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Measurement of Radiation Abutment Dose for 6MV Photon and 9 MeV Electron Beam Combinations by GAFCHROMIC EBT3 Film at Extended SSD

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Abstract: To measure the radiation abutment dose for 6 mega voltage (MV) photon and 9 mega electron volt (MeV) electron beam combinations by gafchromic EBT3 film at extended source to skin distance (SSD). A point dose measurement was done to calculate monitor for delivering 100 cGy dose at 3cm depth in RW3 solid water phantom for 9 MeV electron beam. for 110 cm and 120 cm SSDseparately . Monitoring units (MU) were calculate to deliver a point dose of 50 cGy at 6 cm depth by 6 MV asymmetric beam. Plans were delivered separately on RW3 solid water phantom having gafchromic EBT3 film strips placed at 1, 2 and 3 cm depths. Followed by generating the calibration curve for EBT3 gafchromicfim, profiles at the abutment regions were analyzed by dosimetry software (FimQa pro, version 3.0, Ashland, USA). The value of hot spot and cold spot has increased with increasing electron beam SSD from 110 cm to 120 cm. Maximum value of hot spot for 110 and 120 cm SSD was 141.6% and 146.235 respectively at 2 cm depth whereas maximum value of the cold spot was 76.24% and 72.8% at 3 cm depth. Measurement of the abutment dose in extended SSD of electron beam needs to be evaluated for the adequate dose delivery to the patients in head and cancer as significant hot and cold spot has been observed.
Key Words: Abutment dose, EBT3 gafchromic film, extended source to skin distance ,RW3 phantom , FilmQa pro software.

I. INTRODUCTION

Radiotherapy is widely practiced modality either alone or in combination with chemotherapy in treatment of head and neck cancers. The common practice is to deliver up to 44-46 gray (Gy) to the posterior neck nodes following when field is downsized to exclude the spinal cord and further boost dose to the posterior neck node is delivered via electron beam fields In the conventional and three dimensional (3D) conformal radiotherapy of head and neck cancers, bilateral 6 mega voltage (MV) photon beam in combination with 9 mega electron volt (MeV) or 12 MeV electron beam at extended source to surface distance (SSD) of 110 cm to 120 cm is quiet often used where posterior cervical neck nodes and level 4 nodes are involved [1-3]. Combined (photon and electron) radiation dose up to 70-72 Gy is given in 35-36 fractions from the photon field and an electron field is used to deliver boost dose of 16-18 Gy in 8 – 9 fractions [4-6]. While delivering the electron field, anterior edge of the field is matched with the posterior edge of the 6 MV lateral field which results abutment region between the photon and electron field [7], which poses a challenge to deliver the uniform dose across the abutment region due to difference dosimetric and scattering property of photon and electron beam. Few researchers has investigated the problem of junction dose, a significant hot and cold spot has been reported by them across the junction [8].
Due to part of the shoulder of the patients coming into the electron filed and limitation of the machine and applicator, many times it's not possible to deliver the electron field at normal SSD of 100 cm therefore SSD of 110 cm to 120 cm are used to overcome this problem [9]. It has been reported most of TPS algorithms are not able to calculate the distribution of electron beam dose especially with extended SSD with desired accuracy. Though the effect of extended SSD has been studied by few authors by film dosimetry [9,10], but due to technological advancement in dose measuring tools there is a possibility to get better outcome of the similar study performed on a different linear accelerator such as Primus Plus of Siemens.

II. MATERIALS AND METHODS

A 6 MV parallel-opposed anterior-posterior (AP) / posterior-anterior (PA) fields of field size (X-5cm, X1-0, X2-5cm and Y-10cm)

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having asymmetric collimator were planned manually to deliver a dose of 1 Gy at 6 cm depth in a RW3 solid water phantom (PTW, Freiberg, Germany), density- 1.045gm/cc , electron density-1.012 relative to water and point dose calculation was done at the isocenter of 12 cm thick solid water phantom in a source to axis distance (SAD) set-up with gantry 0º by using 0.6 cc farmer chamber (PTW, Freiberg, Germany) following the International Atomic Energy Agency (IAEA) recommendations published in technical reports series number 398 (TRS-398) [11], and monitoring units (MU) were calculated to deliver 50 cGy dose .

Point dose calculation was also done for 110 cm and 120 cm SSD for a 9 MeV electron beam at 3 cm depth by parallel plate, Roos chamber (PTW, Freiberg, Germany) with an active volume of 0.35 cm^3 as per TRS-398 protocol and MU value has been calculated to deliver the 100 cGy dose at R80 (3cm) depth.

To measure the radiation abutment dose at 1, 2 and 3 cm depth in quoted RW3 phantom, 3 rectangular gafchromic film strip of size 2×15 cm^2 each, has been placed and pasted with micropore at the center of the phantom plates. Films were irradiated in SAD set up for the calculated MU, to deliver the dose of 50 cGy each from AP/PA fields. AP/PA fields are chosen (Figure-1) to reduce the set- up error and easy placement the film in a horizontal plane.

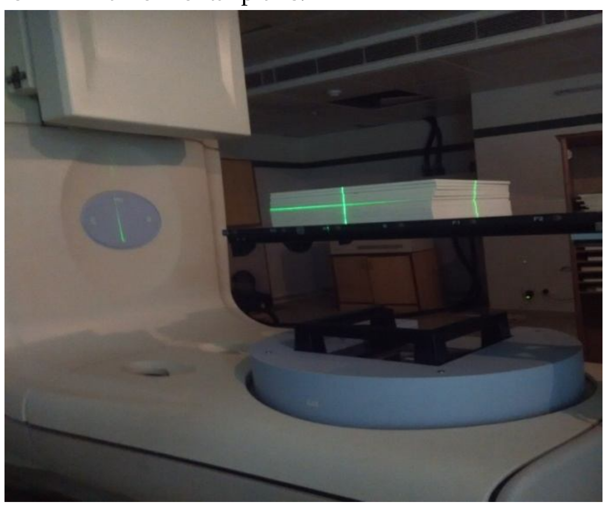

Figure 1: Anterior-posterior (AP) / posterior-anterior (PA) 6 MV photon field set-up on Linac (Primus Plus, Siemens, Germany)

Another manual plan of 9 MeV beam with an applicator of 10×10 cm^2, was delivered in the same phantom for SSD 110 cm to deliver the dose of 100 cGy at 3cm, in such a way that edged of the electron field is perfectly matched with the marked asymmetric field edge of 6 MV photon beam as shown in figure 2. Entire process has been repeated with electron SSD of 120 cm in place of 110 cm.

All gafchromic film pieces were labeled for their orientation and electron beam energy,ssd and depth of irradiation and kept in a small envelope for 48 hours as per the procedure described in the manual [12].

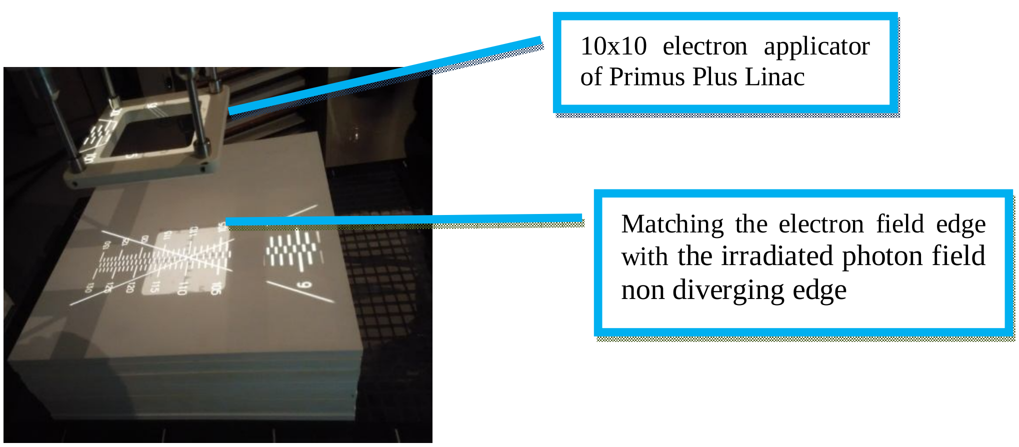

Figure 2: Set-up for irradiating the gafchormic EBT3 film with electron beam Applicator-10x10 cm^2, gantry-0, collimator-0 SSD-110 cm

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A. Dose measurement and analysis of the film

To generate the calibration curve, absolute dosimetry has been done for 6 MV photon beam of Primus Plus (Siemens, Germany) of our institute by following TRS 398 protocol in a RW3 solid water phantom. 0.6 cc farmer chamber (PTW, Freiberg Germany), has been placed at 5 cm depth with SAD 100 cm in the phantom with 10cm RW3 plates for back scattering , absolute dose was measured for 100 MU.

Twelve rectangular gafchromic film pieces of size 5×4 cm^2 from a single EBT3 film were cut. Length of the each piece was kept along the length direction of the film since the performance of the film is dependent of film orientation. Films were irradiated in the similar phantom geometry as we have used for calibration for the known doses of 25cGy to 300 cGy by 10x10 cm^2 field size of 6 MV photon beam One piece of the film is kept unexposed to measure 0 cGy. All exposed films were scanned by flat bed scanner (EPSON Expression 11000xL, Japan), in a landscape orientation, with a resolution of 72 dpi and color depth of 48 bit in transmission mode. Calibration curve has been plotted by film dosimetry software (fimQapro3.0 Ashland, USA,) by converting the dose to pixel value / optical density.

All irradiated rectangular films of the size 2×13 cm^2 irradiated by photon and electron fields were scanned by scanner (EPSON Expression 11000xL, Japan) in transmission mode with the similar setting as used for generating the calibration film. Dose across the junction has been measured by the Fimqapro 2016, film dosimetry software. A cross line profile across the junction of photon and electron field has been measured to find the high dose and low dose points and data have been tabulated. Magnitude and location of hot spot and cold spot has been evaluated, any dose value higher than 107 % is considered as hot spot and below 95% is considered as cold spot as defined by the International Commission on Radiation Units and Measurements (ICRU) in its report numbers 50 and 62 (ICRU, 193; 1999) [13,14].

III. RESULTS

The maximum value of hot spot was found to be 141.67 cGy at 2 cm depth which is 41.6% higher than the prescribed dose (100 cGy) and minimum value of hot spot was 126.6 cGy, 26.6% higher than the prescription dose. Location of hot spot from the junction line was 3.35, 3.5 and 5.3 mm adjacent to photon field for the 1, 2 and 3 cm depth respectively. Table 1 shows the variation in high dose and low dose value for the different depth in the solid water phantom for electron field SSD 110 cm.

The maximum value of cold spot value was 76.24 at 3 cm depth, 23.76% less than the prescribed dose which is significant, no cold spot was seen at 2cm depth however a cold spot of 91.2 cGy, 8.8% less than the prescribed dose has also been observed. Location of cold spot from the junction line was 1.94, 2.29 and 3.53 mm adjacent to electron field for the 1,2 and3 cm depth respectively.

Table 1: Variation of high dose and low dose across the junction of 6 MV photon and 9 MeV electron beam with depth for 110 cm SSD

Depth (cm)	High dose (cGy)	Location (mm)	Low dose (cGy)	Location (mm)
1.00	126.67	-3.50	91.20	1.94
2.00	141.67	-3.35	99.53	2.29
3.00	129.71	-5.30	76.24	3.53

The maximum value of hot spot was found to be 146.23 cGy at 2cm depth which is 46.23% higher than the prescribed dose (100 cGy) and minimum value of hot spot was 137.99 cGy, 37.99% higher than the prescription dose. Location of hot spot from the junction line was 4.1, 4.6, 6.5 mm adjacent tophoton field for the 1, 2 and 3 cm depth respectively.

The maximum value of cold spot was 72.78 cGy, 23.22% less than the prescribed value of the dose (100 cGy) at 3cm depth which is significant, the value of cold spot for 1 cm and 2 cm depths were 85.46 cGy and 93.52 cGy which were 14.54 % and 6.48% less than the prescribed dose of 100 cGy at 3cm depth. Location of cold spot from the junction line was 1.94, 2.29 and 3.53 mm adjacent to electron field for the 1, 2 and3 cm depth respectively.

Table 2: Variation in high dose and low dose value for the different depth in the solid water phantom for 6MV Photon and 9MeV field with SSD 120cm

Depth (cm)	High dose (cGy)	Location (mm)	Low dose (cGy)	Location (mm)
1.00	137.99	-4.10	85.46	1.44
2.00	146.23	-4.60	93.52	2.48
3.00	134.70	-6.50	72.78	2.32

Table 3 shows that there was increase in high dose points (hot spot) by 8.94%, 3.22%, 3.85% for the SSD 120 cm as compare to the value at 110 cm SSD.

Table 3: Comparative variation in high dose points (hot spot) for SSD 110 cm and 120 cm

	Value of high dose in cGy		
Depth(cm)	SSD-110cm	SSD-120cm	
1.00	126.67	137.99	8.94
2.00	141.67	146.23	3.22
3.00	129.71	134.70	3.85

Table 4, shows that there was decrease in low dose points values (cold spot) by 6.29%,6.04%,4.54% for the SSD 120cm as compare to the value at 110cm SSD that shows the increase in cold spot with increase in SSD

Table 4: Comparative variation in low dose points (cold spot) for SSD 110 cm and 120 cm

	Value of low dose in cGy		
Depth(cm)	SSD-110cm	SSD- 120cm	% difference
1	91.20	85.46	-6.29
2	99.53	93.52	-6.04
3	76.24	72.78	-4.54

IV. DISCUSSION

Location of the hot spot is towards photon side & location of cold spot is towards electron side it but the distance of the two increases with increasing SSD and this could be the result of more bulging of low dose isodose values with increasing SSD. Value of hot spot has increased due to increase in penumbra due to extended SSD as reported by Kukołowicz*et al.* [15]. Our results are in good agreement with the results presented by Kemikler *et al.* [16], as they have reported a hot spot of 140% at 2 cm depth for 100 cm SSD and our measured value of hot spot is approximately 142% for 110 cm SSD and 146% for 120 cm SSD. We found the significant variation in hot spot and cold spot values as compare to the results of khan *et al.* [17] for the similar kind of study as they have reported the hot spot value 20% and cold spot10% only. This could be because of measurement techniques, setup error etc.

V. CONCLUSION

Gafchormic EBT3 film along with filmqapro 3.0 dosimetry system is a very effective tool to measure the abutment dose with precision and accuracy. This study recommends measuring the abutment dose for the different extended SSD for the proper and acceptable dose delivery to the head and neck cancer patients. We, also suggest that the more realistic results can be achieved by conducting the study on head and neck phantom because the solid water phantom is a homogenous medium, whereas head and neck of the patient contain various tissues of different density and curvature.

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