Dosimetry for Total Skin Electron Beam Therapy in Skin Cancer

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Increasing frequency of skin cancer, mycosis fungoides, Kaposi's sarcoma etc, it need to treatment dose planning for total skin electron beam (TSEB) therapy. Appropriate treatment planning for TSEB therapy is needed to give homogeneous dose distribution throughout the entire skin surface. The energy of 6 MeV electron from the 18 MeV medical linear accelerator was adapted for superficial total skin electron beam therapy. The energy of the electron beam was reduced to 4.2 MeV by a 0.5 cm×90 cm×180 cm acryl screen placed in a feet front of the patient. Six dual field beam was adapted for total skin irradiation to encompass the entire body surface from head to toe simultaneously. The patients were treated behind the acryl screen plate acted as a beam scatterer and contained a parallel-plate shallow ion chamber for dosimetry and beam monitoring. During treatment, the patient was placed in six different positions due to be homogeneous dose distribution for whole skin around the body. One treatment session delivered 400 cGy to the entire skin surface and patients were treated twice a week for eight consecutive weeks, which is equivalent to TDF value 57. Instrumentation and techniques developed in determining the depth dose, dose distribution and bremsstrahlung dose are discussed.

Key Words: Total skin electron beam therapy, Skin cancer, Mycosis fungoides, Electron dosimetry

INTRODUCTION

Total Skin Electron Beam therapy (TSEB) is one of the most effective modes of treatment for superficially disseminated skin cancer, Kaposi's sarcoma or mycosis fungoides[1,2,3)].

The interest in low energy electron stems largely from the special characteristics of the electron depth dose distribution, particularly the rapid fall off in depth dose near the end of the electron range, since it is desirable to minimize the dose in the underlying tissues[1,45)]. However, since patients with superficial lesions frequently require treatment over all areas of the entire body surface, an acceptable dose uniformity over the treatment area was achieved by choosing the appropriate electron beam energy level with a build up scatterer to get homogeneous skin dose distribution and a technique utilizing two different angled fields for six portals irradiation at six different patient positions[6,78)].

We present a treatment technique and dose distribution of Total Skin Electron Beam therapy (TSEB).

METHODS AND MATERIALS

The total skin electron beam therapy we used was a modification of the six positions, twelve fields technique[9,10,11)]. During treatment, patients stood on an elevated platform with an attached supporting frame at a distance of 3.0 meters from the radiation source. Patients took action successively for six different positions designed to expose the entire skin as uniformly as possible. At each position the patient was irradiated with two field: One with the beam central axis angled 19° above the horizontal plane and the other with the axis 19° below (Fig. 1). Nominal electron energy was 6 MeV produced by a NEC 18 MeV linear accelerator. Collimators were fully open (105×105 cm^2 at 3m) and no treatment cone was used. For this combination of distance and angles, there was a gap of approximately 35 cm between the edges of light fields of the two beams. However, due to air scatter, the electron beam field at this distance was much larger than the light field. We made measurements to determine the dose rate for single and multiple fields and to characterize the beam with and without a 5 mm thick scattering plate in front of patients. The beam is spread over the entire skin surface and it rapidly builded up by having it pass

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본 논문은 1991년도 연세대학교 의과대학 교수연구비에 의하여 이루어 졌음.

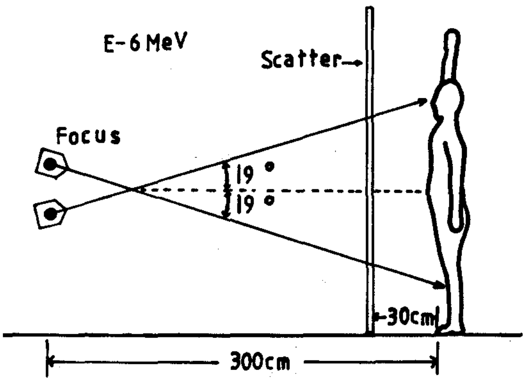

Fig. 1. Geometrical arrangement of the symmetrical dual field treatment technique. Equal exposures are given with each beam.

through an acrylic scattering plate.

The dose profiles of single field and two fields (beam-up plus beam-down) were measured with film (Kodak x-omat TL) and a Farmer type ion chamber with a build up cap in a rectangular polystyrene phantom. All twelve field measurements were made with film in a humanoid phantom. The field flatness along the transverse axis of the beam and in the radial direction was determined both with film and by ionization chamber measurements.

The ionization chamber was a thin window, plane-paralled design (2.5 mm plate separation, 1 cm diameter collecting electrode, 5 mg/cm^2 mylar window) connected to an electrometer with a digital multimeter for display of integrated ionization charge. This chamber was placed at a flat polystyrene phantom provided a hole fit for both the chamber and its sleeve. The readings were obtained at both a positive and negative 300 volts to nullify the effects of polarity reversal[7,18].

Dose distributions in the transverse plane for the six combined fields were obtained by sandwiching film between sections of the 20×30 cm diameter cylindrical paraffin phantom. The film was cut to match the shape of the phantom edge. Surface dose was determined using film wrapped around the outer perimeter of the phantom. The usual precautions to eliminate air pockets between the film and the phantom were taken in all cases[4]. The films were exposed so that the optical density of the processed film fell within the linear response region[5,11]. Films from the same batch were used for all investigations and a calibration film was exposed for each experimentation session to account for variations in processor conditions. All films were developed in a rapid prosessor at on time. The accuracy of film dosimetry for films from the same batch, processed separately, and accounting for processor conditions is expected to be 3~6%. Isodensity distributions were determined using a film densitometry system, whereas optical density data for percent relative dose versus depth was determined manually using a densitometer having a 1 mm aperture diameter (Sakura PDM-5). The measured surface dose using film was compared to the calculated values using publiched obliquity factors[10,12].

Contaminated bremsstrahlung measurements were performed using the plane-parallel ionization chamber in the flat polystyrene phantom described earlier. These measurments were performed at a depth of 5 cm (beyond the practical range of the 6MeV electrons) to determine the maximum amount of bremsstrahlung present in the beam. Additional measurments were done at an 8 cm depth to illusatrate the change in photon contamination with depth.

RESULTS

The dosimetric properties from the six dual fields arrangement are described here along the verticle and axial plane of the humanoid phantom and the patients.

1. Field Uniformity

For treatment of the total skin surface of the patient a uniform field of at least 200 cm in height is required. A horizontally directed beam does not provide an adequate dose uniformity in the vertical plane of the patient. But dual beam angled alternately 19° above and below from the horizontal plane provided a homogeneous dose distribution over the field of approximately 200 cm×120 cm.

The beam profile at the surface along the length of the patient from one of dual beam fiels is shown in Fig. 2.

The field uniformity in 200 cm is±3% and over 250 cm is±7%. There is little difference between the flatness measurements obtained by either film or plane parallel ionization chamber.

The dose distribution around skin contour as shown Fig. 3 was taken at the two and six electron fields with film sandwiched between two abdominal section of a humanoid phantom.

Fig. 4 illustrates the dose uniformity of skin around the body contour by the four and six fields

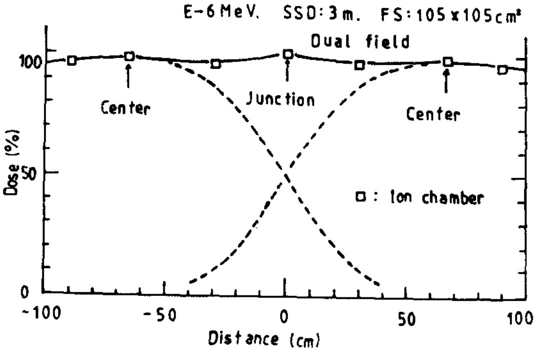

Fig. 2. Surface beam intensity along the length of patient for the single dual ±19°, 6MeV electron field.

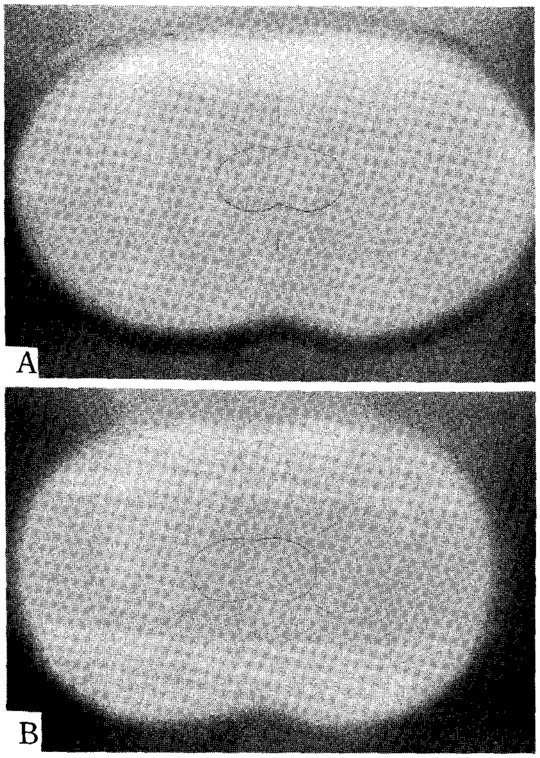

Fig. 3. Film dosimetry in a humanoid (Rando) phantom for the two (A) and six (B) field technique taken using film.

technique. The skin dose along axial plane is uniform within±5% by this six fields which are adequately cover the demension of typical patient body.

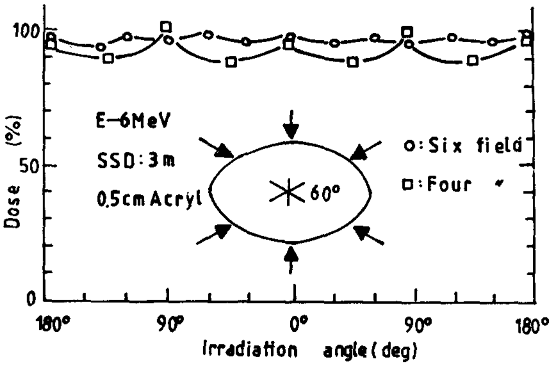

Fig. 4. Skin dose profile around the body contour for six and four field technique taken using film and TLD dosimetry.

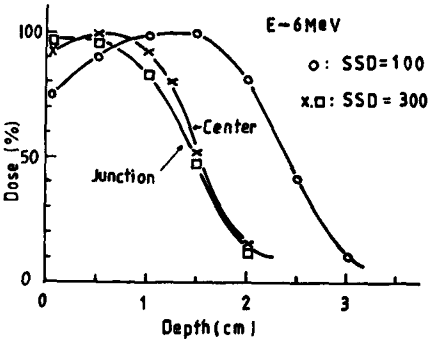

Fig. 5. Relative depth dose distributions at two positions obtained with both film and a plane parallel ionization chamber. Data is shown for a single 6MeV field at source skin distance (SSD) 100 cm, and two position (center and junction) of single dual 6MeV field at 300 cm with 0.5 cm scatterer.

2. Depth dose Distributions

Fig. 5 shows the percentage depth dose (%DD) curve for single dual field on 6 MeV electron at the center and junction point at target skin distance of 1 m and 3 m. This data was taken using film placed parallel to the beam axis and sandwiched between flat slabs of polystyrene. The percentage depth dose of the center for the single dual field is initally greater than that exhibited in the junction point about 8% at reference depth.

Percentage depth dose curves were determined in a plane representing the patient's cross section for a single dual field and six dual field technique spaced at 60° intervals around the phantom of 6MeV electron at 3.0 m distance from target of the

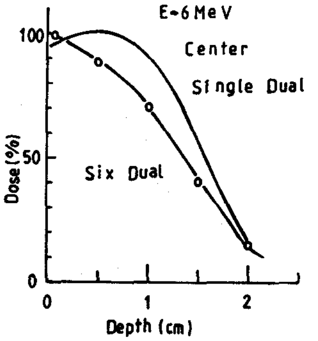

Fig. 6. Relative depth dose for single dual and six dual field in beam center position at SSD 300 cm with 0.5 cm acrylic scatterer.

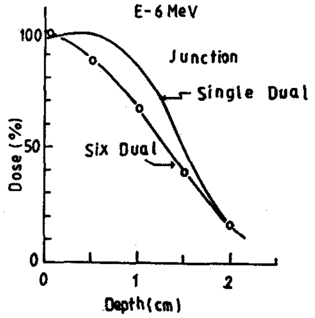

Fig. 7. Relative depth dose for single dual and six dual field in beam overlaped junction location at SSD 300 cm with 0.5 cm acrylic scatterer.

accelerator.

The depth dose distribution at the center for the single and six dual field technique are shown Fig. 6. The depth dose curves of six dual electron field are all normalized to the dose received at the surface of the phantom at the center of the electron field while the single dual field data is normalized to the maximum dose at depth. The dose distribution at the center for the six dual field technique shows that the dose on the surface increases to 100% in comparison with the distribution observed for a single dual field. There is also a decrease in the depth of penetration of beam for the combined six dual field technique in comparison with that for a single dual field which the surface dose is 95%. The depth dose distribution at the junction point for the single and six dual field technique are shown in Fig. 7. There is a marked decrease in the total depth of penetration at the junction point of the electron fields compared to the penetration at the center. This decrease in depth of penetration is primarily caused by the oblique incidence of the beam at the junction point.

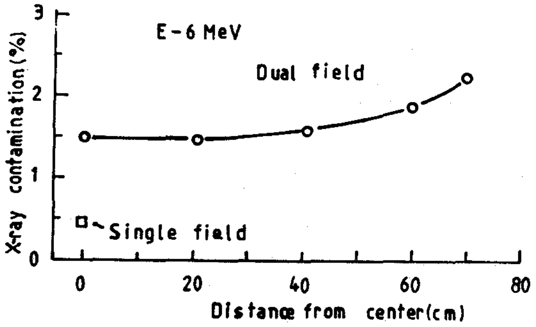

Fig. 8. Relative x-ray contamination along the transverse from center for a single dual field. Measurements were made at a depth of about 4 g/cm^2 of polystyrene.

The surface dose of the phantom is delivered 100% of the dose and the %DD at 1 cm depth are 71% of the single dual field and 67% for the six dual field electron. This data was taken with film sandwiched between two abdominal sections of an humanoid phantom. By inspection, there is little difference between the computer (therac 2300) generated curves and those measured using film. The distribution at the junction is more difficult to calculate because of the oblique incidence caused by both beam angulation and surface curvature.

3. Bremsstrahlung

The bremsstrahlung dose for a single field measured from 300 cm target isocenter distance (TCD) at 5 and 8 cm depth was 0.4% and 0.36%, respectively, compared to the calibration point for the six field technique. Most photon contamination is produced in the head of the linear accelerator but some results from interactions of the incident electrons within the patient. In the patient treated with dual angled fields, the maximum dose resulting from photon contamination at the center was measured to be 1.5% of the total delivered Dmax dose. Taking into account the increased distance to the junction point as compared to the treatment distance with the beam vertical, the dose from photon contamination in this region is between 2, 2% of the delivered dose (Fig. 8). The photon contamination in the beam as determined by plane-parallel ionization chamber measurements agreed to within 0.5% of the values obtained using film.

4. In-vivo Patient Dosimetry

The technique described above was developed for a particular patient with mycosis fungoides to standing position by a multiple overlapping field technique at a distance of 3.0 m from the accelerator target. The technique using six dual field was ensured a more homogeneous distribution of radiation to the skin and then the orientation of the patient with respect to the beam axis and the positioning of the extremities are different for each field. In the six dual field technique patients are treated using anterior, posterior and four oblique fields arranged in 60° increaments about the vertical axis (Fig. 9). Each field consists of two equal components, one with the central axis of the beam aimed 19° above the horizontal and the other pointing 19° below. Lithium fluoride thermoluminescent chips (TLD -100, $3.1\times3.1\times0.38\ mm^3$) were placed at various locations on the patient's body and were left in place for one entire treatment session and dose monitoring at six points on body surface with semiconductor detectors (AM6CE). The dose measurements at the indicated locations show about 10% variations in dose uniformity except in area not directly exposed to the beam. The area not directly exposured to the electrons such as the soles and the parineum needs to be treated boosts with conventional electron beam.

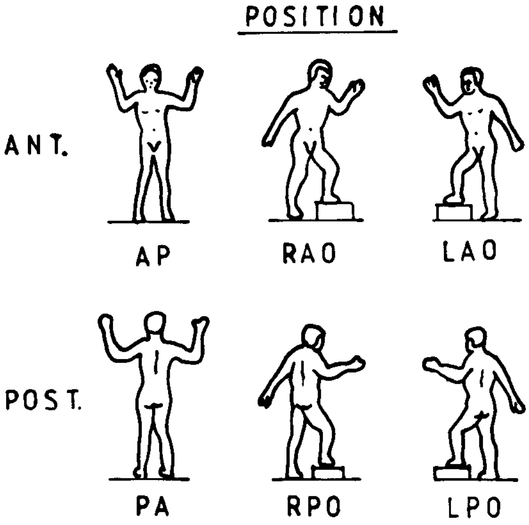

Fig. 9. Treatment positions of the patient for six field treatment technique.

DISCUSSION

The radiosensitivity of all of the classic cutaneous lesions of mycosis fungoides including plaques, nodules, and ulcers is well documented. Because of the sharply limited penetration of the electron beam, it has been increasingly employed in the treatment of mycosis fungoides and of other cutaneous malignancies involving extensive segments of the body[13,14].

Since 1953[1] various techniques and dose regimens have been employed in irradiating the entire skin surface with high energy electrons[15~17].

Electron beams from accelerators show the typical characteristics of a dose maximum occurring just below a normally incident skin surface and a rapid fall off dose with depth to maximum range determined by the incident electron energy.

Studies have been carried out by several centers to determine dose distributions obtained for single field, multi field, translation, arc and patient rotational techniques[19,20]. Phantom studies suggest that patient rotation, using a rotating platform, provides the best dose uniformity over large portions of the body surface, although the eight field technique has proved to be almost as good. The six field technique is simpler to carry out, it provides somewhat less dose uniformity but is considerably better than the two or four field techniques. Since the human body is not a simple cylindrical shape, not only are there areas of overexposure, but there are marked underexposured areas which often require supplementary treatments.

We have adapted a large, clear acrylic scatterer energy degrader plate about 0.5 cm in thickness and 2m×1m in crose section. It is placed about 30 cm in front of the patient and contributes to large angle scatter of the emergent electrons and this improves dose uniformity, particularly on oblique body surfaces, but reduces penetration and the depth dose falls off at a shallower depth. The plate can also provide a mounting surface for monitor ionization chambers located close to the treatment plane[9,13,21].

Dosimetry for TSEB is difficult and complex because of the need to measure and evaluate absorbed dose at shallow depths over a large area in the patient treatment plane. Such large spatial fields do not lend themsolves readily to measurement with conventional linear scanners and isodose plotting equipment. The short ranges of the electrons necessitate special attention if the dosimetry and calibration of such beams are to be accurate. Many radiation detectors are too thick for these high gradient depth dose fields, or exhibit significant variations in directional response. The electric currents generated by small volume, high resolution ionization chambers are often so small that noise and spurious signals arising from irradiation of the signal cable become dominant.

To obtained the valid dosimetry data for use in patient treatment, we used a small volume, parallel plate ionization chambers having a thin window and shallow active depth in a flat solid phantom. The film dosimetry has good spacial resolution of dose distributions in phantom for the different irradiation techniques for various body sections.

For the dosimetry to local anatomical areas in TSEB, small TLD chips were used for each patient in different regions of the anatomy for at least one treatment cycle. Six semiconductor detectors (AM6CE) were attached on the patient skin for beam monitoring duaring irradiation.

For the six dual field technique, a number of positions can be chosen for the arms and legs to be minimized self shielding. The patient stand on a rotatable base having angle markings and with positions for location of the feet indicated. For the four oblique fields, one leg of the patient is elevated about 20 cm off the floor on a pedestal so as to expose slightly more of the upper medial thighs. To be exposed the axillary regions slightly more, the arms extended upward with the fingers.

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국문초록 =

피부암치료를 위한 전자선 전신피부 치료방법과 선량분포 측정

연세대학교 의과대학 치료방사선과학교실

추성실·노준규·김귀언

4-5MeV의 전자선은 피부표면의 흡수선량을 증가시키고 표면하 10 mm 내외에서 급속히 감소함으로 Mycosis fungoides, Kaposi's sarcoma등 전신피부암에 대한 가장적당한 치료방사선으로 알려져왔다. 그러나 평면이 아니고 굴곡이 심한 인체표면에 균일한 선량을 계획하기는 많은 어려움이 있었다.

연세암센터에서는 1980년부터 시행하여왔던 6MeV 전자선의 마름모형, 네방향 조사방법을 개량하고 많은 문헌을 참고하여 상하 양방향의 조사면과 환자위치를 각각 여섯가지 자세로 나누어 조사(Six-Dual-Field)하는 방법을 사용하였으며 이에따른 전신피부표면의 선량과 선량분포를 측정하였다.

선형가속기에서 발생되는 6MeV 전자선을 0.5 cm 두께의 아크릴판으로 감약시키고 콜리메터가 완전히 열린 조사면을 상하 19°씩 옮기므로서 타겟트에서 3 m 거리에 약 2 m×1 m의 균일한선량의 조사면(평탄도 $^{+}$3%)과 10 mm 내외의 실효깊이(80% 선량지점) 및 산란선에 의한 피부표면선량을 증가시킬 수 있었다.

환자는 일부피부가 가려지지않도록 팔과 다리를 적당한 자세로 고정시키고 전자선을 여섯방향에서 각각 2회씩 상하로 조사시키므로서 피부표면에 균일한 선량분포(표준편차 5%)가 가능하였으며 80%의 심부율이 8~10 mm에서 측정되었다. 모든 측정은 인체등가팬텀과 폴리스틸렌팬텀을 사용하였으며 필름, 평형전리측정기 및 표준전리측정기를 이용하였다. 특히 환자피부표면의 흡수선량분포를 확인하기 위하여 열형광측정기와 반도체측정기를 이용하였으며 6~20개의 소형 측정기를 환자 피부표면에 부착시킨후 전자선 치료과정 동안 피폭 시켜 측정하였고 그결과 차폐된 부위를 제외하고 평균 10% 이내의 균일한 선량분포를 얻을수 있었다.