A dosimetric study of deep skin electron therapy with overlapping stationary radiation fields – A case report

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▶ *Case report*

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ABSTRACT

***Background*:** For radiotherapy of total skin including sub-cutaneous tissue up to a depth of 3 cm on the entire left leg of an adult (Angiosarcoma skin), a complex treatment with multiple stationary electron fields was planned at our clinic. The details of dosimetry, clinical dose measurements are presented. ***Materials and Methods*:** The treatment planned with 6 overlapping 9 MeV electron fields in Clinac 2300CD linac. With 25×25 cm cone, a cut-out insert provided 56 × 30 cm field at FSD 213 cm, while patient lying on the floor. Dose distributions were checked using Kodak V densitometric film in cylindrical plastic can phantom. The calibration was carried out using solid water phantom, water equivalent IMRT phantom and water can leg phantom. A dose of 45 Gy in 23 fractions at 5 fractions/week was prescribed. 6 field overlapping field factor was measured by the method described for total body electron irradiation (AAPM). Skin doses were estimated at random selected points using TLD chips and semiconductor diodes. ***Results*:** Measured absorbed doses by three methods were 0.174 cGy/MU, 0.166 cGy/MU and 0.162 cGy/MU agreed well with the calculated value 0.163 cGy/MU. 6 field overlap factor was 2.315. Clinical dose estimates of mean skin dose was 246.0 ± 14 cGy (n=18), delivering higher dose by 23%. The gonad dose estimate under shield was <5%. The excess dose to skin delivered in first 14 fractions was adjusted in following 9 fractions. ***Conclusion*:** It appears that the excess dose in real situation may be due to either floor backscatter or non uniform overlap of dose from adjacent fields.

Keywords: *Electron therapy, deep skin RT, clinical dosimetry, angiosarcoma.*

INTRODUCTION

High energy electrons from 6 MeV to 15 MeV are used for irradiation of superficial lesions because of their shallow penetrations in tissue, rapid fall off dose beyond 80% isodose plane, insignificant dose beyond the practical range and low magnitude of bremsstrahlung dose in tissue. Dosimetry using large fields with high energy electrons in the irradiation of total body skin, moving arc electron beam in the curved body contours etc. require thorough dosimetric work up before executions. These are mainly due to overlap of mixing field borders providing hot spots, depth dose variations due to body curvatures having effect on electron energy degradation and variations in dose build-up effects due to contour variations. Dosimetry protocols for electron beams make use of $N_{D, water}$ calibration factor using thimble ionisation chambers [1-3]. The application of multiple field overlap factor along with linear accelerator output for single field, have been described in earlier reports for treatment of total skin electrons using Stanford Technique [4-6]. For an adult patient seen in our department (angiosarcoma skin), involving total skin including sub-cutaneous tissue up-to a depth of 3 cm on the entire left leg, a complex treatment with multiple stationary electron fields was planned at our clinic. The entire left leg from thigh to ankle level received treatment. A treatment plan with multiple stationary electron fields was executed. Wooden *et al.* [7] described a six field treatment technique with 5 MeV electron beam for irradiation of lower calf, for Kaposi's sarcoma. We executed a similar technique of treatment with higher energy electrons to reach a larger depth. In this paper the details of dose measurements and verification aspects are presented.

MATERIALS AND METHODS

Clinical summary

A male aged 56 years with multi-focal angiosarcoma, on the left lower leg and thigh on the top of elephantiasis. MR imaging showed generalized skin thickening along with diffuse subcutaneous oedema, with variable sized and shaped soft tissue masses, with tumour strands extending into subcutaneous tissue (figure 1). A tissue depth up-to 3 cm was considered suitable for treatment with 9 MeV electrons.

Plan of treatment

The treatment was planned with 6 overlapping 9 MeV electron fields from Clinac 2300 high energy linear accelerator (Varian AG, USA). A 25×25 cm cone stationary electron field with vertical beam (0^{o} gantry angle) was used. A cut-out insert provided 56 × 30 cm single large field, at 213 cm focus to skin distance (FSD) at the floor level. The left leg was immobilized at different angles during treatment. Three fields with patient supine and 3 fields with patient prone (at 60^{o} intervals) were set up for treatment. A dose of 45 Gy in 23 fractions, at 5 fractions/week was prescribed. Dose delivery was planned for 100% dose percentile. 6 mm lead flap gonad shield was used during treatment, to protect testes from stray radiations.

Determination of dose distribution

Dose distribution for 6 fields was checked using a tapering shaped plastic cans phantom filled with water and by keeping Kodak-V densitometric films in between above two cans. The proto-type leg phantom is of tapering type; consisting of two parts. Two plastic cans stand one upon another; 18 cm upper and 10.5 cm lower diameters, total height 25 cm with partition at 12.5 cm holding the film. Central diameter is 13.5 cm. To avoid air gap in between top and bottom cans, a thin layer of dental wax was fixed. Figure 2 shows the phantom used for film exposure obtained at 213 cm source to phantom distance.

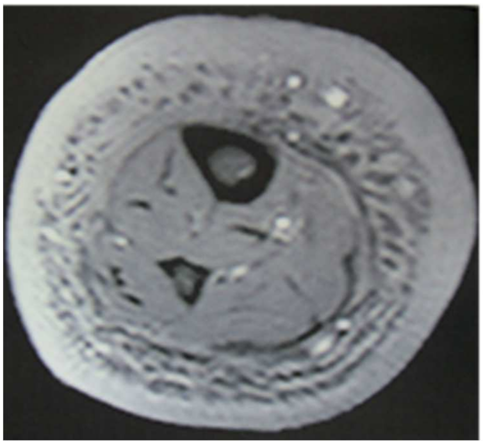

Figure 1. Transaxial MR image of the left leg showing marked thickening in the skin and subcutaneous tissue.

Figure 2. Two can phantoms with lid kept one over the other simulate the regions above and below the knee in terms of variations in thickness, as well as tapering effect. The bottom side of the top can and top side of the bottom can filled with 8 mm thickness of dental wax, to provide smooth surface as well as no air gap for keeping a film in between. Water is filled in the two cans to provide scattering conditions similar to leg.

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As CT scanning was not done for the entire leg, treatment planning system (TPS) was not used to obtain dose distribution for 6 fields. However, to demonstrate the density pattern obtained in the film, we plotted the dose distribution using Eclipse TPS retrospectively, for 6 electron fields. Eclipse TPS does not support an FSD of 213 cm. Plan was generated using maximum field size 25×25 cone at 100 FSD. Therefore 2-dimensional dose distribution for 13.5 cm diameter circular contour were obtained for 100 cm FSD for composite 6 electron fields. It is assumed that depth dose pattern in high energy electrons depends more on incident energy rather than the treatment distance. From the 6 field film density pattern, using a densitometer the depth dose fall off is plotted with normalization (100%) at depth of maximum photographic density.

Estimation of absorbed dose/MU

Three methods were followed for calibration of absorbed dose (cGy/MU) at 213 cm FSD, at the depth of dose maximum.

1) A Solid water phantom (SW) of size 30×30×17 cm was used under a vertical beam, with plane parallel chamber PPC 40 and Dose1 electrometer (Scanditronix Wellhofer). The depth of dose maximum, R_{50} and R_p values obtained from the percentage depth dose curve were used to position the chamber for dose/MU measurements and to calculate Eo and Ep,o energies (mean and most probable energies [3]) of electron beam at 213 cm FSD. A factor Kq = 0.913 was used (TRS 398, IAEA [1]) for this ion chamber.

2) An IMRT phantom (RW_3 tissue equivalent material, Scanditronix Wellhofer) (resembling curved patient contour) was kept at 213 cm FSD, with FC65 chamber (at 2cm depth) connected to Dose 1 electrometer. Absorbed dose/MU was estimated correcting for percentage depth dose at effective point of measurement.

3) The water filled plastic can phantom (same which has been used for film exposure), was used with FC 65 chamber mounted on a special holder supported by Orfit immobilization sheet. Lateral stationary beam was used for calibration (figure 3). Measured absorbed dose/MU was also calculated using inverse square law taking virtual SSD for the selected energy. For obtaining 6 field overlap factor, the method described for total body electron irradiation [6] was followed using the same plastic can phantom. An FC65 chamber placed at 2 cm depth, and rotating the phantom at 60° intervals for 6 field centres, chamber position remaining unaltered.

Clinical dosimetry

Skin dose estimates were made during treatment at random selected points on the leg, with TLD chips (4mmx4mm size) and TLD reader (Model 5500, Bicron Harshaw) as well as semiconductor diodes (Model DPD 10, Scanditronix Wellhofer). One TL detector consisted of 3 TL chips kept together, packed in plastic bags. Reading of 3 chips were averaged to evaluate mean dose, using a calibrated control dosimeter exposed to a known dose. Individual semiconductor diode has a calibration factor obtained from phantom irradiation separately.

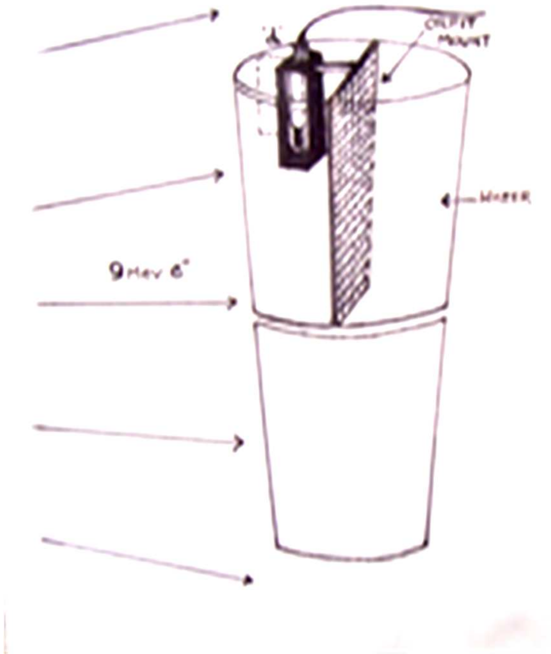

Figure 3. Plastic can phantom used for film dosimetry in Figure 2 provided with an ion-chamber mounting facility, to provide 2 cm depth in water. Absorbed dose measurements was carried out with lateral beam irradiation geometry. The phantom was kept at FSD 2.13 M simulating patient irradiation geometry.

RESULTS

Figure 4 shows the film density pattern showing good radiation dose distribution for 6 electron fields. Figure 5 show the dose distribution plot, obtained from Eclipse TPS. The depth dose patterns a) for a single electron field obtained with parallel plate chamber measurements and b) for 6 overlapping electron fields measured from the film density pattern (figure 4) is shown in figure 6. Estimated electron energies Eo and Ep,o values were 8.37 MeV and 8.87 MeV respectively. Measured absorbed dose/MU were 0.174 cGy/MU for SW phantom, 0.166 cGy/MU for RW3 phantom, and 0.162 cGy/MU for water can phantom (figure 3). Calculated dose rate using inverse square law was 0.163 cGy/MU. The ratio of absorbed dose/MU for six fields together (overlap factor), against single direct field is 2.315.

Table 1 shows the results of clinical dose measurements with TLD and semiconductor diodes. These dose measurements have estimated mean skin dose 246.0 $\pm$ 14 cGy (n=18) on 6 treatment days. It could be observed that there was 23% overdose occurred in 14 fractions. Table 2 shows the results of gonad doses compared with dose above the flap shield. Dose under shield was estimated <5% of planned dose. The excess dose delivered (as observed by clinical dosimetry) was adjusted with reduced dose/fraction in the remaining 9 fractions to complete planned dose (45 Gy/23 fractions, 5 fractions/week).

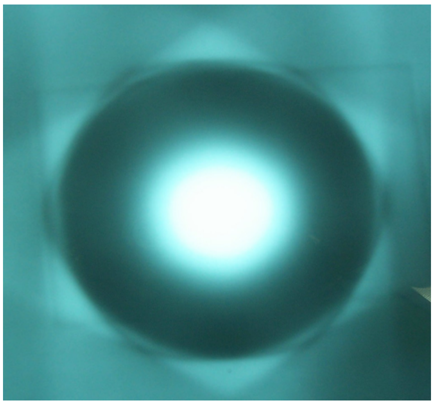

Figure 4. Radiographic pattern obtained with 6 fields at 60° intervals. Phantom rotated at Equal intervals keeping the field stationary. The radiographic pattern shows an Uniform annular shell pattern, giving a satisfactory distribution of radiation dose to an useful layer thickness of skin and subcutaneous tissue shown in figure 1.

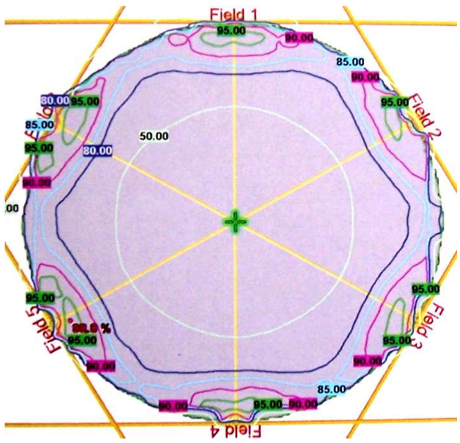

Figure 5. TPS Dose distribution for 6 electron fields. Exact matching of edges are well demonstrated.

Table 1. Estimated skin doses by TL and Semiconductor dosimeters.

Day of measurement	Control dosimeter cGy	Estimated Dose (knee) cGy	Estimated Dose (mid field) cGy	Estimated Dose (ankle) cGy
1 TL	189.1	254.3	265.7	250.3
2 ,,	,, ,,	238.6	239.0	275.8
3 ,,	195.7	236.3	242.8	248.6
4 ,,	,, ,,	224.9	245.2	246.2
5 ,,	,, ,,	272.8	240.5	249.2
6 DPD	200.0	225.7	235.1	237.7
				Mean dose 246.0±14

Table 2. TLD Estimated doses (cGy) above and below gonadal shield, for a planned dose of 200cGy.

Position of TLD	1	2	3	4	5	Mean
Above Shield	32.0	24.4	58.2	29.0	49.3	38.6±14.4
Below Shield	10.0	7.5	9.5	9.1	10.3	9.3± 1.1

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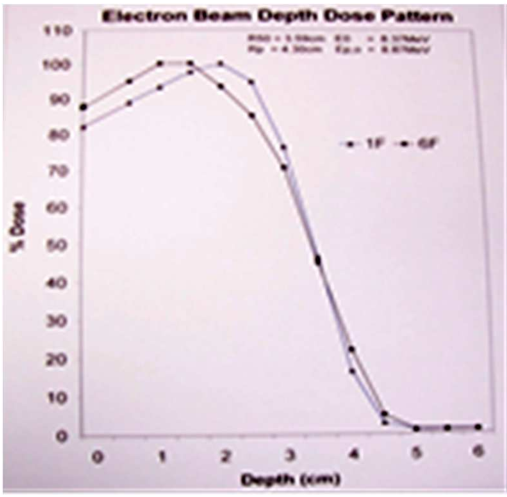

Figure 6. Depth dose pattern for stationary single field at 213 cm (ionisation measurement) and depth dose pattern of 6 fields together at 213 cm (film density measurement) are shown.

DISCUSSION

The paper has outlined a case report in which traditional electron treatment was executed with a complex 6 overlapping fields. The present work has been reported with 3 objectives. Firstly, the clinical utility of 6 stationary electron fields, to provide homogeneous dose distribution for the treatment of skin flap in long extremity, is demonstrated. This type of plans give rise to complex junction effects, the degree of complexity increase when curved surfaces and penumbral effects are added. It was felt that the analogy of magna skin field irradiation (Stanford Technique 4) could be useful for dosimetry. With 6 fields at 60^{o} apart to each other, the dose distribution with good homogeneity (figure 4) was found acceptable. Solan *et al.* [8] describe the guidelines for selecting the quality of electron radiations (energy and type of skin lesions). Based on similar guidelines, a 9 MeV electron energy was selected to provide adequate treatment to tissue depths 3.0 to 3.5 cm (for a shell type gross tumour volume, figure 1). Tumour dose prescription was to 100%, which extends from depths 1 to 2 cm in tissue, and 80% dose line covering up-to a depth of 2.8 cm (figure 6).

The prescription of dose was to 100% dose percentile, accepting clinical range dose at 80% isodose. This report described, 3 different methods to calibrate the beam output. Two measurements with vertical beams in tissue equivalent plastic phantom, with plane parallel chamber and FC 65 chambers. The third method of measurement was by innovation using a locally available plastic can containing water to simulate the dimensions of leg. This method was necessary to find out the 6 field overlap factor. Our value of 2.315 for 6 field factor compares well with the factor 2.55 reported by Wooden *et al.* [7] and Stanford Technique factor 2.46 (using film dosimetry method) described by Gossman and Sharma [9].

Parallel plate chamber PPC 40 has estimated dose output 7% higher than the curved phantoms with both vertical and lateral irradiations (0.174 cGy/MU compared to 0.166 cGy/MU and 0.162 cGy/MU). Only parallel plate chamber is recommended for calibration of electron beams with energies less than 10 MeV by recent protocols [1,2]. As the electron dose output by calculation (from the 9 MeV output for this applicator) using inverse square law at 213 cm, was 0.163 cGy/MU which agreed well with the FC65 chamber measured value, this was used for patient treatment planning. The utility of leg phantom (plastic can) with water, simulating the dimensions of thigh and knee regions is explained for estimating 6 field overlap factor which also simulated real clinical situatio. Such methodology was not reported earlier in literature, and therefore present work assumes importance.

Thirdly, we report an estimated excess dose of 23% recorded by clinical dosimetry. The estimated results were based on 'TLD control dosimeter' receiving known dose on individual days (table 1). Therefore we accepted the dose estimates as true dose to skin, accepted after prolonged discussions in the department. To avoid excess skin reactions due to excess dose received in first 14 fractions, remaining dose was adjusted in succeeding 9 fractions at low dose/fractions (1.8Gy/fr). The depth dose pattern for single field with nominal energy 9 MeV with phantom on the floor gave a practical range of 4.30 cm estimating most probable energy of the beam as 8.87 MeV. The physics of electron beams

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indicate (Review Khan [4], Jayaraman and Lanzl [10], Klevenhagen *et al.* [11], Saunders and Peters [12] , Gagnon and Cundiff [13] that there will be increased scatter dose due to back scattered electrons due to high atomic number media interfaces, about 20-30% for energies around 10 MeV. Similar effect may be possible due to back scatter from floor and large angle scattering from air around. This may be one of the reasons for increased skin dose. As the clinical prescription was to 100% dose percentile, clinical range (80% reference isodose) occurring at a depth of 2.8 cm in water was found acceptable for this treatment.

Patient's leg was tilted to achieve 3 field centres 0 deg, ±60 deg in supine and prone positions of patient. The leg was immobilized at each treatment position individually. There may be possible overlaps in the edges of each field during patient's irradiation, but 6 field phantom film exposure, 60^o regular intervals was considered which deviate from field conditions. This may be one of the reasons leading to non-uniform overlaps of dose pattern. Moreover, the ion chamber was at 2 cm depth in the can phantom, whereas the positions of TL chips were on the skin surface to register low energy scatter electrons. In the dose uniformity measurements, Anacak *et al.* [14] reported dose inhomogeneities in skin doses in total skin electron therapy (TSET) as high as 15%. Their individual doses at the location of dorsum of foot are 123 ± 21 % of prescribed dose, the order of magnitude in skin doses are comparable to our present work.

CONCLUSION

This paper has highlighted the importance of clinical dosimetry to confirm the actual dose delivered to the patient during the execution complex treatment plans. Extensive studies to resolve this dosimetry problem encountered in the use of overlapping multiple electron fields and to explain the physics involved in such irradiation plan are recommended.

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Conflict of interest: *Declared none*

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