Original Research

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A new method for ideal dose distribution of two adjacent fields for external beam radiation therapy

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Abstract

Background: Adjacent treatment fields are commonly used in external beam radiation therapy, such as mantle and inverted-Y fields for the treatment of Hodgkin's disease and craniospinal fields used in the treatment of medulloblastoma and head and neck tumors when the lateral neck fields are placed adjacent to the anterior supraclavicular field. In each of these situations, there is a possibility of introducing very large dosage errors across the junction. Consequently, this region is at risk for severe complications if it is overdosed, or tumor recurrence if it is underdosed.

Methods: For prevention of adjacent field overlapping a new method is introduced. In this method the patient's couch of the treatment machine is rotated for 90° clockwise and counterclockwise. Then the gantry is rotated for α and β that are measured by geometrical methods in opposite direction for each field. The adjacent fields have a common edge and then the overlap region in treatment volume is eliminated.

Results: By phantom dosimetry, the maximum dose in the junctional volume of the two adjacent treatment fields is measured to be 102%. This technique provides an inhomogeneity of about 2%.

Conclusion:In some cases, the measurements have shown that the dose inhomogeneity is as large as 45%. Compared with the dynamic intensity-modulated radiotherapy (IMRT), this technique also provides a superior dose homogeneity such that inhomogeneity becomes about 2%.

Keywords: Adjacent fields, External radiation therapy, Dosimetry

Introduction

The problem of adjacent fields has been extensively studied [1,17]. A number of techniques have been devised to achieve dose uniformity in the field junction region. Some of the more commonly used techniques are: 1) Angling technique, in which the two beams are away from each other (Fig. 1), so that the two beams are aligned vertically [1]. If the width of the treatment fields is defined according to the 50% decrement lines of adjacent fields, it could introduce dose uniformity in the treatment volume [18]. However, in prac-

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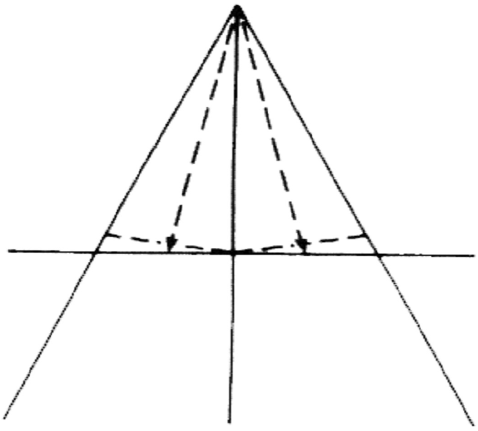

Fig.1. Angling the beams away from each other so that the two beams abut and are aligned vertically.

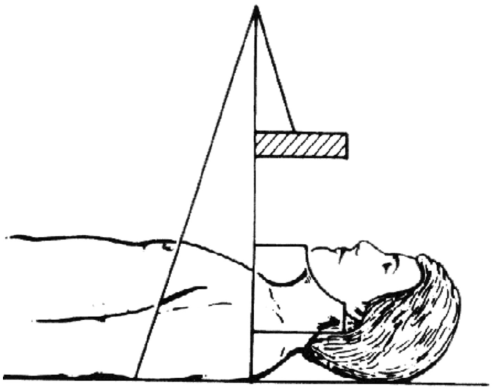

Fig.3. Isocentric split beam technique for head and neck tumors.

tice, introducing such an angle is too difficult, therefore hot and cold spots will be created.

2) Fields separation technique, in which the fields are separated at the skin surface (Fig. 2). The junction point is at depth where as the dose is uniform across the junction. The separation or gap between the fields is calculated on the basis of geometric divergence [13] or isodose curve matching [2,3,14]. Although this technique is usually more acceptable and practical for depths of more than 5 centimeters, cold and hot spots are usually created at the upper and/or lower parts of the region [15].

3) Isocentric split technique, in which the beam is splitted along the plane containing the central axis by using a half beam block or a beam-splitter, thus removing the geometric divergence of the beams at the split line [9,13] (Fig. 3). This technique is usually applied for orthogonal treatment fields. Although a desired homogeneity is created at the abutting region, but hot or cold spots may also be created [13,16,19].

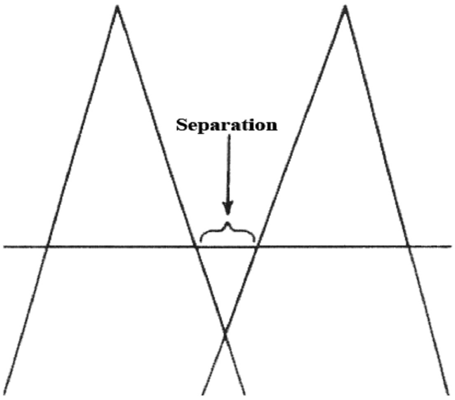

Fig. 2. Fields separated at the skin surface. The junction point is at depth where as the dose is uniform across the junction.

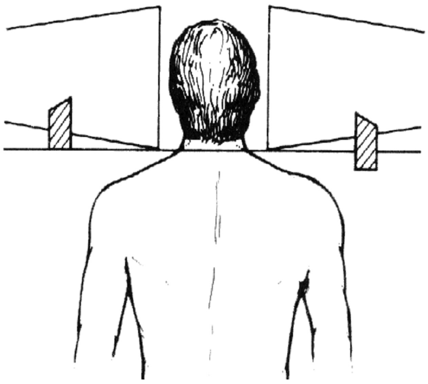

Fig. 4. Craniospinal irradiation using penumbra generators.

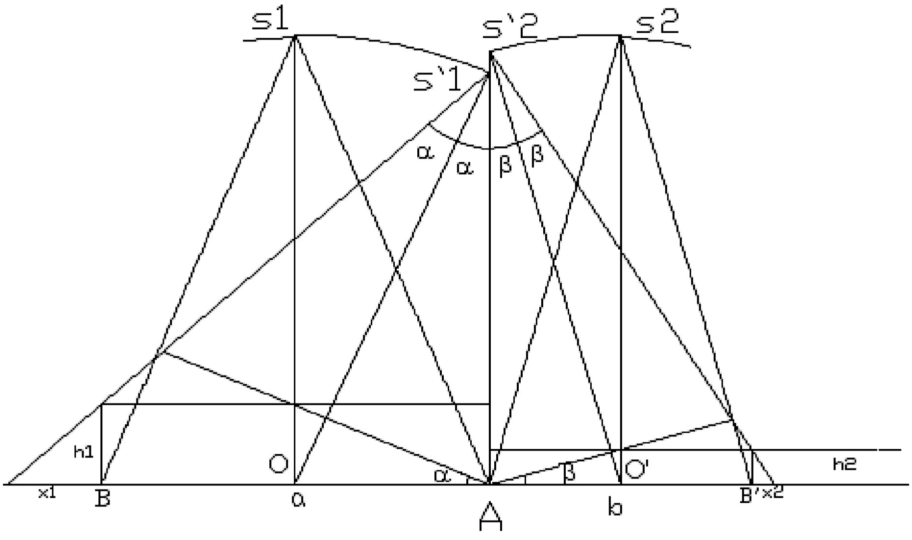

Fig. 5. Rotation of treatment couches 90°, Rotation of gantry for angles α and β towards the common edge of the treatment volume for positions S_1 and S_2 respectively while moving the treatment couch for h_1 and h_2 towards the source for two parts and treatment field, provide an inhomogeneity of about 2%.

Spoiler technique, in which two lead wedges are used to provide satisfactory dose distribution across the field junction [8]. These lead wedges are custom designed (Fig. 4).

This technique is also applied for orthogonal treatment fields. Although the thickness of the shields is specified by a time consuming dosimetry, however, it is not able to obtain a perfectly homogeneous physical dose distribution in the junctional area [6,7].

In clinical practice, the fields are usually abutted at the surface if the tumor is superficial at the junction point. Care is however taken that the hot spot created due to the overlap of the beams at depth is clinically acceptable, considering the magnitude of the overdosage and the volume of the hot spot. In addition, the dosage received by a sensitive structure such as the spinal cord must not exceed its tolerance dose.

For the treatment of deep-seated tumors such as in the thorax, abdomen, and pelvis, the fields can be separated on the surface. It is assumed in this case that the cold spots created by the field separation are located superficially, where there is no tumor.

To improve this treatment and eliminate hot and cold spots, it is necessary to introduce a new method for treating adjacent fields.

Methods

We will consider the lengths of two adjacent fields as $AB= a$, and $AB' = b$ and the position of radiation sources as S_1 and S_2 respectively (Fig. 5). When one treats the patient with these two fields, hot spots will be created as mentioned above. To prevent such an effect the following steps can be taken:

Rotating the treatment couch for 90° horizontally.

At the position S_1, for treatment of the first field the gantry rotates for the angle *a* towards the common edge of the treatment volume (i.e. A in Fig. 5).

When the treatment machine adjusts at position S_2, the gantry rotates for angle *b* towards the common edge (A) of the treatment volume.

These two fields have a party ray perpendicular to the surface of the treatment couch at point A.

The result of this treatment technique is as follows:

The central axis of the treatment fields is not perpendicular to the surface, which is not important in the treatment planning. However, it is convenient to correct it by isodose shift method [14].

The treatment fields increase for a length of X_1 and X_2 at the surface of the body, which is very small compared with the length of the fields, and can be omitted.

To omit the X_1 and X_2, the treatment couch moves for h_1 and h_2 centimeters toward the source. Where:

$$\sin\alpha = a/2d,\ \sin\beta = b/2d,\ d = S_1O = S_2O' \quad (1)$$

According to Fig. 5 one can write:

$$h_1 = X_1 \cot an2\beta\ ,\ \ h_2 = X_2 \cot an2\beta \quad (2)$$

and,

$$X_1 = d'_1 \tan 2\alpha - a\ ,\ \ X_2 = d'_2 \tan 2\beta - b, \quad (3)$$

where $d'_1 = S'_1A$ and $d'_2 = S'_2A$, are vertical distances of the source S' from the body for two fields.

Substituting eq.(3) in eq.(2) with some calculations one can obtain:

$$h_1 = (a/2)\tan\alpha \quad \text{and} \quad h_2 = (b/2)\tan\beta,$$

where

$$d'_1 = \sqrt{d^2 - a^2/4} \quad \text{and} \quad d'_2 = \sqrt{d^2 - b^2/4}$$

For example if $a=b=25_{cm}$ and, $d= 80_{cm}$ one can obtain:

$\alpha=\beta= 9°$ and, $h_1=h_2= 2_{cm}$

but, if $a=25_{cm}$, $b=15_{cm}$ and $d=100_{cm}$,

then:

$\alpha=7°$, $\beta= 4.3°$, $h_1=1.6_{cm}$ and $h_2= 0.6_{cm}$

Therefore, when SSD increases, α, β, h_1 and h_2 decrease.

Results

In clinical practice, a completely homogeneous physical dose distribution in the junctional area of two adjacent fields is virtually impossible to obtain. Even if a reasonably homogeneous physical dose distribution is obtained, because of time-dose relationship, the biological effective dose may be heterogeneous [20]. The matching between the mantle and the para-aortic fields in the treatment of Hodgkin's disease is of particular concern because of the need to avoid an overlap of a portion of the spinal cord. If this overlap occurs, the dose that is received can cause irreversible neurological damage [21].

The most commonly used method for matching adjacent fields in Hodgkin's disease is the geometric matching technique [22]. The distance between the fields at the patient's surface is calculated so that the adjacent field edges join at the chosen depth, usually at the midline. However, the field lengths and the depths to the central axis plane are commonly different between the mantle and the para-aortic field leading to inhomogeneity due to different beam divergences. Additionally, the formula for gap calculation assumes the patient's surface is flat, not taking into account the effect of the sloping body surface.

Lutz and Larsen [23] described a technique to match the mantle and para-aortic fields with the patient treated alternatively in supine and prone position. Film dosimetry in a solid plastic phantom with same setup showed about 15-20% higher dose distribution at the level of the spinal cord. This was attributed to beam divergence differences between the larger mantle and shorter para-aortic fields.

Keys and Grigsby [24] proposed a modification of the existing formula for calculating the gap for the fields on a sloping surface. The effect of sloping surface can cause about 1 centimeter overlapping at the spinal cord because of erroneously positioning the para-aortic field at a distance calculated by a standard formula from the edge of the mantle light field on the skin surface. Film dosimetry using the skin gap calculated using the standard formula showed maximum dose in the junctional area to be 145% and spinal cord dose 125%. Isodose curves using the modified formula to calculate the gap demonstrated much more uniformity at the junction, with the region near the spinal cord receiving 115% of the central axis dose.

An isocenter shift method was introduced by Tae et al [15] and was more accurate and easier than the others were. Although after a film dosimetry they demonstrated no hot spots, but a cold spot will be created as low as 50 %.

A dynamic supraclavicular field-matching technique for head and neck cancer patients treated with IMRT was introduced by Duan et al [25].

The results of their activity show an average inhomogeneity range of 6%. They compared their method with the conventional single-isocenter and half-beam technique and they mentioned an inhomogeneity for the later technique as high as 22.8%.

This new technique has been applied for the treatment of spinal cord with two adjacent fields. Dosimetry showed a maximum dose in the juctional area as much as 102%. The same results could be obtained by using the isodose curves for the adjacent fields.

Conclusion

A comparison between the new technique and all the previous methods, mentioned above, provides superior dose homogeneity not only in the abutment region but in the upper and lower regions as well.

In some cases, the measurements have shown that the dose inhomogeneity is as large as 45% [25]. Compared with the dynamic intensity-modulated radiotherapy (IMRT), this technique also provides superior dose homogeneity [25] such that inhomogeneity becomes about 2%.

From a practical point of view clinical radiation therapy applying this technique for treatment planning is very simple and there is no delay time in treatment of patients.

The physicist can calculate α, β, h_1 and h_2 from the mentioned relations and apply the steps 1, 2 and 3 for treatment of patients (Fig.5).

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