DOSE MEASUREMENT OF TOTAL SCALP RADIATION TREATMENT USING LATERAL PHOTON-ELECTRON TECHNIQUE

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ABSTRACT

Purpose: To find the optimal abut or overlap area between photon-electron field and to measure superficial and intracranial dose using lateral photon-electron technique of total scalp radiation treatment.

Methods and Materials: CT scan of the Alderson Rando phantom was used in GE Target treatment planning system to find the optimal abut or overlap area between photon-electron fields. Each treatment fraction composed of two lateral-opposed fields of 6-MV photon (with square blocks) and two 9-MeV electron square fields. After the optimal plan was selected, film verification of the plan using solid water phantom instead of Alderson Rando phantom was performed. TLD chips were used to measure the intracranium and superficial skin dose of Alderson Rando phantom.

Results: Abutting photon-electron field resulted in 9-12 mm wide cold area along the junction. To compensate for this cold area, 6 to 7-mm overlapping between photon and electron irradiated field was applied in phase I of treatment and no overlapping photon-electron was used in phase II. This resulted in more homogeneous dose distribution. Film verification of the plan showed concordant result with the treatment planning system. By using TLD measurement, the average doses at frontal lobe, corpus collosum and parietal lobe relative to prescribed dose were 19.2, 12.3 and 10.9 %, respectively. The superficial skin doses at vertex and forehead relative to prescribed dose were 99 and 113.5 %, respectively.

Conclusion: Overlapping electron-photon field using square block in phase I and abutting electron-photon fields using square block in phase II were suggested as a useful technique to deliver homogeneous skin dose while avoiding the radiation dose to the underlying brain. The adaptability of the suggested photon block and electron insert has a great advantage and increases the convenience for clinical service. Since the distance between abutting and overlapping junction is very small, care must be taken in the setting up and the immobilization of the patient's head in the treatment room.

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INTRODUCTION

Tumor of scalp is occasionally seen. It has many histological subtypes such as squamous cell carcinoma, angiosarcoma, melanoma and cutaneous lymphoma. Among these suptypes, angiosarcoma spreads transdermally for far wider than clinical appearance.[1] Surgical resection is unsuccessfully performed in such a widespread lesion. In this case, radiation therapy is the treatment of choice. The goal is to give a homogeneous dose distribution to the superficial scalp. This is quite difficult to achieve because of complex shape of the head. Moreover, the underlying brain should receive minimal radiation dose.

The lateral-opposed photon field with enough bolus is the simple technique which can provide adequate radiation dose to the scalp. Lead block is used to protect vital structures such as eyes. However, this technique irradiates too much of underlying normal brain.

A variety of radiotherapy techniques, including matching parallel-opposed photon and electron fields,[2,3] abutting electron fields,[4,5,6] and remote-controlled afterloading high-dose-rate (HDR) mold brachytherapy,[7,8] were suggested to overcome the inhomogeniety of dose. Yaparpalvi[6] proposed different energy electron beams as a simple alternative for achieving dose homogeniety. Also, intensity modulated radiation therapy (IMRT) has the potential for delivering homogeneous dose distribution to the scalp. However, Locke[9] reported that IMRT using tomotherapy resulted in a higher dose to the lens, brain, and orbit when compared to conventional lateral photon -electron technique. Electron arc or pseudoarc therapy used in breast irradiation[10,11] was not well established in scalp irradiation.

Because some techniques are complex and involve field matching problem, or may require sophisticated equipment such as IMRT; we then choose conventional parallel-opposed photon and electron fields proposed by Akazawa[2] and Tung[3] for treatment in our institution. Akazawa suggested no overlap area between photon and electron match line. While Tung suggested that electron field should overlap the photon field by approximately 3-4 millimeters to obtain more uniform dose distribution at the junction region. To alleviate the problem of overdose and under dose at the match line or overlap area, shifting of the junction was suggested. Both studies were performed in computer planning and in vivo measurement.

Regarding the different dose prescriptions, beam energy and set-up in our institution; we aimed to find the optimal abutting or overlapping edge which obtain a uniform dose distribution in the junction area and to use this technique as a class solution for irradiation of total scalp. The intracranial absorbed dose measurement was also reported.

MATERIAL AND METHOD

Since this is an experimental study and we would like to know the intracranial absorbed dose, The Alderson Rando® Phantom (The Phantom Laboratory, Salem, NY) was used to assess the in vivo dose distribution. Thermoplastic mask (MED TECH co.) was used to fix the phantom head in supine position.

Three-dimensional (3D) computed tomography of the Alderson Rando Phantom was obtained for treatment planning purpose. The treatment planning system is GE Target. To facilitate the set-up and ensure reproducibility; the 6-MV photon and 9-MeV electron fields, from Varian Clinac 1800, shared the same field center. A 100-cm source-to-surface (SSD) technique was implemented.

For the photon fields, fix-sized rectangular field (19x18 cm^2) was utilized. Fall-off at anterior, posterior and vertex of the head was confirmed for adequate skin flash. Caudal border was set up at the bottom of C2 vertebral body. Square-shaped cerrobend blocks, 7.2x7.2, 8.4x8.4 and 9.8x9.8 cm^2, were made for photon shield at the center of the fields and must be symmetrical bilaterally. In the treatment planning system, these square-shaped cerrobend blocks were virtually created. For the electron fields, fix-sized square fields of 7.2x7.2, 8.4x8.4 and 9.8x9.8 cm^2 were created.

Each treatment fraction composed of two lateral-opposed fields of 6-MV photon and two 9-MeV electron fields. To avoid dose to the underlying brain, the photon fields were used to encompass median sagittal strip of the scalp while the electron fields irradiated central part of the lateral scalp as demonstrated in figure 1. Photon and electron doses were prescribed at the surface. The total dose of photon beam at surface was equal to the transit plus exit dose. Electron dose was then weighted and must be equal to total dose of photon beam. The prescription dose was 2 Gy per fraction. A 1.5-cm bolus was placed at each side of the scalp of Alderson Rando Phantom to bring the maximum dose to surface of the scalp. If the junction was shift, it would shift equally and divide the total dose into two phases.

Four types of the junctions were planned. First, non-overlap junction; photon block was equal to eletron field. Second, non-overlap junction with shifted junction; the same size of photon block and electron field was used in phase I and junction shift toward center of the field was used in phase II by reducing the size of photon block and electron field. Third, overlap junction; electron fields were larger than photon block. Fourth, overlap junction in phase I followed by non-overlap junction in phase II. A photon block which was smaller than the electron field was used in phase I, while a photon block which was equal to the electron field was used in phase II.

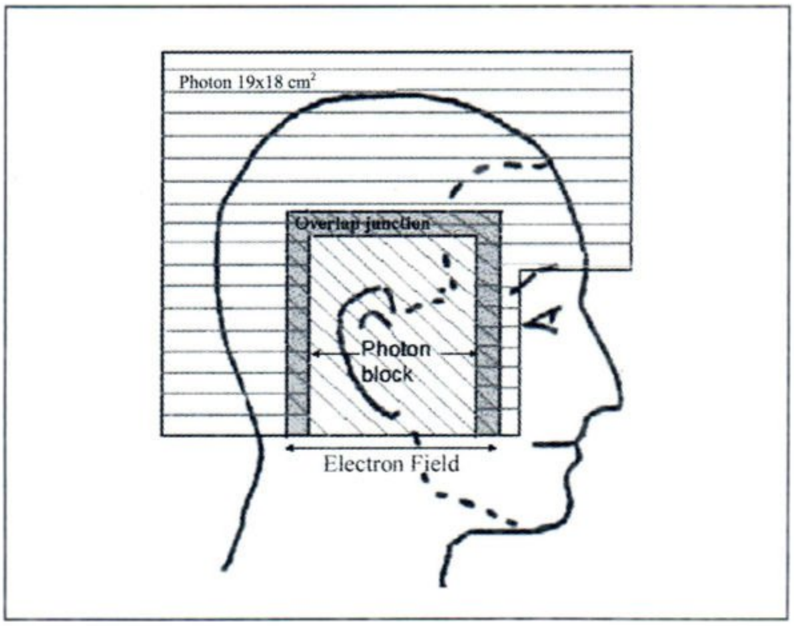

Fig.1 Shows the photon and electron fields irradiate to Alderson Rando Phantom. Horizontal line represents the photon fields while diagonal line represents electron field. Shade area represents the photon-electron overlap.

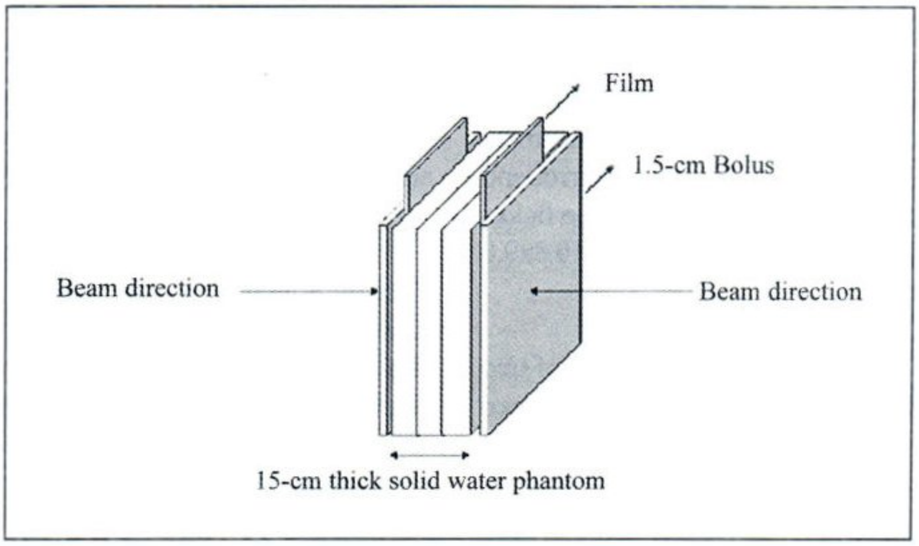

Fig.2 shows setting up solid water phantom for plan verification.

To verify the accuracy of treatment plan and to verify the hot and cold area; a solid water phantom with separation of 15 cm (same separation as Alderson Rando Phantom) was used for the treatment verification. The fields used in the treatment verification had the same geometry and accessories as their counterparts in the original Alderson Rando Phantom-planning plan. Kodak X-Omat V films were placed at both sides of solid water phantom. The films were then covered with 1.5-cm bolus bilaterally as shown in figure 2.

LiF TLD-100 chips were used to measure absolute dose on the skin surface and the intracranium of Alderson Rando Phantom. The existing regularly-spaced cavities in the intracranium of Alderson Rando phantom were used as measurement locations. At each measurement location, the absorb doses were read and averaged from the TLD chips. The linearity of TLD chips were calibrated for dose measurement between 150 and 300 cGy. To verify the stability of TLD chips, the standard group of TLD chips was irradiated with 100 cGy of 6-MV photon. Both the standard group and the study group TLD chips were read at the same time. The accuracy of the TLD dose measurements in this study was estimated to be ± 5 %

RESULTS

Using treatment planning system, we try to find the optimal overlap between photon and electron fields that gave the most homogeneous dose distribution (i.e., minimize the cold and hot area). The good junction composed of phase I and phase II altogether.

The acceptable range of uniform dose distribution at the junction in our experiment was 100 ± 10 % of the prescribed dose. Strip of cold and hot area beyond the acceptable range at the field junction was measured.

Table 1 demonstrates average cold area of non-overlap junction.

Experiment	Photon block (cm2)	Electron field (cm2)	Average cold area (mm)
No overlap 1	7.2x7.2	7.2x7.2	12
No overlap 2	9.8x9.8	9.8x9.8	9

Table 2 demonstrates average cold area of non-overlap junction with shifted junction

	Phase I		Phase II		Cold Area
experiment	Photon block (cm2)	Electron field (cm2)	Photon block (cm2)	Electron field (cm2)	Average (mm)
No overlap 1	8.4x8.4	8.4x8.4	7.2x7.2	7.2x7.2	12
No overlap 2	9.8x9.8	9.8x9.8	8.4x8.4	8.4x8.4	13.5

Non-overlap junction and no junction shift

Photon block and electron field at the same size were chosen (Table 1). This resulted in an abutment of photon and electron field. No junction shift was used. As expected, a cold area (i.e.,<90 % of the prescribed dose) of 9 to 12 mm wide along the field junction was observed.

Non-overlap junction with shifted junction

Subsequently, photon block and electron field at the same size were used at phase I. Junction shift toward center of the field was used in phase II by reducing the size of photon block and electron field (Table 2). Again, there was a cold area of 12 to 13.5 mm wide at the field junction.

Overlap junction

In this experiment, we tried to decrease cold area by making overlap between photon fields using 8.4x8.4 cm^2 square block and 9.8x9.8 cm^2 square electron field without junction shift (Table 3). Unfortunately, this process resulted in hot area for an average of 19 mm wide.

Table 3 demonstrates average hot area of overlap junction.

Experiment	Photon block (cm^2)	Electron field (cm^2)	Average hot area (mm)
overlap 7 mm	8.4x8.4	9.8x9.8	19

Table 4 demonstrates average cold or hot area when there was photon-electron overlap in phase I but no overlap in phase II

	Phase I	Phase II	Cold or hot		Area
Experiment	Photon block (cm^2)	Electron field (cm^2)	Photon block (cm^2)	Electron field (cm^2)	Average (mm)
Overlap 6 mm	7.2x7.2	8.4x8.4	8.4x8.4	8.4x8.4	0
Overlap 7 mm	8.4x8.4	9.8x9.8	9.8x9.8	9.8x9.8	0

Overlap junction and junction shift

In this experiment, we applied junction shift at the middle of treatment course. The overlap of photon-electron field was used in phase I. Nevertheless, there was no overlap of photon-electron field in phase II. This reduced the hot area and did not create any new cold area. The sizes of photon blocks and electron fields are shown in Table 4.

Film verification

According to the results of the above experiments (overlap 6 and 7 mm), film dosimetry was undertaken in the solid water phantom as described previously. Irradiated films were developed and scanned. Optical density was measured and interpreted. The relative dose at the field junction was concordant with the treatment planning result. Homogeneous dose distribution along field junction was observed.

Absolute dose measurement

Optimal plans from table 4 were used for irradiation of the Alderson Rando phantom. TLD chips were placed in the intracranium of the phantom. The TLD chips measured the absorbed dose in the position representing frontal lobe, corpus collosum, parietal lobe, occipital lobe and cerebellum. The absorbed doses were normalized to prescribed dose. The average doses at frontal lobe, corpus collosum and parietal lobe were 19.2, 12.3 and 10.9 %, respectively. These areas were under the photon block. Doses at occipital lobe and cerebellum were 74.3 and 96.5 %, respectively. These areas absorbed the dose from the photon fields (parasagittal region).

TLD chips were also placed at the skin surface at vertex and forehead. The corresponding doses were 99 and 113.5 %, respectively. These areas received dose exclusively from bilateral opposed photon field.

DISCUSSION

Total scalp irradiation is a challenging procedure because of complex shape of the head. Various treatment techniques were suggested to ensure dose uniformity along scalp while minimizing dose to the underneath brain. Abutting electron field technique,[4,5,6] electron arc therapy,[10,11] mould brachytherapy[7,8] and IMRT[9] are labor intensive and require sophisticated equipment. The current study proved that even simple technique using bilateral opposed photon-electron matching beams can produce dose homogeneity. This technique required a wax bolus placing over the scalp in order to bring the dose to the skin. Field shifting is usually applied to minimize hot spot.

The drawback of this technique is that it requires the accuracy on the process of cut block, making photon shield and daily setup. Moreover, the treatment was divided into 2 phases by shifting the overlap junction. The overlap of photon-electron field in phase I resulted in hot spot in the junction area while the non-overlap of photon-electron field in phase II resulted in cold spot in the same area. Thus, the biological effect on the junction would not be uniform on the daily basis. To minimize the non-uniform dose based on biological effective dose, two-phase treatment on the same day (i.e., prescribed 1 Gy from phase I and 1Gy from phase II) would result in more biologically uniform dose. However, trade off between the setup time and the biological effective dose should be considered. An alternative way is to deliver the dose in phase I and II on alternate day fashion.

The optimal overlap of photon-electron field in our study is 6 mm. This figure was different from 3.5 ± 1 mm reported by Tung.[3] However, Locke[9] discovered that an additional margin of overlap was required over the posterior vertex area. The difference could be explained by the disagreement of the electron energy from different machine, technique and different bolus thickness among the studies.

Tung[3] reported that 10% of the brain received dose more than 45 Gy (prescribed dose = 55 Gy). While Locke[9] reported 20% of brain received dose more than 20 Gy (prescribed dose = 50.4 Gy). In this study, although, we did not calculate the dose volume histogram, but our result showed that high dose region was limited to the area irradiated exclusively by bilateral photon fields. The dose to the brain depends on size of the photon block; the larger the photon block, the less dose to the brain.

Making photon blocks and electron metalloid inserts requires experience. A 3-4 mm difference in width of the round-shape block is hardly met. This meant that the block itself would be even very small difference in size and prone to setup error. Our solution was to make a 6-7 mm difference in width of the blocks and electron inserts between phase I and II. Three square photon shields at 7.2x7.2, 8.4x8.4 and 9.8x9.8 cm^2, and three electron inserts at 7.2x7.2, 8.4x8.4 and 9.8x9.8 cm^2 are recommended to be used in clinical service. Matching of photon block and electron inserts was chosen based on sizes of the patients' heads. Special care must be given for radiation therapist in setting up and immobilizing patients' heads in the treatment room so as to decrease random error along the field junction.

CONCLUSION

Total scalp irradiation is a rare indication in clinical service. Abutting electron-photon fields using square block was suggested as a useful technique to deliver homogeneous skin dose while avoiding dose to underlying brain. The adaptability of the suggested photon block and electron insert has a great advantage and increases the convenience for clinical service.

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REFERENCES

1. Rosai J, Sumner HW, Major MC, et al. Angiosarcoma of the skin. Hum Patho 1976; 7(1): 83-109
2. Akazawa C. Treatment of the scalp using photon and electron beams. Med Dosi 1989; 14(2):129-131
3. Tung SS, Shiu AS, Starkschall G, Morrison WH, Hogstrom KR. Dosimetric evaluation of total scalp irradiation using a lateral electron-photon technique. Int J Radiat Oncol Biol Phys 1993 Sep; 27(1):153-160
4. Able CM, Mills MD, McNeese MD, Hogstrom KR. Evaluation of a total scalp electron irradiation technique. Int J Radiat Oncol Biol Phys 1991 Sep;21(4):1063-1072
5. McKenzie AL. A simple method for matching electron beams in radiotherapy. Phys Med Biol 1998 Dec;43(12):3465-3478

6. Yaparpalvi R, Fontenla DP, Beitler JJ. Improved dose homogeneity in scalp irradiation using a single set-up point and different energy electron beams. Br J Radiol 2002 Aug;75(896): 670-677
7. Ozyar E, Gurdalli S. Mold brachytherapy can be an optional technique for total scalp irradiation. Int J Radiat Oncol Biol Phys 2002 Nov; 54(4):1286-1288
8. Nakamura R, Harada S, Obara T, Ehara S, Yoshida A, Akasaka T, et al. Iridium-192 brachytherapy for hemorrhagic angiosarcoma of the scalp: a case report. Jpn J Clin Oncol 2003 Apr; 33(4):198-201
9. Locke J, Low DA, Grigireit T, et al. Potential of tomotherapy for total scalp treatment. Int J Radiat Oncol Biol Phys 2002 Feb; 52(2): 553-559
10. McKenzie MR, Freeman CR, Pla M, Guerra J, Souhami L, Pla C, et al. Clinical experience with electron pseudoarc therapy. Br J Radio 1993 Mar, 66:234-340
11. Leavitt DD, Peacock LM, Gibbs FA, et al. Electron arc therapy: physical measurement and treatment planning techniques. Int J Radiat Oncol Biol Phys 1985; 5:987-995