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Dosimetry of Rotational Total Skin Electron Irradiation in the Treatment of Mycosis Fungoides

Juan C. Gaspar-Olvera, Eugenio Torres-García*, Rigoberto Oros-Pantoja, Patricia Vieyra-Reyes

Facultad de Medicina, Universidad Autónoma del Estado de México.Paseo Tollocan s/n esquina Jesús Carranza, Col. Moderna de la Cruz, CP. Toluca, Estado de México, México.

Abstract:

Purpose: *The aim of this study was to perform the dosimetric characterization of the rotational total skin electron irradiation technique using a dual electron field with 4MeV.*

Methods: *An anthropomorphic phantom was placed on a rotating platform exposed to a dualelectron field at 400 cm source-surface distance. The4 MeV dualelectron field was produced by a linac at High Dose Rate mode. A plane-parallel ionization chamber, EBT2 radiochromic film and OSL detectors were used to determine the dosimetric characteristics of this treatment technique and the results were compared with the four dual field technique.*

Results: *Isodose curves of 100, 98, 95-88% covered an area of 130 x 60 cm^2, 140 x 80 cm^2 and 180 x 80 cm^2 respectively. The flatness and symmetry of the horizontal and vertical profiles were according to reported statistics in the literature. Absorbed dose percentage on anthropomorphic phantom surface was between 95 and 105 %. The results show that maximum absorbed dose was deposited on the cylindrical phantom surface. Differently than the standard techniques.*

Conclusions: *Rotational total skin electron irradiation technique with 4 MeV electron energy is according to all requirements established by the EORTC. Thus, it could be implemented in clinical practice.*

Keywords: *Total Skin Electron Therapy, Mycosis Fungoides, High Dose Rate, OSLD.*

1. Introduction

The Total Skin Electron Therapy (TSET) has been investigated and carried out since 1950 [1,2]for Mycosis Fungoides Treatment (MFT), it is a special radio therapy technique as many studies have shown the favourable effects in both curative or palliative modalities, which maintain low radio toxicity. TSET technique was developed to irradiate uniformly the whole skin of the patient with electron beams. Whole skin surface, epidermis and dermis are the target regions [3,4].Thus, maximum absorbed dose must be deposited on the skin surface and decrease quickly after some millimetres of depth. Due to the high complexity of the anatomical surface, TSET technique has been a challenge to the physicists, this has led to development of different irradiation techniques. Basically three techniques are recognized by the IAEA: Translational technique, Stanford and Rotational [5,6].

The Stanford technique uses six dual fields, the patient is placed standing to 3 m from the isocenter and an acrylic plate is laid in front of the patient to scatter electrons. During the treatment, the gantry is situated at ±20°respect to the radiation beam axis. The patient is placed in six static angular positions every 60 degrees (anterior, posterior, right anterior oblique, left anterior oblique, right posterior oblique and left posterior oblique) and irradiated with a dual field in each position.

On the other hand, in the rotational technique the patient is placed standing on a rotating platform to enhance the dose distribution on the skin surface. In both cases, 4 or 6 MV has been used.

The Total Skin Electron Therapy has been improved over the years at Centro Medico Nacional, Siglo XXI (CMN - SXXI) in México City, México, currently a four dual field treatment technique is applied and it is intended to be replace with rotational technique. Studies have shown that the dose uniformity on surface of the patient is better for the rotational technique than six or four dual field technique [6, 7,8,9].

According to recommendations of the European Organization for Research and Treatment of Cancer (EORTC) [10,11], for all TSET technique mentioned above their objectives must be: a) Dose distribution on the skin surface should not exceed ± 10% of prescribed dose. b) Absorbed dose in bone marrow due to total x-ray contamination must be less than 0.7 Gy to avoid hematologic sequelae. c) Optimal source-patient distance should be between 3 and 8 m. d) Administered dose on the skin surface should be between 31 and 36 Gy. e) 80% isodose line should not be less than 4 mm depth. f) 20% isodose line should be less than 20 mm depth from skin surface. g) Give minimum 26 Gy to 4 mm depth from skin surface.h) Areas on skin surface that are receiving a dose below 80% of prescribed dose must be complemented by an additional localized irradiation.

Therefore, the aim of this study was to determine the dosimetric characterization of the rotational total skin electron irradiation technique using a dual electron field with 4MeV to improve dose uniformity in the treatment plane and on anthropomorphic phantom surface.

2. MATERIALS AND METHODS

2.1. Linear Accelerator

A Elekta SL-18linear accelerator with4 MeV energy at High Dose Rate (HDR) mode was used at CMN - SXXI. To implement this new technique, the anthropomorphic phantom was placed on a rotating platform facing a dual electron field to 108 ° and 71°respect to radiation beam axis at 400 cm source-surface distance, as it is shown in Figure 1, in order to cover the patient completely and givea better uniform dose on treatment plane of area equal to 200 cm x 100 cm. To cover this area, the HDR accessory tray was placed on the head gantry to open collimator at its maximum field size of 40 cm x 40 cm at isocenter and after it was rotated to 45 °.

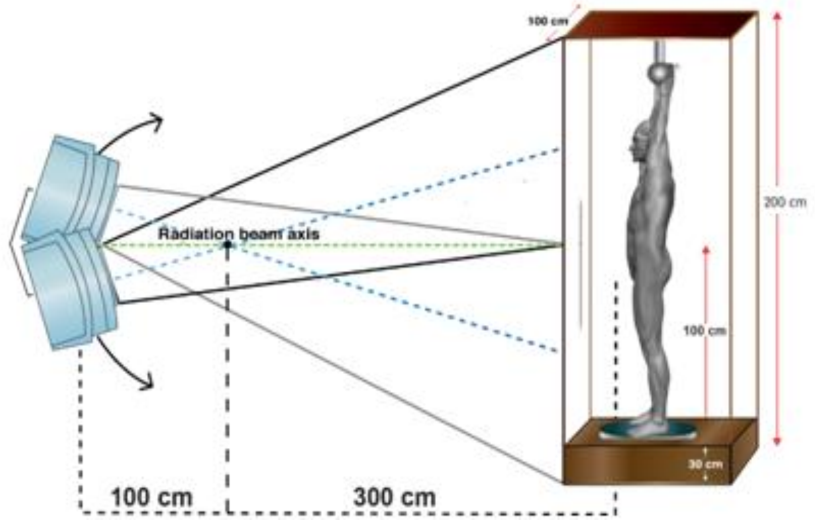

Figure1. *Experimental diagram of the rotational technique*

2.2. Rotating Platform

A MDF wooden rotating platform was constructed with adjustable angular speed control, its speed is independent of the weight over it and its revolutions per minute (rpm) were controlled manually. The floor – rotating disk and rotating disk – isocenter distances were 30 cm and 100 cm respectively, thus the total floor-isocenter distance was 130 cm. The rotating platform has a system of adjustable height to position the isocenter to the median plane of each patient, also handlebars for support and security of the patient was placed. A gamma-alarm was used to startand stop the treatment. Angular speed was determined to ensure the recommended absorbed dose by EORTC and achieve greater security and comfort for the patient.

2.3. High Dose Rate Mode

For Total Skin Electron Therapy using an extended SSD, a high dose rate (HDR) is required to decrease treatment time. In standard mode linear accelerator is calibrated at depth of maximum dose in water to 100 cm SSD for photons or electrons and deliver 1 cGy/MU and 300 MU/min; in HDR mode under the same conditions of calibration for Elekta linear accelerator used in this work, it delivers 10 cGy / MU to depth of maximum dose and 3000 MU/min.

2.4. Optically Stimulated Luminescent Dosimeter (OSLD)

The Optically Stimulated Luminescence (OSL) is an increasingly popular method of dosimetry. OSLD has the same applications as Termoluminescent Dosimeter (TLD), therefore OSLD can be used for *in vivo* dosimetry. In this work, OSLDs were used to measure the absorbed dose in an anthropomorphic phantom since OSLDs have a greater accuracy compared with TLD [12,13]. Linearity was determined for 50, 100, 150, 200, 250 and 300 cGy, the reference conditions were as follows: field size of 10 cm x 10 cm, 100 cm SSD, 1.8 cm Z_{ref}, RW3 solid water phantom and 4 MeVelectrons. Three OSLD detectors were used for each dose and each detector was stimulated and read three times with a micro Star reader to reduce the statistical uncertainty.

2.5. Stationary and Rotational Percent Depth Dose

A stationary dual field was defined in case the phantom is not rotating and a rotational dual field in case the phantom is rotating on its own axis. Depth dose of both fields were determined on the radiation beam axis. The stationary dual field percentage depth dose was measured with a PPC 05 plane-parallel ionization chamber, inserted in a RW3 solid water phantom at 0.6 mm Z_{max}. The rotational dual field percentage depth dose was obtained with radio chromic films EBT2. Four samples of films with dimensions of 4 cm x 6 cm were used; their form was fitted to the phantom's curved surface. As cylindrical phantom was used, the abdomen of an anthropomorphic phantom, whose diameter was 30 cm. EBT2 film was digitized with a flatbed scanner Epson Expression 10000 XL configured in transmission mode with a colour depth of 48 bits RGB (16 bits per colour) and spatial resolution of 300 points per inch (ppp), the calibration curve represented by a second order polynomial was obtained by irradiating a film series of known dose in range of 0 to 5 Gy to determine the absorbed dose.

2.6. Isodose Curves on Treatment Plane

Treatment plane refers to the position of all OSLDs in the treatment field to Z_{max}. 171 OSLDs were placed on acrylic plate and they were distributed in a matrix array where rows were from -90 to 90 cm and columns were from -40 to 40 cm. Values obtained were normalized relative to the calibration point located at coordinate (0,0), this position is 1.30 m above the floor so that the rotating platform has a height adjustment system to put the isocenter medium plane of each patient.

2.7. Absorbed Dose Verification in an Anthropomorphic Phantom

Prescribed absorbed dose is about 200 cGy/session for a total skin electron therapy, so it was measured and verified using an anthropomorphic Alderson Rando phantom. In head, neck, thorax, abdomen and hip on phantom surface and at anterior, posterior, left and right positions 20 OSLDs were placed. Dosimetry on anthropomorphic phantom was made with the following reference terms: 400 cm SSD, collimator rotated 45° and field size of 40 cm x 40 cmat isocenter, 4 MeV energy, HDR applicator, 3 rpm and 1136 MU for each radiation beam at 108 ° and 71 ° in HDR mode.

3. RESULTS AND DISCUSSION

In the present work, angular speed was set to 3 rpm for rotational dosimetry, to achieve the absorbed dose recommended by EORTC, also this speed generates security and comfort for the patient.

3.1. OSLD Calibration Curve

The calibration curve obtained describes a linear behaviour of absorbed dose in the range of 0 to 300 cGy, this dose magnitude is typically the most used in external radiation therapy treatments with electrons. Dose prescribed in total skin electron therapy per session is about 200 cGy,so a linear model was used to calculate the absorbed dose, as follows,

$$Dose\ absorbed\ = a + (b * N.accounts)\ [cGy] \dots\dots\dots. \qquad (1)$$

Where:

$a = 5.13\ \pm 2.18$

$b = 0.00219\ \pm 0.00005$

3.2. Stationary and Rotational Percent Depth Dose

Results in Figure 2 show that the maximum dose for Stationary Percent Depth Dose (SPDD) was at 6 mm depth and half of it was at 10.8 mm depth, also it was found that from 19 mm depth X-ray contamination was 6%. The most probable energy $((E_p)_o)$ at phantom surface were3.22 MeV, this value was calculated with practical range in water,$R_p = 1.50\ cm$. Using $R_{50} = 1.08\ cm$in water, the mean energy of electron beam,$\bar{E}_o$was 2.52 MeV,and lost energy in the gap between the Elekta accelerator output window and phantom was 0.78 MeV.

On the other hand, 100% of the dose was deposited on phantom surface for Rotational Percent Depth Dose (RPDD), where $R_{50} = 8.3\ mm$ andR_p = 13mm, from 17 mm depth X-ray contamination was 3.7 %.

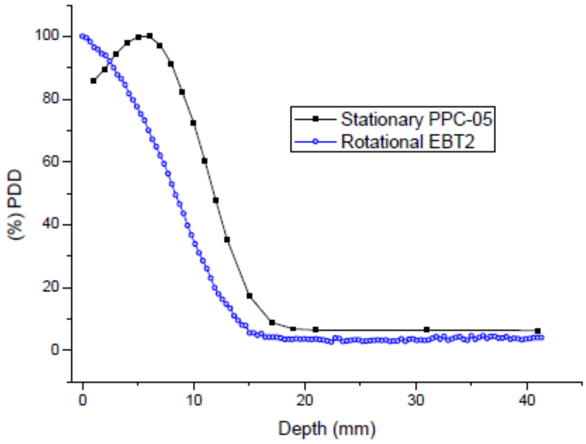

Figure2. *Stationary and Rotational percent depth dose at 400 cm SSD and 4 MeV HDR mode, collimator 45 ° and 40 cm x 40 cm at isocenter, HDR applicator*

The comparison of the dosimetric characteristics of the four dual field techniqueversus the new rotational technique is show on table 1.

Table1. *Dosimetric characteristics of stationary and rotational dual field*

Technique	Stationary (dual field)	Rotational (dual field)
Nominal energy (HDR)	4 MeV	4 MeV
Source-Surface Distance	400 cm	400 cm
Field size (at isocenter)	40 X 40 cm	40 x 40 cm
$z_{max}\ (mm)$	6	0
$R_{50}\ (mm)$	10.8	8.3
$R_p\ (mm)$	15.1	13
$X\ ray\ contamination$ (%)	6	3.7
Dual fields	4	1
Treatment time /session to 2 Gy	30 minutes (2 days)	7.6 minutes

3.3. Isodose Curves and Profiles

Isodose curves shown in figure 3 were obtained from the percentage of dose distribution. They are in an area of 180 cm x 80 cm. 100, 98, 95-88% curves show a good homogeneity on treatment plane, these curves cover an area of 130 cm x 60 cm, 140 cm x 80 cm and 180 cm x 80 cm respectively.

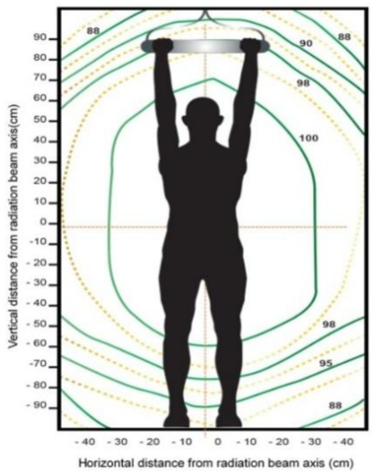

Figure3. *Isodose curves measured with the OSLDs at 400 cm SSD and Z_{max}.*

Horizontal profile shown a good symmetry and flatness of 2.4% and 0.7% respectively as it is shown in figure 4, while vertical profile shows a flatness of 5.4% and symmetry of 0.7%, these values are within the recommendations for total skin electron therapy [5,6].

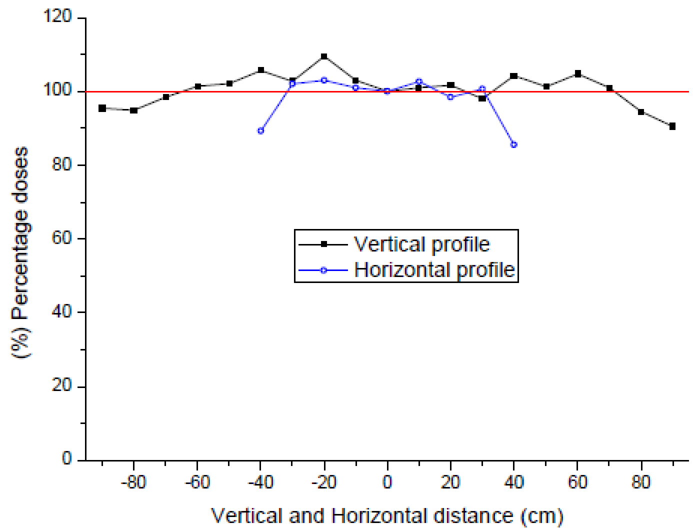

Figure4. *Horizontal and vertical profile measured on radiation beam axis with OSLDs at 400 cm SSD cm and* Z_{max}.

3.4. Absolute Dose Rate

Surface Rotational dose rate is related to Stationary dose rate in Z_{max} by a rotational factor, which was measured using EBT2 radio chromic film. For each dosimetric system, the ratio between rotational dose rate measured on cylindrical phantom surface and stationary dose rate measured in RW3 solid water was 0.4. Multiplying the stationary dose rate of 88.24 cGy/ 4000 MU by the rotational factor of 0.4, was obtained an absorbed dose on the surface of 35.29 cGy per 4000 MU, so a rotational dose rate on the surface of 0.0088 cGy/MU.

3.5. Absorbed Dose Verification

Using an anthropomorphic phantom, the doses for each anatomical region were expressed as a percentage of the prescribed dose of 200 cGy, as it is shown in table 2.

Table2. *Percentage absorbed dose at anthropomorphic phantom*

Anatomical Region	Position	Absorbed Dose (cGy)	S D (±)	Percentage absorbed dose with OSLDs (%)
Head	Anterior	197.54	4.81	99
	Posterior	200.80	4.87	100
	Left	190.12	4.66	95
	Right	190.75	4.64	95
Neck	Anterior	210.34	5.06	105
	Posterior	194.17	4.74	97
	Left	210.60	5.07	105
	Right	210.88	5.08	105
Chest	Anterior	202.77	4.91	101
	Posterior	195.37	4.77	98
	Left	197.12	4.80	99
	Right	197.27	4.80	99
Abdomen	Anterior	201.61	4.89	101
	Posterior	196.18	4.78	98
	Left	195.72	4.77	98
	Right	206.58	4.99	103
Hip	Anterior	198.21	4.82	99
	Posterior	191.91	4.70	96
	Left	202.92	4.92	101
	Right	205.95	4.98	103

With the continuous rotation, the depth dose can be considered as an infinite sum of depth dose from oblique electron beams, which eliminates completely the build-up region, where the depth dose was represented as a continuously decreasing function. Therefore, the rotational technique allows that the maximum dose is deposited on the surface, reducing radiotoxic effects on healthy tissue. In HDR mode, the linear accelerator delivers a dose rate of 3000 MU/min, it was suitable for rotational total skin electron irradiation using SSD extended to 400 cm. the described technique was characterized and it becomes acceptable when dual field (108° and 71°) was combined with the rotating platform to improve the homogeneity of dose distribution in the treatment plane of 200 cm x 100 cm to obtain a rotational dose rate at surface of 0.0088 cGy/MU.

The calibration of the rotational technique requires a rotational factor linking the dose in Z_{max} for stationary dual field with the rotational dual field at the surface. Podgorsak, Pla and Heese [14] have demonstrated that the rotational factor changes insignificantly with cylindrical phantoms over 15 cm in diameter and as a result of it, a constant rotational factor can be applied to all patients, regardless of size. The rotational factor can be easily measured with some appropriate dosimetry equipment, in this work that value was determined using EBT2 radio chromic film, its magnitude was 0.4.

The absorbed dose verification on anthropomorphic phantom surface in different places was obtained with a prescribed dose of 200 cGy, which is regularly used by session for total skin electron therapy, dose homogeneity was confirmed in ± 10%, it is recommended by the EORTC. 1136MU per field were used, a 3 rpm rotation speed was fixed and therefore the phantom was exposed to 23 turns in7.6 min treatment time per session, start and stop of treatment was controlled with a gamma-alarm, it was placed on the rotating platform. The results show that for 4 MeV the irradiation time is about twice that for 6 MeV according to Piotrowski et. Al [9]. On the other hand, a comparison of rotational technique described in this work, versus four dual field technique which is currently performed in CMN - SXXI was made, the results show that treatment time per session is shorter4 times in the proposed technique and the uniformity of absorbed dose distribution is increased on skin surface. Therefore, it is expected to obtain better clinical results for the patients and they will not be exposed to multiple positions for a long time.

4. Conclusion

All dosimetry results presented in this work comply with the previsions of EORTC. The Rotational total skin electron irradiation technique with 4m SSD and 4 MeV, increases the uniformity of the absorbed dose distribution on the entire phantom surface. The optimal rotational speed for the rotating platform was determined. If it is compared with the stationary technique, the treatment time decreases from 30 minutes to 7.6 minutes, because one dual field was used instead four dual fields, and the maximum absorbed dose is deposited on the skin surface decreasing the damage to subcutaneous healthy tissue. Also, the usefulness and accuracy of OSLDs in TSET have been shown. Therefore, the methodology presented here can be more efficient for the treatment of Mycosis Fungoides.

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