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Improving the matching of photon and electron fields for Inverse Hockey Stick Technique (IHS technique)

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Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Data Interpretation
E Manuscript Preparation
F Literature Search
G Funds Collection

Summary

Background The problem of geometrical aspects of field matching was investigated very extensively in 80's and earlier. In the 90's accelerators were equipped with asymmetric jaws that solve the problem in most cases. However, it is still not possible to have homogeneous dose distribution in the matching region if two beams with different penumbra are matched, which is the case if a photon beam and an electron beam are matched.

Aim To improve the matching of photon and electron fields in IHS technique with individual block.

Materials/Methods Three individual blocks made from Wood's alloy were designed with the angles of the lateral wall at 2.2, 6.5 and 9.0 degrees. Profiles of photon beams of the energy of 6MV were measured on a Mevatron KD2 with a PTW field analyser with diamond detector for the typical beam size used in the IHS technique ($20\times20cm^2$). The measurements were performed for open beam and for beam modified with all blocks at depths of 1, 2, 3, 4 and 5cm. The SSD was 100cm. Profiles of the electron beams were also measured. Measurements were carried out for field size of $15\times15cm^2$. The measurements were carried out for 9, 12 and 15MeV electron beams with a PTW field analyser in the water phantom with Markus chamber, type 23343. The SSD was 100cm. For each electron energy measurements were performed at 1, 2, 3, and 4cm at depths up to 80% of distal isodose depth, i.e. at 1, 2 and 3cm, at 1, 2, 3 and 4cm, and at 1, 2, 3, 4 and 5cm for 9MeV, 12MeV and 15MeV, respectively. The penumbra width was obtained. The measured data were saved in digital form. By means of spreadsheet the sum of dose distributions of each electron field and each photon field was calculated.

Results The penumbra of the photon beams was changed by application of the individual block. The larger the angle of the lateral wall of the block, the larger was penumbra width. For the largest angle block the penumbra reached almost 14mm at 40mm depth. For blocked fields the 50% profile did not coincide with the light field edge. The larger the angle of the lateral wall of the block, the more the 50% profile value was moved outside of the light field edge. Application of the modified block decreased the difference between the maximum and minimum dose in the matching region by about 10%.

Conclusions The proposed technique of modifying the photon beam penumbra allows the dose distribution in the join-up/overlap region to be improved.

Key words **field matching • modification of beam penumbra • inverse hockey stick technique**

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Background

One of the most important aims of treatment planning is to achieve a homogeneous dose distribution within the Planning Target Volume (PTV). If a conventional technique is applied all portals cover the PTV entirely. In such cases the homogeneous dose distribution is usually obtained by means of setting appropriate weights to individual beams and/or by modifying the dose distribution of the individual beams by wedges or compensators. In some cases, however, for some reasons only a part of the PTV is covered with each single beam. In this case not only appropriate weights must be defined and right modifiers must be used but also the geometry of all beams must be defined, which allows homogeneous dose distribution in the matching region to be received. The problem of geometrical aspects of field matching was investigated very extensively in 80's and earlier, mainly for patients suffering from Hodgkin's disease treated with so-called mantle technique with photon beams [1,2]. Later the problem was extensively investigated for craniospinal irradiation in leukaemia and medulloblastoma patients [3]. These days the divergence of the therapeutic beams makes it possible to obtain the homogeneous dose distribution only at one depth in the patient's body. In the 90's accelerators were equipped with asymmetric jaws that solve the problem in most cases. However, it is still not possible to have homogeneous dose distribution in the matching region if two beams with different penumbra are matched. This is the case if a photon beam and an electron beam are matched (e.g. tumours of the head and neck and craniospinal irradiation with photon and electron fields) [4,5]. The penumbra of a photon beam is at least two times smaller than an electron beam. This situation applies also in the so-called inverse hockey stick technique (IHS technique) which is applied for irradiation of the chest wall and supraclavicular lymph nodes for patients after radical mastectomy. In Figure 1 the typical geometry of these beams is shown. As was shown by Kukolowicz et al. and by Pierce et al. this technique enables the heart and the lung to be spared from radiation very effectively [6,7]. The disadvantage of this technique is the very long matching line of the electron and the photon beams and all related consequences. A more homogeneous dose distribution may be obtained by increasing the penumbra of the photon beam. Papiez et al. modified a photon beam penumbra by application of a stepped block [8]. For technical reasons it is difficult to apply this technique in the clinic.

Aim

In the paper a method of changing the photon beam penumbra by applying an individually designed block is proposed. The influence of applying an individual block on the dose distribution in the matching region for the IHS technique is analysed.

Materials and Methods

Three individual blocks made from Wood's alloy were designed with the angles of the lateral wall at 2.2, 6.5 and 9.0 degrees (the α angle). In Figure 2 the shape of the blocks is presented. The height of the blocks was 8cm, which allowed attenuation of the primary beam to less than 4% of its initial value. Profiles of the photon beams of the energy of 6MV were measured on a Mevatron KD2 with a PTW field analyser. The measurement geometry is presented in Figure 2. The source-phantom surface distance was 100cm. Measurements were carried out for a square field of size 20×20cm^2. The block was placed on the standard block tray at 58cm distance from the source The edge of the block was always placed on the central axis parallel to one of the jaws. Measurements were performed with the

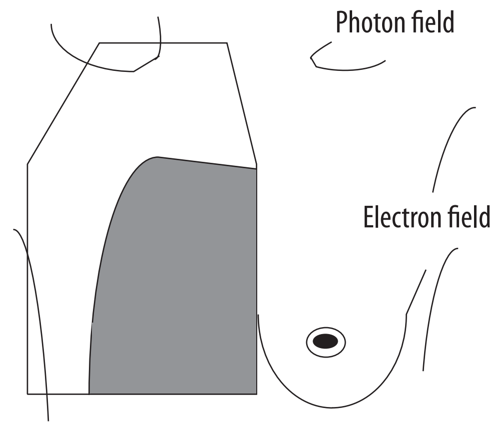

Figure 1. Beam geometry for postmastectomy irradiation with IHS technique.

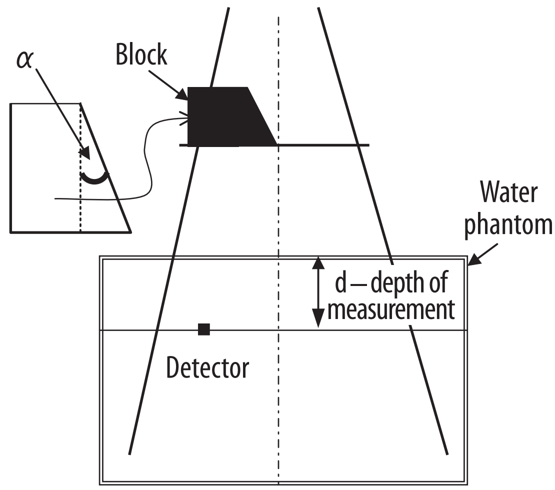

Figure 2. Modified block and geometry of measurements.

diamond detector PTW-Freiburg/IPTP-Dubna, Type 60003 at 1,2, 3, 4 and 5cm depth in the water phantom. Profiles for asymmetric open photon field of 10×20cm^2 at 1, 2, 3, 4 and 5 cm depth were also measured. The jaw perpendicular to the measurement direction was placed on the central axis. Profiles were saved in digital form and normalized to the dose at the mid-point between the edges of the beam. Profiles of the electron beams were also measured. Measurements were carried out for the typical field size used for irradiation of the chest wall with IHS technique which is 15×15cm^2. The measurements were carried out for 9, 12 and 15MeV electron beams with PTW field analyser in the water phantom with Markus chamber, type 23343. The SSD was 100 cm. For 9MeV measurements were performed at 1, 2 and 3cm, for 12MeV at 1, 2, 3 and 4cm depths, and for 15MeV at 1, 2, 3, 4 and 5cm depths (for each energy at depths up to 80% of distal isodose depth). Both measurements for photons and electrons were carried out with a 0.1mm grid. All electron profiles were normalized to the dose at the central axis and saved in digital form. For each profile, both electron and photon fields, the penumbra width was obtained.

The accuracy of the measurements was defined in terms of distance to agreement. It was 0.2mm for photons and 0.3mm for electrons (1 standard deviation).

By means of Excel spreadsheet the summary dose distribution of each electron field and each photon field was calculated. All electron profiles for one energy were normalized at its depth of maximum dose. The photon beams were normalized to the maximum, i.e. to 100% at 1.6cm depth at the mid-point between the light edges of the beam. The distance between the photon and the electron fields was set to have as homogeneous dose distribution as possible at 2cm depth. The uniformity of the dose distribution was described separately for each pair of electron and photon beams by the difference between the maximum and minimum dose in the matching region. These dose distributions were compared with the dose distribution calculated for the appropriate electron beam and for the asymmetric open photon beam of 10×20cm^2.

Results and Discussion

In Figure 3 profiles of open asymmetric photon beam and the photon beam modified with blocks at 2cm depth are presented. In Table 1 the width of penumbra of the photon beams is presented at depths of 1, 2, 3, 4 and 5cm.

The penumbra width depended slightly on the depth. The greater the depth of the measurement, the larger was the penumbra width. The difference in the penumbra width at all depths of measurements was less than 2mm. The larger the angle of the lateral wall of the block, the broader was the penumbra width. For the smallest value of the lateral wall of the block the penumbra width did not differ from the penumbra for the open beam. For the largest value of the lateral wall of the modified block the penumbra

Table 1. Penumbra width for 6MV photon field and for 9, 12 and 15MeV electron beams at different depths.

Depth (cm)	1	2	3	4	5
X6MV open	4.8mm	5.1mm	5.3mm	5.5mm	5.8mm
X6MV block 2.2 deg	4.7mm	4.7mm	5.1mm	5.6mm	6.2mm
X6MV block 6.5 deg	7.0mm	7.0mm	7.3mm	7.9mm	8.6mm
X6MV block 9.0 deg	12.1mm	11.8mm	12.2mm	13.0mm	13.6mm
electr. 9MeV	9.9mm	14.6mm	18.2mm		
electr. 12MeV	8.1mm	11.1mm	16.3mm	21.1mm	
electr. 15MeV	7.0mm	9.2mm	13.2mm	18.3mm	23.1mm

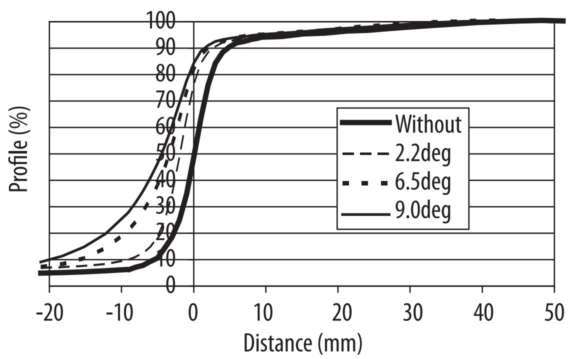

Figure 3. Profiles for asymmetric open and modified photon field at 2cm depth. Light field edge there is at zero position.

width reached almost 14mm at 50 mm depth. For blocked fields the 50% profile did not coincide with the light field edge, which was at zero position in all situations. The larger the angle of the lateral wall of the block, the more the 50% profile value was moved outside of the light field edge. For the largest angle block the 50% profile value was displaced by about 4mm outside the light field. For the smallest angle block the 50% profile value was displaced by less than 2mm. Similar results are observed for wedged fields, especially for wedges of large angle on the thick side of the wedge. The influence of the modified block on the profile shape in the open part was very small.

In Table 1 the width of the penumbra of the electron fields is given. For all energies the penumbra width depends strongly on the depth. The greater the depth, the larger was the penumbra width. At 1cm depth the penumbra was about 6–8mm smaller than the penumbra width at 3cm depth. At the depth of 20mm, where the dose distribution for electron fields of energy 9, 12 and 15MeV is very close to its maximum, the penumbra width was 15, 11 and 9mm, respectively.

Due to large changes in the electron beams' penumbra and very small changes in the penumbra of photon beams with depth it is not possible to match both beams perfectly at all therapeutic depths. The smallest differences in the penumbra width for electron and photon beams at 2cm depth were received for the photon beam modified with the block of the largest wall angle. For this block the penumbra width was 11.8mm. For electron beams of energy 9, 12 and 15MeV the penumbra widths were 14.6, 11.0 and 9.1mm. In Figure 4 the summed dose distributions from electron beams and the photon beam modified with the 9 degree angle block are presented. In Table 2 for each pair of electron and photon beams the maximum and minimum dose are shown.

The results reveal that application of the modified block allows improvement of the homogeneity of the dose distribution in the matching region. Block application allows a decrease of the difference between the maximum and the minimum dose by more than 10%. The difference between maximum and minimum dose depends very much on which range of electron beam was treated as the therapeutic one, in other words what minimum dose is accepted in an individual radiotherapy department. If the 80% range was treated as the therapeutic one (the R80 for 9, 12 and 15MeV is about 3, 4 and 5cm, respectively) the difference between the maximum and the minimum dose exceeds 40% for the set with the open asymmetric photon beam and about 30% for the set with the modified photon beam. If the 90% range was the therapeutic one the difference for both sets of beams was smaller by about 10%. In all cases the over- and underdose regions are very small. According to ICRU

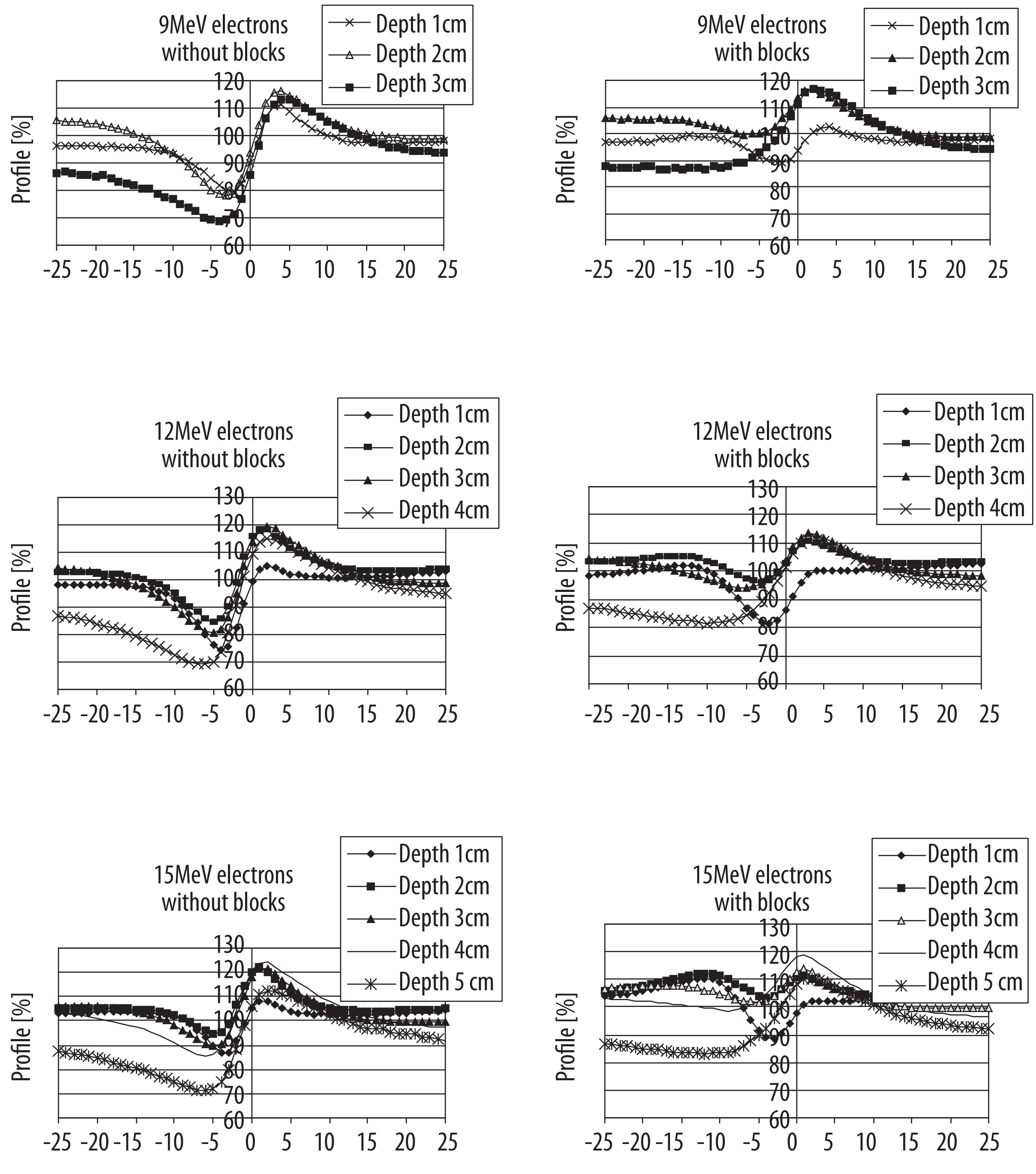

Figure 4. Comparison of dose distribution in the matching region for 9, 12 and 15MeV electron beams and 6MV photon beam with and without block. Electron beams are always on the negative side of the axis. easurements.

Report 71 the requirements regarding dose homogeneity for the dose distribution for electron field plans are kept the same as for photon beam plans – the doses delivered to the PTV should be in the range of 95% to 107% [9]. However, in the Report it is said that for electron field plans less strict requirements may be accepted. The review of Polish clinical practice regarding the application of electron beams reveals that 80%, 85% and 90% therapeutic ranges are applied. In our institution for the IHS technique the 90% isodose as the envelope isodose is applied. For this therapeutic range the difference between the maximum and the minimum dose for unmodified and modified geometry is 32% and 20%, respectively.

Table 2. Minimum and maximum doses in the matching region for 9, 12 and 15MeV electron beams and 6MV photon beam with 9 degree block and without block.

Depth (cm)	1		2		3		4		5	
	min	max	min	max	min	max	min	max	min	max
9MeV without block	79.3%	111.0%	78.0%	116.1%	69.1%	113.2%				
9MeV with block	89.4%	102.4%	99.5%	116.5%	86.5%	116.5%				
12MeV without block	74.8%	105.1%	84.6%	118.4%	80.6%	119.6%	69.2%	114.9%		
12MeV with block	81.3%	102.1%	96.0%	110.7%	93.9%	113.2%	81.7%	113.4%		
15MeV without block	87.1%	108.2%	94.8%	122.0%	87.9%	121.6%	85.6%	124.1%	71.3%	112.6%
15MeV with block	88.2%	110.2%	103.6%	111.8%	101.8%	113.7%	98.6%	118.6%	83.3%	110.4%

The IHS technique is used in many radiotherapy departments due to the good sparing effect of the heart and lungs. The latter organ is especially well spared if an individual bolus is designed [6]. The disadvantage of the technique is its poor dose uniformity in the matching region. Application of the modified block enables much better dose homogeneity to be achieved, but one must remember that the dose distribution is sensitive to geometrical errors. It is obvious that the technique is more sensitive the larger is the difference between the penumbras of the photon and the electron beams. Therefore application of the modified block again improves the technique. Analysis of the dose distribution calculated with treatment planning system (TMS ver. 6.1) for a geometry without block shows the hot spots at depths larger than 7mm so the skin is not exposed to high danger of injuries. The most sensitive structures are at depths less than 5mm [10].

From a technical point of view producing an individual block with a wall of 9 degrees is not difficult and may be achieved with commercially available block cutters (the further from the central axis a block is placed, the larger is the angle of a block wall). The only thing that must be done is to move the block shape for cutting an appropriate distance in the direction of the opposite corner of the field. The distance may be calculated based on simple mathematics. Placing a block on a block tray one must remember that there must be a gap of about 4mm between the shadows of the photon block edge and the electron shape forming the cut-out at the patient skin. This is because for a photon modified beam with a block there is no coincidence between 50% of the profile and light field (see Figure 3). The best match is obtained if both therapeutic fields are matched at 50% profiles. Unfortunately there is no commercially available treatment planning system which allows calculation of dose distribution for a modified photon block beam. On the other hand the modified block influences the dose distribution in the matching region only. The dose distribution is not influenced in the remaining part of the beam. The right position of the block may be defined by means of measurements of summed dose distributions of electron and photon beams with a film performed for the first few patients.

One should emphasize that the proposed modifying technique may also be applied in all cases when there is a need to match two photon fields. It may be effectively used for example for matching of tangential and supraclavicular fields for irradiation of breast cancer patients.

Conclusions

The proposed technique of modifying the photon beam penumbra allows improvement of the dose distribution in the join-up/overlap region of the electron and photon beams. The technique is easy to implement in daily routine clinical practice, but one must pay close attention to the proper placing of photon and electron blocks.

References:

1. Armstrong DI, Tait JJ: The matching of adjacent fields in radiotherapy. Radiology, 1973; 108: 419–22

2. Garavalglia G: Field separation of adjoining fields. Med Phys, 1981; 8: 882–4
3. Holupka EJ, Humm JL, Tarbell NJ, Svensson GK: Effect of set-up error on the dose across the junction of matching cranial-spinal fields in the treatment of medulloblastoma. Int J Radiat Oncol Biol Phys, 1993; 27(2): 345–52
4. Michalski JM, Klein EE, Gurber R: Method to plan, administer, and verufy/verify supine craniospinal irradiation. J Appl Clin Med Phys, 2002; 4: 310–6
5. Dobbs J, Barret A, Ash D: Practical radiotherapy planning, 3rd edition, Arnold, pp. 72–4
6. Kukolowicz P, Wieczorek A, Selerski B, Kuszewski T: The modified inverse hockey stick technique for adjuvant irradiation after mastectomy. Nowotwory, 2004; 54: 481–7
7. Pierce LJ, Butler JB, Martel MK et al: Postamastectomy radiotherapy of the chest wall dosimetric comparison of common techniques. Int J Radiat Oncol Biol Phys, 2002; 55: 1220–30
8. Papiez E, Dunscombe PB, Malaker K: Matching photon and electron fields in the treatment of head and neck tumors. Med Phys, 1992; 19: 335–41
9. International Commission on Radiation Units and Measurements. ICRU Report 71. General Recommendations for Prescribing, Recording, and Reporting External-Beam Therapy. Report 71, Bethesda, MD: ICRU, 2004
10. Archambeau JO, Pezner R, Wasserman T: Pathophysiology of irradiated skin and breast. Int J Radiat Oncol Biol Phys, 1995; 31: 1171–85