RESEARCH ARTICLE

Determination of an Effective Wedge Angle by Combination of Two Arbitrary Universal Wedge Fields in Radiation Therapy of Cancer Patients with Megavoltage Photon Beams

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Abstract

    <u>Background</u>: Wedge filters are commonly used in radiation oncology for eliminating hot spots and creating a uniform dose distribution in optimizing isodose curves in the target volume for clinical aspects. These are some limited standard physical wedges (15°, 30°, 45°, 60°),or creating an arbitrary wedge angle, like motorized wedge or dynamic wedge,… The new formulation is presented by the combination of wedge fields for determining an arbitrary effective wedge angles. The isodose curves also are derived for these wedges. <u>Materials and Methods</u>: we performed the dosimetry of Varian Clinac 2100C/D with Scanditronix Wellhofer water blue phantom, CU500E, OmniPro - Accept software and 0.13cc ionization chamber for 6Mv photon beam in depth of 10cm (reference depth) for universal physical wedges (15°, 30°, 45°, and 60°) and reference field 10.10cm^2. By combining the isodose curve standard wedge fields with compatible weighting dose for each field, the effective isodose curve is calculated for any wedge angle. <u>Results</u>: The relation between a given effective wedge angle and the weighting of each combining wedge fields was derived. A good agreement was found between the measured and calculated wedge angles and the maximum deviation did not exceed 3°. The difference between the measured and calculated data decreased when the combined wedge angles were closer. The results are in agreement with the motorized single wedge appliance in the literature. <u>Conclusions</u>: This technique showed that the effective wedge angle that is obtained from this method is adequate for clinical applications and the motorized wedge formalism is a special case of this consideration.

Keywords: Universal physical wedge - profile - megavoltage photon beam - radiation therapy

Introduction

    One of the methods of treating of cancerous patients is radiation therapy in the form of curative or palliative by using a Co-teletherapy machine or linear accelerators(Abrath and Purdy, 1980). Acceptable dose uniformity is within ±5% in radiation therapy. wedge filters are commonly used for uniforming , modifying or optimizing isodose distribution in the target volume for better dose delivery (Khan and Gibbons, 2014). Wedge filters are of the several types like physical or dynamical. The physical wedge is usually made of dense materials such as lead or steel and is mounted on a tray and inserted in the radiation field at a specified distance from the patient. Dynamical wedge generated electronically through the motion of independent jaws within the treatment region. Most accelerators are provided with a selection of wedges that are mounted externally on the head of the machine. The wedge isodose angle has been defined as the angle

between the isodose curve passing through reference depth and the normal horizontal line on the central axis on this depth. According to the international commission on radiation units and Measurements (ICRU),the path of the radiation beam decreases the dose rate and this must be taken into account in dose calculation by a wedge transmission factor, defined as the ratio of dose in water at a point on a central axis with and without the wedge. In some systems of radiation therapy a single universal wedge maybe used that mounted inside the head and moved by remote control and is named by motorized wedge (Bentel et al., 1982). For single 600 motorized wedge, Paula and et al. (1985) explained a new method for obtaining an effective wedge angle by combining an open field with a 600 motorized wedge with specified weighting doses that can be determined as the ratio of the slopes of the central-axis depth dose curves for open and wedge fields(Petti and Siddon, 1985). For a motorized wedge, Rajesh Kumar and etal. (2011) used an analytical approach

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for an arbitrary effective wedge angle.The relationship was established between the wedge beam weight and effective wedge angle (Kumar et al., 2012). Inhikar Rajesh and et al. (2007) estimated the transit dose for motorized wedge treatment in the Equinox telecobalt machine. The actual measurements carried out with ion chamber for universal wedge and motorized wedge showed no variation between the dose delivered with TLD measurement (Kinhikar et al., 2007b). The motorized wedge filter has a number of advantages, like no probability of physical injury to operators and patient; no need to handle physical wedges; making wedge selection faster and easier, which results in higher patients throughout and less fatigue for operators and flexibility to generate arbitrary wedge angle instead of the limited standard angles. Clinical commissioning of a motorized wedge filter for a Theratron Equinox telecobalt unit has been reported in the literatures (Kinhikar et al., 2007a; Sahani et al., 2009).

Tamer Dawod (2015) evaluated the motorized wedge supported by the dosimetric performance 3-D treatment planning system for Electa Precise linear accelerator by comparing the calculated and measured doses for symmetric and asymmetric wedge fields in depth of d_max, 5cm, 10cm, 20cm in water phantom for 6mv and 15mv photon beams. By using 0.125cc ionization chamber a good agreement was found between calculated and measured dose. Maximum deviation was not longer than %5. This deviation for a symmetric field was less than asymmetric and increased with increasing wedge angle. The result of this study showed that Electa precise with motorized wedge for symmetric and asymmetric field is adequate for the clinical applications. In 2007, Rajesh A. Kinhikar et al. evaluated thetelecobaltTheratron Equinox-80 with a single motorized wedge. They configured Eclipes 3-D treatment planning(Varian PaloAlto,USA)for universal wedges (15°, 30°, 45°, and 60°) and their profile and central axis depth doses were measured with blue water phantom and compared with actual universal wedges in a homogeneous phantom generated in Eclipse for various field sizes. The variation in measured and calculated dose at 10cm depth was within %2 and angle within 2°. Then, the motorized wedge was successfully configured in Eclipse for four the above wedge angles (Kinhikar et al., 2007b). In 2014, SJ-Weston et al. evaluated six Electa Precise Linac creating an arbitrary angle by a combination of open and motorized wedge with specified weightings for definite dose delivery. They found a range of %4 in measured transition factor for 6mv photon beams (Weston et al., 2014). The aim of this study was the consideration of combining two specified wedge shape fields with determined weighting and containing an arbitrary effective wedge shape distribution and effective wedge in the clinical radiation therapy.

Materials and Methods

Theory

For determination of an arbitrary effective wedge angle θ by combining the standard, universal wedge angles ϕ and ϕ , one can obtain a weighting factor for this combination from the isodose lines or profiles of these wedge shaped fields in the reference depth 10cm.For this purpose, profiles and isodose lines combining two wedged shape fields are drawn in the blue water phantom for depth 10 cm by 0.13cc ionization chamber as shown fig. 1.

According to Figure 1, one can write:

$$tan\ \phi=MN/U=(ON-OM)/U, \qquad (1\text{-}a)$$
$$tan\ \phi=AB/U=(OB-OA)/U, \qquad (1\text{-}b)$$
$$tan\ \phi'=(A'B')/U=(OB'-OA')/U \qquad (1\text{-}c)$$

If the wedge waithings of two fields are respectively α and 1-α, multiplaying both sides of Eq. (1-b)by α and Eq.(1-c)by(1-α), gives

$$\alpha tan\ \phi=(\alpha((\alpha(OA)-(OA)/U, \qquad (2\text{-}a)$$
$$(1-\alpha)\ tan\ \phi'=((1-\alpha)OB'-(1-\alpha)OA')/U \qquad (2\text{-}b)$$

by combining two Eqs.(2a)and(2b),according to Figure 1, one can obtain

$$\alpha tan\ \phi+(1-\alpha)\ tan\ \phi'=[\ (\alpha OB+(1-\alpha)OB')/U]-[\ (\alpha OA+(1-\alpha)OA')/U]. \qquad (3)$$

Or

$$\alpha tan\ \phi+(1-\alpha)\ tan\ \phi'=[\ (ON-OM)/U]=tan\ \theta \qquad (4)$$

By rewriting the Eq.(4),the weighting factor can becomes

$$\alpha=(\ tan\ \theta\text{-}tan\ \phi')/(\ tan\ \phi\text{-}tan\ \phi') \qquad (5)$$

From fig.1 one can

$$\alpha(OA)+(1-\alpha)OA'=OM, \qquad (6)$$

Where OA ,OA´ and OM are profiles of combining wedge-shapedfields. This means that

$$PDD\_\theta=\alpha PDD\_\phi+(1-\alpha)\ PDD\_(\phi'). \qquad (7)$$

Measurements

Relative dosimetry is done for obtaining PDD, profile and isodose curves. Using scanditronixWelhopher water blue phantom, MCU500EU, OminoPro_Accept software and 0.13cc ionization chamber for 6MV photon beam of varian2100C/D linac in depthes of 1, 4, 7, 10, 13cm of 10cm for universal physical wedges (15°, 30°, 45°, and 60°) and reference field of 10.10cm², PDD, profiles and isodose lines curves are plotted.

Results

Using ScanditronixWelhopher water blue phantom, CU500E, OmniPro - Accept software and 0.13cc ionization chamber for 6MV photon beam of varian2100C/D linac the percentage of depth dose curves, profiles (for 10.10 cm² wedge fields 0°, 15°, 45°and 60° in depths of 1, 4, 7, 10, and 13 cm are obtained from the relative dosimetry. Combining the profiles gives isodose curves. For example,
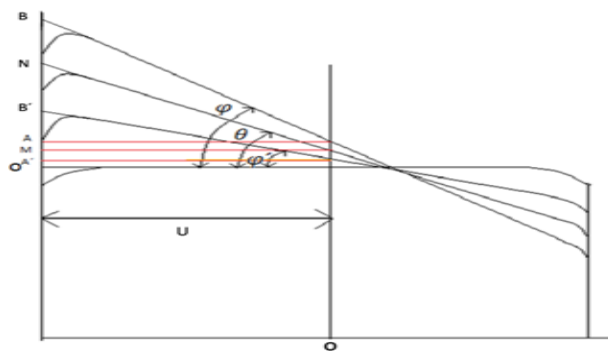

Figure 1. Combination of the Isodose Curves of two Wedges Fields with Angles ϕ and ϕ´ and Generating the Desired Wedge Field with Angle

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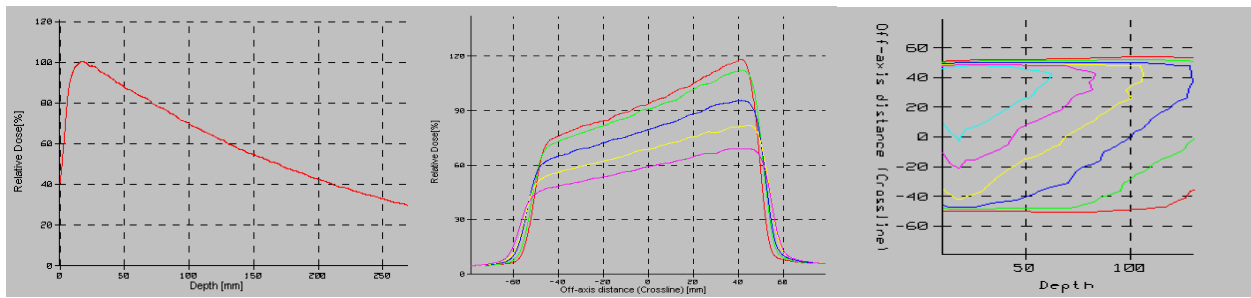

Figure 2. A). PDD for 45°_wedge shape field 10cm.10cm; B). Profile for 45°_wedge shaped field 10cm.10cm in depths 1, 4, 7, 10, 13cm; C). Isodose for 45°_wedge shape field 10cm.10cm in depths of 1, 4, 7, 10, 13cm

Table 1. The Combination of two Wedges Fields (15°,30°,45°, and 60°) with Weighing %40 and %60 and Generated Effective wedge Angle in Comparison with Measurement

40/60	60		45		30		15		0	
	measurement	Analytical	measurement	Analytical	measurement	Analytical	measurement	Analytical	measurement	Analytical
0	40.9	43.7	28.1	30.96	21.4	21.3	10.7	11		
15	47.2	47.3	35.4	36.05	27.6	27.4			9.4	7.4
30	51.3	50.6	41.3	40.7			26.6	24.3	14	14.7
45	52.7	53.6			36.6	38.3	29.7	30.6	21.8	21.8
60			50.4	51.1	46.9	45.8	39.2	39.7	32.1	32.5

Table 2. The Combination of two Wedges Fields (15°,30°,45°, and 60°) with Weighing %20 and %80 and Generated Effective wedge Angle in Comparison with Measurement

20/80	60		45		30		15		0	
	measurement	Analytical	measurement	Analytical	measurement	Analytical	measurement	Analytical	measurement	Analytical
0	51.2	51.9	37.5	38.6	28.3	27.45	12.3	14.6		
15	53.3	53.2	41.5	40.8	31.5	30.3	20	21.1	5.2	3.7
30	55.1	54.6	43.8	42.9			21.9	24.5	9.4	7.4
45	52.7	53.6			35.3	35.75	24.5		13.2	11.3
60			48.8	48.2	39.5	39.99	30.2	29.85	18.1	17.7

these curves a given or 10.10 cm², 45° wedge angle fields in Figures. 2 (a, b, c).

For two arbitrary weighting α=20% and α=40%, the Eq.7 is examined. By combining four standard wedges (15°, 30°, 45°, and 60°)and open fields from Eqs.(5 and 7) the effective angle θ are derived for two above values α and tabulated in tables 1 and 2

By using Eq.7 for these two values the related profiles are combined and plotted by the OmniPro software and the slope of these effective wedge angle profiles are measured and compared with analytical angle tabulated in tables 1 and 2.

Discussion

In this study an analytical method for generating an effective wedge arising of a combination of two physical wedges (PW) with any weighting is presented and compared with measurements and other researches.

Paula and Siddon describe a technique for determining an effective wedge angle from a combination of open and motorized 60° wedge angle fields with data from the Philips.SL/75-6MV accelerator by weighting factor parameter that interpreted physically as the ratio of the slopes of the central depth dose curves of the effective motorized wedge fields. Their results were consistent with the data within 3°(Petti and Siddon, 1985).

Jingeng Zhu introduces a new method for generating wedge- shaped dose distribution through dynamic multileaf ... dose delivery rather than computer control ... His ... tested ... the shape of standard ... 30°... and ... the maximum deviation with ... (Zhu 2005).

By combining of physical motorized wedge field and open field with different weighting factors, Rajesh et al. generated desired angle ...-shaped (0° to 60°) ... The simulation similar ... 1.5 for φ´=0 and the ... is ... of our ... alism of the measured calculated MU obtained from Enox_80. The obtained values are ... agree ... within ... nhikar et al., 2007b) ... used enhanced dynamic wedge (EDW) technique ... adjust ... can ... 09) determined an arbitrary wedge ... for ... accelerator CLINAC 600C/D generating 6Mv beams of X-ray. in this technique, the deviation between the calculated and measured dose value is lower than ±5 (Bajuscová et al., 2010).

In a similar research in 2010, Misbah Ahmad et al. reported maximum variation of 8.9% between EDW and PWs. Rajesh Kumar and et al for pland motorized wedge angles in different fields reported difference between planed and measured wedge angles less than 2°.

In another similar study, Sathiyan Saminathan et al., in 2012 in Greater Poland Cancer Centre the dosimetric properties of varian EDW and PW were analyzed and compared in 6MV photons. The maximum variation in the output factor is between 1.5%-3.8% for all fields and EDW has a higher wedge factor compared to that of the physical wedge for a particular wedge angle(Saminathan

et al., 2012). In this research the wedged angle obtained by the presented formalism and measurement was less than 3° that is comparable with the studies of Tamer Dawod on the motorized 60 wedge angle of 6MV Electa Precise linac (Saminathan et al., 2012). furthermore, it is consistent with the method analytically performed by Petti and Siddon for effective wedge angles with a 60°_universal motorized wedge that by comparison with measurement had a deviation within 3° over the range of wedge angle and field size(Petti and Siddon, 1985). In our research the maximum deviation with measurement are less than 3° as shown in table 1 and 2.

In conclusion, the effective wedge angle obtained by a combination of the universal wedge fields for clinical applications is exactly acceptable and in agreement with measured data.

Acknowledgements

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