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ORIGINAL ARTICLE

The dosimetric effect of asymmetric collimator misalignment on matched half beam blocked fields

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Summary

Purpose: *The purpose of this study was to assess the dosimetric effect of the asymmetric jaw misalignment on the junction region for 6 MV photon beams.*

Materials and methods: *Dose uniformity was measured at the junction with film dosimetry. The Kodak X-Omat V film was exposed in a solid water phantom at* 0^0 *and* 180^0 *collimator position for exact matching. This procedure was repeated for 1 mm, 2 mm, and 4 mm overlaps and gaps. Furthermore, the dose distributions were obtained by mathematical summation using the dose profile data for appropriate overlaps and gaps.*

Results: *Film dosimetry showed that the collimators underlapped and the fields overlapped for exact matching for this machine. When the two asymmetric fields were matched without gap, both the calculated values and film dosimetry results showed that there was approximately 9% inhomogeneity above the prescribed dose. A 2 mm overlap and gap produced inhomogeneities nearly of 35% and 30% above or below the prescribed dose, respectively. The 4 mm overlap and gap created an inhomogeneity of +65% and –50%. The dose inhomogeneity produced for 1 mm overlap and gap was 22% above and 6.8% below the prescribed dose, respectively.*

Conclusion: *Asymmetric collimators should be evaluated routinely related to inhomogeneity at the junction, especially for the mono-isocentric set-up technique. Small misalignments of asymmetric collimators cause serious inhomogeneity at the junction. If the homogeneity can not be improved, other methods of field matching have to be developed.*

Key words: asymmetric collimator, field matching, film dosimetry, radiotherapy

Introduction

The major problem with the standard technique for irradiation of the breast and head and neck cancers is field matching at the junction region. Because of the beam divergence overdosing or underdosing across the junction is unavoidable. However, the dose uniformity across the junction between two matching photon fields can be optimised by creating non-divergent field edges using independent collimators. Modern linear accelerators are equipped with independently movable jaws, which allow the junction of non-diverging fields. Asymmetric collimators are being employed in an increasing number of clinical applications [1-4]. They eliminate the need for heavy secondary shields to produce non-divergent treatment fields such as the supraclavicular portal that is matched to tangential breast portals [4,5] or bilateral neck portals [6-9]. The advantage of such a technique is that it can reduce patient set-up time, and attain dose uniformity at the junction and better reproducibility.

The most common application of asymmetric collimation is the matching of two adjacent fields at the central axis. For some breast treatments using a single

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set-up point, the junction is created through collimator movement without resetting-up the patient. The American Association of Physics in Medicine (AAPM) Task Group 40 [10] recommends a tolerance of 2 mm for symmetric jaw positioning, while they make no recommendation on the position of independent collimator. Current linear accelerator specifications for the positional accuracy of such collimators are not strict enough to ensure that a clinically acceptable match is produced. Lee [11] discussed that a digital display tolerance of 1 mm gap would produce a cold spot of over 10% of the prescribed dose. The work of the Rosenthal et al. [7] showed that over and underdose due to the digital display tolerance are much larger, in the range of 15-20%. Since the authors give a different magnitude of over and underdose for the tolerance of ±1 mm, a systematic evaluation should be done under clinical circumstances. This paper describes a dosimetric evaluation for the asymmetric jaw misalignment at the junction region.

Material and methods

The measurements and calculations were performed with a 6 MV photon beam produced by a Saturne 42 (Varian Oncology Support System) linear accelerator equipped with independent collimation. On this machine, the independent collimator setting, that is the lower set of jaws in the treatment head, is designed as the "X" jaws. All collimators were tested and found to be within our quality assurance tolerance of ± 1 mm for collimator position and digital display. Measurements were made by 5×10 cm (X_1=5, X_2=0, Y=10) field size. For all matching studies, Kodak X Omat V films were isocentrically placed at the dose maximum depth of 1.5 cm in a RW3 (PTW, Freiburg, Germany) solid water phantom. The gap between the phantom slabs was kept minimal by using special adhesive tape. The phantom was oriented perpendicular to the beam direction. The film was first exposed to 25 cGy with one asymmetric collimator, then the collimator position was reversed and the same film was exposed to the same dose again for exact matching. This procedure was repeated for ± 1 mm and ± 2 mm jaw misalignment. Optical density profiles were measured using a film scanner (Wellhofer, WP 102, Germany). The optical densities were converted to doses based on the calibration curve. The dose was normalized at a point of 2 cm from the match line. The calibration curve was obtained by irradiating the films from 10 cGy to 200 cGy at 1.5 cm depth in a RW3 solid water phantom using 6 MV photon beams. In addition, an exposure was taken to provide a dose profile for the asymmetric field. Optical density profiles were measured and converted to doses. The beam profile was converted to the numerical data using the software of the Wellhofer WP700. To examine the effect of gap and overlap, the dose profiles were shifted apart or put together with appropriate gap and overlap to create the asymmetric collimator misalignment. Then, composite dose distributions were generated by manual summation of the data of the beam profiles. The dose distributions on the matching region were evaluated for the asymmetric jaw misalignment.

Results

In this study, the effect of asymmetric collimator alignment on the magnitude of the dose inhomogeneity was evaluated along the matchline. Figures 1-3 show the radiographic images of two asymmetric fields for exact match (no gap), an overlap and gap of 2 mm between the jaws. If the two asymmetric fields were matched perfectly, the dose distribution along the match line would be uniform. However, it is seen that the collimators underlapped and the fields overlapped for exact matching for this machine. Figure 4 represents the relative dose profiles obtained by the mathematical summing of the numerical data of the profiles at the junction. When the two asymmetric fields are matched without gap, both the calculated values (mathematical summation) and film

Figure 1. Radiographic film of the matched asymmetric fields showing overdose at the junction. The jaw edges are exactly matching (no gap).

Figure 2. Radiographic film of the matched asymmetric fields showing the junction area for 2 mm overlap.

Figure 3. Radiographic film of the matched asymmetric fields showing the junction area for 2 mm gap.

dosimetry data show that there is approximately 9% (8.5%) inhomogeneity above prescribed dose. Figure 5 shows the results all together. A 2 mm overlap resulted in an inhomogeneity of +36%. A 2 mm gap resulted in an inhomogeneity of –28%. The 4 mm overlap and gap created an inhomogeneity of +65% and –50%, respectively. The dose distribution was obtained for 1 mm gap and overlap at the junction. The dose inhomogeneity was –6.8% and +22%, respectively.

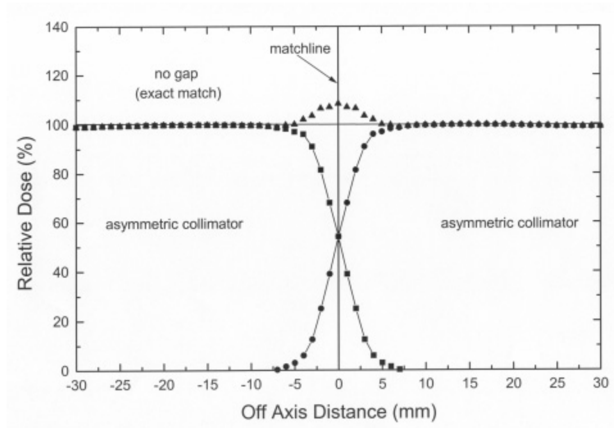

Figure 4. Composite dose profile of two asymmetric fields obtained by mathematical summation for exact matching (no gap).

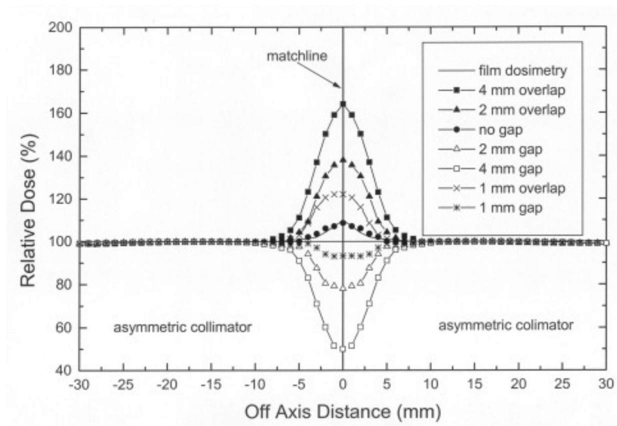

Figure 5. Relative dose profiles at the junction. Solid line shows the profile of film which is seen in Figure 1.

Discussion

Matched fields are routinely used in the radiotherapy of head and neck and breast cancers. The dose uniformity across a junction between two matched photon fields can be optimized by creating non-divergent field edges using asymmetric collimators. Many authors have reported unacceptable over and under-dose due to the associated jaw tolerance [8,9,11,12]. Lee [11] reported cold spot of more than 10% at the junction for an exact matching technique. The work of Rosenthal et al. [7] proved that 2 mm tolerance resulted in a dose inhomogeneity of 30-40%.

In this study, the dose inhomogeneity was found approximately +9% for exact matching. For 2 mm overlap and gap, the dose inhomogeneity was +36% and –28%, respectively. These values are consistent with the relevant literature [7,12]. A 4 mm overlap and gap results of this study are similar with those of Fabrizio et al.

[8]. A 1 mm overlap and gap led to about +20% and –7% dose inhomogeneity, respectively, at the junction. Saw and Hussey [12] reported that a 1 mm overlap and gap resulted in approximately ±15% dose inhomogeneity. The higher junction doses may be attributed to the geometric penumbra because the geometric penumbra for the "X" jaws is smaller than that of the "Y" jaws. If the "Y" jaws could be used in this study, the smaller junction dose would be expected.

If the position has been set using the collimator digital display, the light field can only be used to confirm the correct position of the junction. However, it has been clearly seen that differences may exist between collimator display and actual position. Because of the mechanical and electronic tolerances, it is obvious that the asymmetric fields will not be perfectly matched. Mechanical accuracy of the jaw alignment for non-diverging fields is essential. The results show that ± 1 mm specification for jaw alignment may not be adequate for mono-isocentrical set-up in this machine because of the dose inhomogeneity. In the ICRU report 50 [13], the degree of heterogeneity inside the target volume should be kept within + 7%, and –5% of the prescribed dose. If the treatment will be done by mono-isocentrical set-up, the physician should be aware of the magnitude of the dose inhomogeneity. It may be concluded that a tolerance of less than ± 1 mm on the digital display of asymmetric collimator is required. Furthermore, regular quality assurance of asymmetric collimator display will minimize the potential over and under-dose areas at the junction. If the homogeneity can not be improved, other methods of field matching have to be considered.

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