Dosimetry of translational technique for total body irradiation with electrons in Alderson anthropomorphic phantom, for the treatment of mycosis fungoides

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Dosimetría de la técnica traslacional para la irradiación corporal total con electrones en el fantasma atropomórfico de Alderson, para el tratamiento de la micosis fungoide

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Resumen

Total skin electron irradiation (TSEI) is one of the most widely used techniques in the treatment of mycosis fungoides (MF). The objective of this work is to carry out the dosimetric characterization of the translational method using a mobile platform at constant speed for TSEI, being a longitudinal prospective study design, making use of descriptive statistics with a quantitative approach. The dosimetric and geometric characteristics were established according to the Varian 21 iX linear accelerator for clinical use, treatment method and conditions of the translational platform (TP) with two degrees of freedom (speed and height), using a 1 cm thick lucite, thus degrading the energy and obtaining the

Abstract

La irradiación total de electrones de la piel (TSEI) es una de las técnicas más utilizadas en el tratamiento de la micosis fungoide (MF). El objetivo de este trabajo es realizar la caracterización dosimétrica del método traslacional utilizando una plataforma móvil a velocidad constante para TSEI, siendo un diseño de estudio prospectivo longitudinal, haciendo uso de estadística descriptiva con enfoque cuantitativo. Las características dosimétricas y geométricas se establecieron según el acelerador lineal Varian 21 iX para uso clínico, método de tratamiento y condiciones de la plataforma traslacional (TP) con dos grados de libertad (velocidad y altura), utilizando una lucita de 1 cm de espesor, degradando así la energía y obteniendo la dosis máxima a una profun-

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maximum dose at a depth of 4.8 mm and a photon contamination of 0.74%, which are within the parameters established by the American Association of Physicists in Medicine (AAPM) in report No. 23.1 In Mexico, the translational technique with TSEI has not been implemented for MF cancer procedures, and due to the physical limitations of the patients, there is no homogeneous dose distribution on the skin surface with the Stanford and rotational technique.

PALABRAS CLAVE

High dose rate, Absorbed dose, Lucite.

didad de 4.8 mm y una contaminación de fotones de 0.74%, los cuales se encuentran dentro de los parámetros establecidos por la Asociación Americana de Físicos en Medicina (AAPM) en el informe No. 231. En México, la técnica traslacional con TSEI no se ha implementado para procedimientos de cáncer de MF, y debido a las limitaciones físicas de los pacientes, no existe una distribución de dosis homogénea en la superficie de la piel con la técnica de Stanford y rotacional.

KEY WORDS

Tasa de dosis alta, Dosis absorbida, Lucite.

Introduction

MF cancer is an affectation in non-Hodking type T cells with predominance in the cutaneous region, the procedure varies depending on the stage in which it is found, being more frequent in men than in women in advanced ages at fifty years, its Planning in advanced stages is palliative and its main characterization is edema at the tissue level, the most aggressive stage is known as Sézary syndrome (SS).[2] Among the techniques that have been developed, the International Atomic Energy Agency (IAEA) endorses three techniques for total skin irradiation: The Stanford technique, the rotational and the translational. Each technique seeks that the MF treatment with TSEI in high dose rate (HDR) mode obtains a homogeneous dose distribution on the skin surface in shorter treatment times. TSEI in HDR mode has been one of the most used methods for the treatment of MF cancer, including SS. Over time, different methods have been implemented that have improved the conditions of the patient after TSEI, likewise, dose fractions have been proposed to the various strategies in order to reach an optimal treatment.[3] The International Society of Cutaneous Lymphomas (ICSL) and the European Organization for Research in the Treatment of Cancer (EORTC) agree with the standardization based on clinical trials, research developments and the inter-institutional effectiveness for the development of cutaneous lymphoma treatments in its different stadiums.[4] Radiation therapy and chemotherapy are the most widely used methods for the treatment of MF in the various stages IA, IB, IIA, IIB, III, IVA, and IVB.[5]

The EORTC suggests that an optimal dose for the treatment of MF with TSEI should be in the range of 30-36 Gy.[6]

Therefore, the objective of this work was to perform dosimetry under reference conditions and relative dosimetry in the treatment plane, providing an absorbed dose distribution on the surface of the Alderson anthropomorphic phantom (APA) through a platform translational built with the necessary parameters for the treatment of MF under a fixed electron beam with a different method from the conventional ones (Stanford or rotational).

Materials and methods

Design and construction of translational platform

Constant speed TP was developed, built and implemented at the Ixtapaluca High Specialty Hospital (HRAEI) in the radiotherapy unit in conjunction with the department of biomedical engineering and the Autonomous University of the State of Mexico, in which aspects were highlighted such as materials, resistance, rigidity, safety, movements (speed and height), functionality and quality control. The materials used for the TP were low Z avoiding secondary radiation contamination.

Figure 1

Experimental setup for calibration

Source: Own elaboration.

6 MeV electron beam calibration

LINAC Varian 21 iX electron beam was calibrated for the 6 MeV energy with a liquid water phantom, ionization chamber (IC) Markus Advanced, IC Semiflex, and electrometer in charge mode. IC Markus Advanced was positioned at the depth of $Z_{ref} = 1.31\ cm$ (equation 1) in the phantom of liquid water, a 100 cm SSD and a $10\ x\ 10\ cm^2$ cone (reference conditions), according to the TRS 398 protocol of IAEA thus obtaining a $D_{w,Q}$ (absorbed dose in water under reference conditions).

The benchmark of the IC Markus Advanced Z_{ref} is given by:

$$Z_{ref} = 0.6xR_{50} - 0.1\ \frac{g}{cm^2}\ \left[\frac{g}{cm^2}\right] = 1.3\ \frac{g}{cm^2} \qquad (1)$$

R_{50} is the depth in water where the dose reaches 50%

Dosimetry under reference and relative conditions

In the dosimetry under reference conditions, the linear accelerator, treatment system (CLINAC iX - SN567), liquid water phantom, CI Markus Advanced model TN34045 and electrometer were used, all in reference conditions, following the TRS 398 protocol, thus obtaining the profile and percentage of depth dose (PDD) with and without lucite for an energy of 6 MeV. The electron scattering lucite serves as an energy degrader to bring the maximum dose close to surface.

In the relative dosimetry, the exact speed of the TP was established with a 170 cm SSD, where it was taken into consideration:

SSD of 170 cm: In order to standardize this height, in each procedure the mechanical pistons are actuated as necessary. SSDs different from 170 cm change the geometric field and therefore the speed.

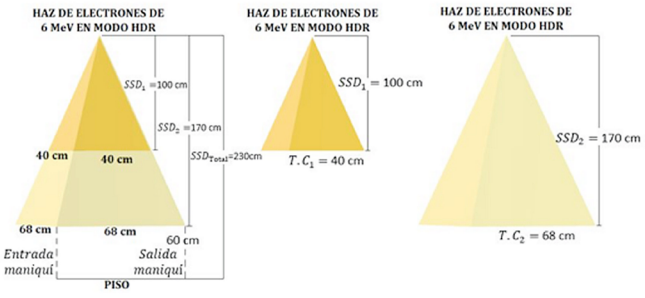
Geometric field size of the incident beam, calculated by similar triangles and/or proportionality (figure 2).

T.C = Beam field size

$$T.C_2 = \frac{SSD_1 * SSD_2}{T.C_1} \qquad [cm] \qquad (2)$$

Figure 2

Divergence of the incident beam



Source: Own elaboration.

Treatment time

$$t = \frac{D}{HDR * \frac{dD}{dt}} \qquad [min, seg] \qquad (3)$$

Where:

D is the prescribed dose [cGy]

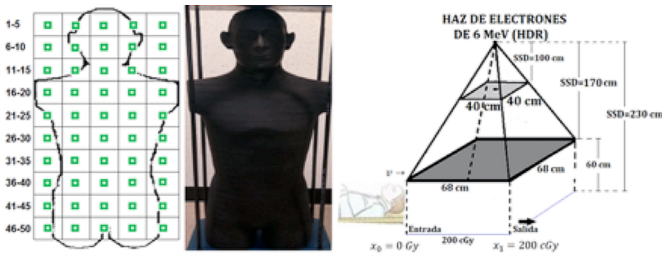
HDR is CLINAC's high dose rate [UM/min]

$\frac{dD}{dt}$ is the performance of the CLINAC to use 170 cm SSD [cGy/UM]

The APA was positioned on TP, thus performing relative dosimetry with radiochromic films EBT2 (RF-EBT2) on the APA surface with a size of 3 cm x 3 cm located 8 cm on the X axis and 10 cm from the Y axis one of the another in the treatment plane, estimating the dose distribution on the APA surface, a total of 50 RF-EBT2 was used (figure 3) with an n of 3 (150 RF-EBT2). The TP was driven by the motor mechanism at a constant speed under the fixed 6 MeV electron beam in HDR mode. The procedure was started with the APA moving at constant speed. The treatment begins outside the electron beam, then the APA passes through the beam and finally the procedure ends when the APA completely exits the electron beam. Ensuring a homogeneous dose distribution at every point on the phantom surface.

Figure 3

Translation characteristics for surface absorbed dose distribution



Source: Own elaboration.

RF-EBT2s were digitized on a flatbed scanner (EPSON EXPRESSION 11000XL), following the manufacturer's recommendations as well as those of Task Group 235 of the AAPM[7] the image processing for the RF-EBT2 was performed in ImageJ software in the red channel due to its greater sensitivity.[8]

Results and discussion

Dosimetry

Dosimetry was performed under reference conditions, thus obtaining the profile and PDD of the energy of 6 MeV of electrons with and without lucite, later with the data obtained from R_50 and R_p The LINAC was calibrated following the guidelines and recommendations of the IAEA TRS 398, adjusting that 1,001cGy= 1UM.

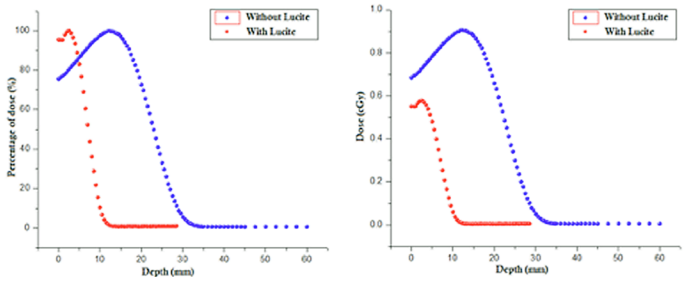
TP was built according to the technical specifications of the Linac Varian 21 iX with two variable degrees of freedom (height and speed), guaranteeing the parameters with QA (frequency inverter and measurement lasers), both for speed QA.

To perform the relative dosimetry, we first obtained the ODnet Vs Dose graph (RF-EBT2 calibration), with its respective polynomial adjustment of third degree (figure 6) and uncertainties (equation 4), which was estimated as a reference to measure the dose on the surface of APA, as well as apply the experimental arrangement (figure 5) for irradiation in APA.

The uncertainties for RF-EBT2[9] are obtained by the following formula:

Figure 4

PDD with and without lucite; energy of 6 MeV



Source: Own elaboration.

$$\sigma_{ODnet} = \frac{1}{\ln(10)} * \sqrt{\left(\frac{\sigma_{PI}}{PI}\right)^2 + \left(\frac{\sigma_{PsI}}{PsI}\right)^2} \qquad (4)$$

Where:

PI is the intensity of the radiated film.

PsI is the intensity of the film without radiating.

$\sigma_{P_{SI}}$ is the standard deviation associated with the transmittance of the RF-EBT2 without irradiating.

$\sigma_{P_{SI}}$ is the standard deviation associated with the transmittance of the irradiated RF-EBT2.

Table 1

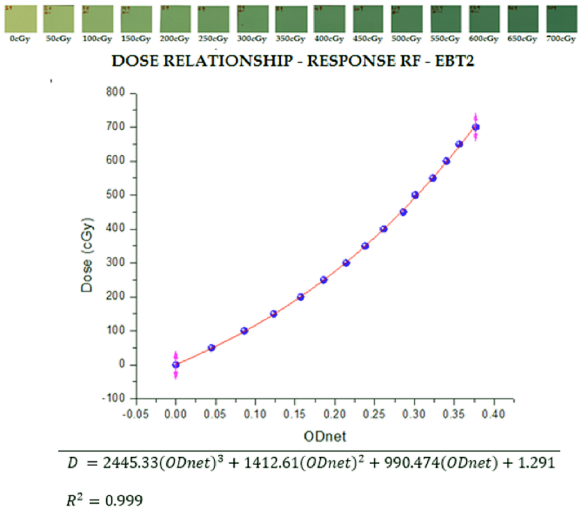
Data obtained from the RF-EBT2 readings

Dose (cGy)	*ODnet*	σ *o Dnet*
0	0	-
50	0.045	0.005
100	0.086	0.005
150	0.123	0.005
200	0.157	0.005
250	0.186	0.005
300	0.214	0.006
350	0.238	0.006
400	0.261	0.006
450	0.286	0.006
500	0.301	0.007
550	0.323	0.006
600	0.340	0.007
650	0.356	0.007
700	0.377	0.007

Source: Own elaboration.

Figure 5

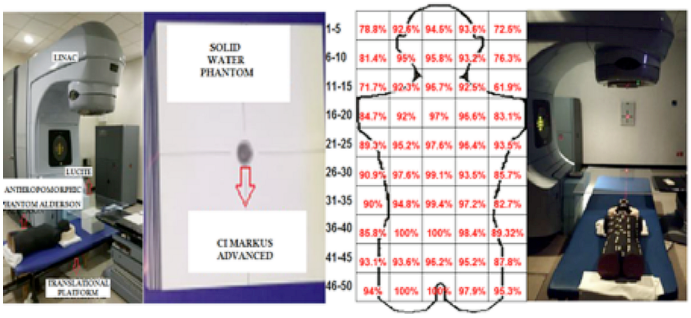
Calibration of the RF-EBT2



Source: Own elaboration.

Figure 6

Distribution of absorbed dose on the surface of APA



Source: Own elaboration.

In the relative dosimetry, the absorbed dose distribution was obtained in the treatment plane on APA as shown in figure 6, however, the dose was verified with IC Markus Advanced type parallel plane.

Conclusions

The TP complies with the technical stipulations established for its optimal use in the delivery of the treatment, for which translation tests were carried out with a weight of 60 Kg to 100 Kg, guaranteeing at all times a constant speed in a range of 5 cm/sec at 12.5 cm/sec; parameters necessary for the implementation of the technique due to the relationship between the dose and constant speed.

The absorbed dose distribution at reference conditions and at 170 cm shows symmetry and flattened within the parameters established by NOM-033-2016 (± 5% for electrons). The Lucita is effective for treatment, because the maximum dose is at a depth of 4.8 mm from the APA surface with photon contamination of 0.74%, which is within that suggested by the AAPM in report No. 23.

In the translational technique, the absorbed dose was calculated with respect to the prescription dose, the performance of the equipment and the established speed, this being verified by IC Markus Advanced in a solid water phantom, later with RF-EBT2 in the APA surface, thus corroborating the procedure dosimetrically, to which it was evidenced that the total prescribed dose was delivered in the APA sagittal midline, this due to the translation of the PT with respect to the central axis of the radiation beam. Additionally, it improves the position, comfort and delivery of the dose in the treatment plane, this procedure being feasible for a clinical implementation in patients, however, it is advisable to perform the pertinent dosimetry to verify the dose distribution and the homogeneity of the same in each hospital center.

This technique presents a viable alternative for bunker radiotherapy rooms where the Stanford technique cannot be implemented. The cost of implementing the translational technique is higher than other techniques, due to the design and construction of the translational platform, however, the benefit of the dose distribution at the tissue level obtained justifies the implementation of what is proposed in this research.

Conflicts of interest:
Authors declare that there is no conflict of interest.

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