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ORIGINAL PAPER

In vivo EBT radiochromic film dosimetry of electron beam for Total Skin Electron Therapy (TSET)

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Abstract EBT radiochromic films were used to determine skin-dose maps for patients undergone Total Skin Electron Therapy (TSET). Gafchromic EBT radiochromic film is one of the newest radiation-induced auto-developing photon and electron-beam analysis films available for therapeutic radiation dosimetry in radiotherapy applications. EBT films can be particularly useful in TSET; due to patient morphology, underdosed regions typically occur, and the radiochromic film represents a suitable candidate for monitoring them.

In this study, TSET was applied to treat cutaneous T-cell lymphoma. The technique for TSET was implemented by using an electron beam with a nominal energy of 6 MeV. The patient was treated in a standing position using dual angled fields in order to obtain the greatest dose uniformity along the patient's longitudinal axis. The electron beam energy was degraded by a PMMA filter. The *in vivo* dose distribution was determined through the use of EBT films, as well as of thermoluminescent dosimeters for comparison (TLDs). EBT results showed a reasonable agreement with TLDs data.
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Introduction

Total Skin Electron Therapy (TSET) is effective and frequently used in the treatment of cutaneous T-cell lymphoma, also called mycosis fungoides [1–5]. The initial lesions are confined to the skin at a depth of about 1 cm. This means that the treatment has to be performed with electron beams of an average energy of 3–5 MeV. These energies are rarely available in linear accelerators, so it may be possible to use polymethylmethacrylate (PMMA) filters to degrade the energy beam. Cutaneous lymphomas are treated by irradiating the whole body surface, which is irregular in itself, with an electron dose distribution as uniform as possible. A variety of irradiation techniques have been reported

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in literature, such as scattered single-beam [6] and patient-rotation [7] ones. Another technique, that is, the method employing a pair of angled beams (dual beam) and the rotation of the patient, is the most widely used [8—11]. There is no basic dosimetric protocol for TSET, so the *in vivo* dosimetry measurement is of importance to determine the distribution of the dose to the patient's skin, and to verify which dose the patient has effectively received. It is important to evaluate the contribution given by multiple, adjacent angled beams. Due to patient morphology, underdosed regions typically occur, and have historically been measured using multiple TLDs.

A suitable dosimeter to map the patient exposure is represented by the GAFCHROMIC film (International Speciality Products — ISP) [12], an organic-based radiochromic film which — with respect to radiographic silver halide film — better fulfils dosimetric features, such as ease of handling, low energy-dependent response, extended measurable dose range, insensitivity to visible light, self-developing characteristics, dose rate independence. Over the past few years, the above-mentioned features have made the early model HD810, MD55-1, MD55-24 and HS GAFCHROMIC films suitable to be employed in dosimetry and quality control, in a wide range of therapeutic applications (conventional and intravascular brachitherapy with high and low dose-rate sources, radiosurgery, conformal radiation therapy, intensity modulated radiation therapy, proton therapy).

International Speciality Products has recently released a new radiochromic film which can measure doses within the cGy-to-Gy range. This feature makes the film ideal for dosimetry in clinical radiotherapy applications, the dose delivered during the routine radiotherapy fractions being matching the effective range of the new product named EBT Gafchromic.

The EBT model has two sensitive layers and is designed for two-dimensional dose measurement in high-energy beams [13]. The aim of the present work was to show the performance of EBT in determining the dose distribution in patients undergone TSET.

In particular, EBT dosimetry was applied during TSET treatments in four patients with mycosis fungoides.

To obtain a complete evaluation of the exposed area, images of the EBT films were acquired by a flatbed scanner and analyzed with a dedicated analysis program.

The EBT results were then compared with the TL measurements obtained from TL dosimeters applied near the EBT films during the patient irradiation.

Before the introduction in clinical use, the main dosimetric characteristics of EBT films (dose-response curve, post-exposure response) were studied.

Materials and methods

EBT radiochromic film

A Gafchromic EBT film, lot no. 34351-05, was used to measure the absorbed dose. As quoted by the manufacturer, the film is designed to be used in the 0.01—8 Gy dose range. The structure of the new EBT film model consists of two substrates; the substrate's properties and composition are reported in literature [14—16].

The dose response of the EBT films was measured by a commercially available flatbed scanner. The maximum absorption band for the EBT model is centered at 633 nm [17], and is about 10 times more sensitive than the HS model [18]. A selection of wavelengths in the red portion of the visible spectrum is indicated to obtain an optimized film response [19].

Irradiation procedures

Patient irradiation in TSET

During TSET, the patient was irradiated in a standing position with a high dose-rate electron beam, delivered by a Clinac 2100 C/D (Varian) linear accelerator, at a nominal energy of 6 MeV [20]. Such irradiation was performed from 6 directions, using 2 axial electron beams, each with a 20-degree angle to the horizontal level, gantry at 290° and 250° (Fig. 1). In this way, dose nonuniformity along the patient's longitudinal axis was reduced.

A PMMA filter (200-cm height, 120-cm width, and 1-cm thickness) was placed between the gantry and the patient's surface, at a distance of 35 cm from the patient. The single beam was characterized under such irradiation condition. In particular, the PDD curve was evaluated in a 30-cm × 30-cm, 20-cm thick solid phantom (RW3), with a single field perpendicular to the entrance surface of the phantom. Dose measurements were performed with a Roos ionization chamber (mod.W34001-0317). The practical range R_p and the depth at which the dose reaches the 50% of the maximum value, i.e. R_{50}, were also estimated, obtaining the following values: $R_p = 1.45$ cm; $R_{50} = 1.00$ cm. As recommended by the AAPM Task Group 23, the $E_{p,0}$ and the E_0 parameters, i.e. the most probable energy on the surface and the mean energy on the surface, were used to characterize the electron beam energy. The following values were obtained: $E_{p,0} = 3.31$ MeV, $E_0 = 2.33$ MeV.

In the same irradiation conditions, also the PDD curve of the dual beam was obtained. In Fig. 2, the PDD curves of the single and dual beams are shown.

Dose calibration of the dual beam

The beam calibration in terms of dose to water was performed following the indication of IAEA TRS n.398 [21], in the same set up of patient TSET irradiation. So, the absolute dose value D at a reference point P_{ref}, chosen at the

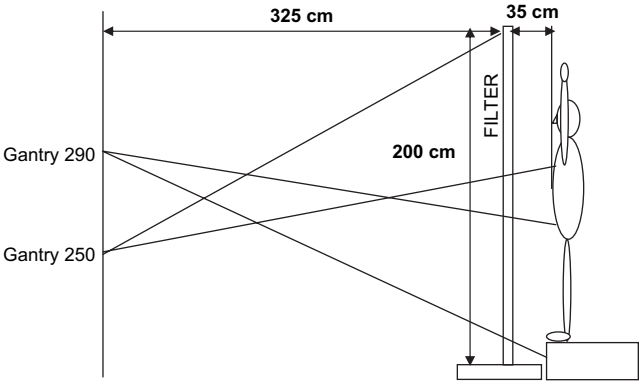

Figure 1 Representation of dual field and patient's position.

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