%	1.4–2.2%	(Platoni et al., 2012)
353 cm/251° and 289°				5%	<2%	(Schiapparelli et al., 2010)

arise primarily from the unusual target volume (whole-body skin surface) extending to a depth of about 5 mm. Because of this shallow depth, high energy electrons produced by a clinical linear accelerator are the choice of radiation source. TSET was implemented with a linear accelerator at Stanford University in the 1950s; afterwards several procedures have been modified based on it (Page et al., 1970). It involves the use of multiple angled beams directed toward a standing patient at large source-surface distances. To obtain lower electron energies and a more homogeneous beam a scatterer-degrader is placed in front of the patient who is irradiated by a pair of angled beams (dual-fields) relative to the horizontal line. In order to treat the whole skin, the patient is positioned on a platform and dual fields are delivered for six turntable orientations in steps of 60°.

The prescribed total dose may vary according with stage and patient conditions. TSET is one of the most effective treatments for mycosis fungoid in which the patient is irradiated with the most uniform electron field dose distribution and a low x-ray background standing on a rotational platform at about 3 m of the source (electron beam from a linear accelerator), with six different positions in order to cover the entire body surface with a dual field. The AAPM report 23 (AAPM, 1987) represent the most important guideline for the implementation of this technique. It states that a vertical and a horizontal dose uniformity of ±8% and ±4% over all 160 cm × 60 cm area of the treatment plane are achievable goals for most techniques. The European Organization for Research and Treatment of Cancer (EORTC) (Jones et al., 2002) stipulates that the 80% isodose curve should be at least 4 mm deep to the skin surface along the primary beam axes and the dose at 20 mm should be lower than 20% of the maximum dose.

Table 1 summarizes the irradiation geometry conditions (source surface distance (SSD) and gantry angles), some beam parameters (depth of maximum dose d_{max}, depth at 50% of maximum dose R_{50}, and mean energy at surface E_0), the dose uniformity in the treatment plane and the x ray contamination for TSET published by different authors.

A carefully and accurate dosimetry process is needed previously to the first treatment in order to achieve certain dose constraints and dosimetry parameters based on international guidelines and clinical experience. In this work we present the results of dose distributions for a nominal 6 MeV electron beam obtained during the commissioning process for TSET technique using thermoluminescent dosimeters and radiochromic films calibrated with an ionization chamber. Verification of depth doses in different anatomical regions was performed by delivering one session of the actual treatment to an anthropomorphic phantom.

2. Materials and methods

2.1. Linear accelerator

The Instituto Nacional de Ciencias Médicas y Nutrición Salvador Zubirán (INCMNSZ) is equipped with a TrueBeam linear accelerator model (Varian Medical Systems, Palo alto, CA) which can generate electron beams with a nominal energy of 6 MeV at high dose rate of 2500 MU/min (approximately 2500 cGy/min at isocenter). For this treatment option, called high dose rate total skin electron mode (HSTSe), a special tray is not needed.

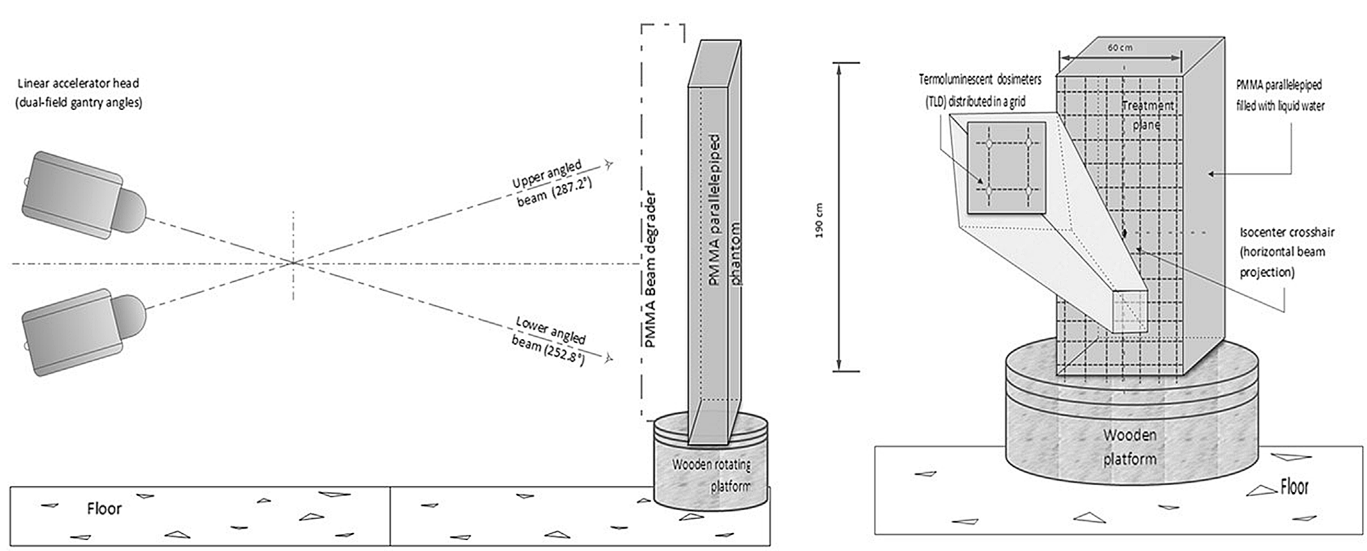

Fig. 1. Sketch of the irradiation geometry of TSET technique implemented at INCMNSZ. The drawing is not to scale. Left: Geometry conditions with two gantry angles forming one dual field on the treatment plane. Right: Beam's eye view of the TLD grid irradiation.