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Wedge Angle Confirmation in Computer Controlled Wedge Field

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ABSTRACT. Wedge is a beam amending devices that causes an advanced decrease in the intensity across the beam resulting in a tilt of the isodose curves from their normal positions. The use of a computer-controlled wedge system is an important segment of radiotherapy and increases the uniformity of dose in the target volume. The aim of this study is to verify the virtual wedge angles from the machine setup angles in Siemens' ONCOR Linear accelerator (Linac) and compare it with published data of different linear accelerators as a function of beam energy and field sizes. This experiment was carried out on Siemens' ONCOR impression linear accelerator. The doses at different depths were measured by using the CC13 ion chamber. During our work, the source to surface distance was kept 100 cm. The square field sizes on which we worked were 10, 15, and 20 cm^2. The selected virtual wedge angles for our study are 15, 30, 45, and 60 degrees. This work was carried out for both photon energies 15 MV and 6 MV, tissue-equivalent water phantom IBA blue water phantom inside which all the observations were taken. The LDA99 detector for the virtual wedge profile was used. The wedge angle was calculated for the Siemen's given formula. The variation in wedge angle from machine setup angle and published data as a function of beam energy and field sizes were analyzed. The variations increase with field size and wedge angle but decrease with beam energy. Variation is under 3% which is acceptable before treatment planning.

Keywords: Wedge angle; Variation wedge; Virtual wedge.

INTRODUCTION

In current radiotherapy techniques the heart toxicity and breast cancer are getting to be concerned issues.[1] Breast radiotherapy has continuously been challenging in term of size and shape of breast as well as the region of the whole breast volume encompassing critical organs or organs at risk. One of the fundamental encounter when planning whole-breast radiotherapy is the reality that treatment is slightly limited to what is really a different technique in order to avoid these nearby serious organs.[2] In most of the patient radiations related cardiac maladies have been commonly establish which were treated for lymphoma, breast cancers, seminoma, peptic ulcer diseases and lung cancer, the risk of cardiac illnesses may be connected to both radiation and exposed volume.[3] Quality of a radiation beam is most typically expressed in terms of its penetrating power, which is especially a function of the mean photon energy and it should be fully defined by its depth dose characteristics in water but an increase within the surface dose with the field size is additionally renowned due to the electron scattering from dominant materials.[4] In order to attenuate radiation toxicity, the understanding and familiarity of wedge filter handling during treatment planning system is necessary. During the treatment of breast, thoracic and pelvic tumors the use of wedge angle has been common and the steep dose gradient may produce hot spots in lungs, heart, and rectum.[5]

Wedge angle is defined as the angle by which an isodose curve at a certain depth (normally 10 cm) is tilted along the central beam is called wedge angle. It can also be defined as the 50% of isodose line and normal to the central axis of beam.[6] PWs are available in the range of 15, 30, 45 and 60 degrees whereas virtual wedges (VWs) are available in all possible values of angles lying (10 - 60 degrees). The use of physical wedge (PW) in radiotherapy is easy. However, they are limited to

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angles (15, 30, 45 and 60 degrees) and field sizes. PWs are heavy due to high density and atomic number of materials used and creates low energy photons and electrons scatters .Treatment time for PW increased because of diminished primary beam intensity and time required for installation and removal. With the development of computer controlled method collimator jaws can be moved which produce the virtual replacement of PW.[7] Siemens has presented a VW that generates dose distribution comparable as created by wedge through the motion of one of the collimator jaws across the field during irradiation. For a definite VW field, the speed of the jaw motion is constant but the dose rate varies. VW was designed to produce dosimetric properties same as of PWs.[8] In virtual treatment we do not require handling of PW and attain accurate and faster treatment. After this concept of dynamic wedges (DW) and virtual wedges were purposed. DW and VW both are computer-controlled wedges that generates wedge shaped profiles. VW differs from DW in two ways. First, in VW the moving jaws closes and then fully opens during treatment. Second, the jaws moves with the constant speed while the dose rate is varied as a function of time.[9] Tumor movement can be produced by the skeletal muscular, respiratory, cardiac, and gastrointestinal systems. Respiratory motion in particular affects all tumor sites in the thorax and abdomen; the disease of most significant in this case is lung cancer. Intra-fractional organ motion (tumor motion) is a noticeable problem in radiotherapy and respiratory motion is just one potential source of error in radiotherapy.[10, 11]

In this study we will go through the variation in the wedge angle from the prescribed formula and how much it will effect during treatment planning system.

MATERIALS AND METHODS

All the measurements were taken on Siemens' ONCOR linear accelerator having 82 Leaves MLC as Y-collimator, while PW produces by collimator jaws in X-direction. In the commissioning of TPS, the beam data for wedge field needs to be more precise because minor instability can cause greater impact in clinical setting due to dose gradient profile. Because of altered techniques were used to generate wedged dose distribution and their positions with respect to the target of linear accelerator The linear accelerator is fixed at Atomic energy medical center (AEMC), Karachi for both 6 MV and 15 MV X-ray beams using 3D water phantom (Blue phantom, IBA Germany). The measurement of water tank is 480 mm × 480 mm × 400 mm and walls are made of acrylic. Water phantom has 0.1 mm point accuracy with 500 mm/s scanning speed. We align the water phantom with the laser such that the vertical axis (y-axis/in-plane direction) is the up down position. The scanning the orientation in gun target and up-down direction can compromise the treatment planning system of wedged field but in open field orientation does matter. For accurate scanning process, the phantom must be positioned so that it is adjusted with in-plane direction. This can be done by line up probe holders with the field's edge. For measurements Standard relative dosimetry setup was arranged, using CC13 ion chambers, (IBA, Germany), portable IBA electrometer/control unit, CU-500E and dosimetry computer having Omnipro-accept software. CC13 Ion chamber was kept at beam's central axis, with chamber center at water surface, such that the distance from source to surface (SSD) was 100 cm. In plane beam profiles were measured only for 10 cm depth for various field sizes (10 × 10 cm^2, 15 × 15 cm^2, 20 × 20 cm^2) for nonphysical wedged field. Then all the profiles converted into tabular form using option in the Omnipro accept software. We confirmed the wedge angles of 15, 30, 45 and 60 degrees from the Siemens' given formula. All the deviations were finally analyzed as a function of field size and energy. These variations were compared with published data.

The dose is varied according to eqs. (1) and (2).[12]

$$\text{MU (x)} = \text{MU (0)}\, e^{(-\mu\ x \tan\theta)} \tag{1}$$

$$\frac{dMU}{dt} = \text{v MU}\ \mu\tan\theta\ (0)\, e^{(-\mu\, x \tan\theta)} \tag{2}$$

Where:

MU (x) = Number of monitor units that is given while a point at position x is irradiated.

MU (0) = Number of monitor unit enters to the console of machine; also number of monitor units at x = 0.

θ = Chosen wedge angle.

μ = Operative attenuation coefficient of the beam.

V = Velocity of moving jaws.

μ in eqs. (1) and (2) varies as a function of beam energy. When applying computer control wedge a default effective attenuation coefficient (μ_{def}) is required. In such case, a calibration coefficient (C) is used to alter effective attenuation coefficient in eq. (3).

$\mu = C \times \mu_{def}$ (3)

By regulating the C factor VW angle was altered to achieve calibration. We require only four points for the measurements of wedge angle according to Siemens' acceptance procedure. Two central axis points taken along a beam profile at 9 and 11 cm depths. The definition of computer control wedged angle according to the Siemens' manual is agreed by eq. (4).[13]

$$\text{Wedge angle} = \theta = \tan^{-1}\left[\frac{(D_p - D_q)/\Delta d}{(D_9 - D_{11})/2}\right] \quad (4)$$

D_9 and D_{11} are the doses at 9 cm and 11 cm depths on the central axis respectively. Lateral coordinates (D_p and D_q) ± field width/4 (for 15 and 30 degrees of wedges angles) or ± field width/6 (for 45 and 60 degrees of wedges angles) at 10 cm depth.

A wedge pair system can be used in treatment planning system (TPS), wedge angling is useful in reimbursing slopping surface such as in nasopharyngeal handling in which wedges are used to stable for decreases thickness anteriorly. An important application of wedge pair in treating relatively low lying injuries ,for which two beams are placed at a direction of less than 180 degree generally called hinge angle, for this, normal wedge angle can be calculated by

90 - ½ (hinge angle).[14]

Wedge angle can be calculate for selected field sizes (10 × 10 cm^2, 15 × 15 cm^2 and 20 × 20 cm^2) and for 6 MV and 15 MV beam from eq. (4), profile will be measured for 15, 30, 45 and 60 degrees of wedge angle. The deviation of calculated angles from machine angles will be obtained by deducting the calculated values from real values for all selected field sizes. By calculating the deviation we can verify the formula according to our data.

RESULTS AND DISCUSSION

According to Siemens' instruction, the values of D_p and D_q for all concerned field sizes and wedge angles are shown in Table 1. The deviations in calculated wedge angles for 6 MV and 15 MV energy for all concerned field sizes are shown in Tables 2 and 3 respectively.

Table 1: Values of D_p and D_q for various field sizes an angles.

Field Sizes (cm^2)	Wedge Angles (°)	D_p (cm)	D_q (cm)
10 × 10	15 and 30	2.5	– 2.5
	45 and 60	1.67	– 1.67
15 × 15	15 and 30	3.75	– 3.75
	45 and 60	2.5	– 2.5
20 × 20	15 and 30	5	– 5
	45 and 60	3.33	– 3.33

Table 2: Percent deviations in the virtual wedge angle from machine set-up angles at 10 × 10 $cm^{2,}$ 15 × 15 cm^2 and 20 × 20 cm^2 for 6 MV.

Field Sizes (cm^2)	Machine Set-up Wedge Angles (°)	Calculated Wedge Angles (°)	Deviation (°)	Percent Deviation (%)
10 × 10	15	14.69	0.31	2.067
	30	29.16	0.84	2.800
	45	44.75	0.25	0.556
	60	58.42	1.58	2.633
15 × 15	15	15.15	-0.15	1.000
	30	30.33	-0.33	1.100
	45	46.35	-1.35	3.000
	60	61.97	-1.97	3.283
20 × 20	15	15.35	-0.35	2.333
	30	30.64	-0.64	2.133
	45	45.85	-0.85	1.889
	60	59.9	0.1	0.167

Figs. 1 and 2 show the percent deviation between machine set-up angles and calculated angles for 6 MV and 15 MV energy levels. The Figs. show that the deviation is independent of machine set-up angles and field sizes (percents of deviation are 4% and 3% for two energy levels.

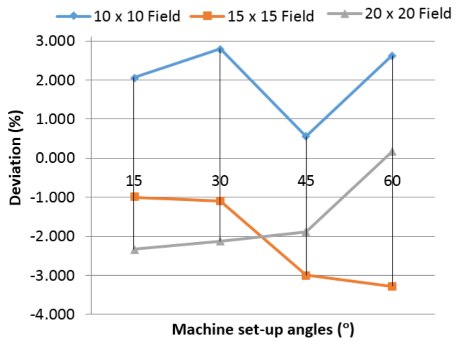

Fig. 1: Deviation between calculated and machine set-up angles at various field sizes for 6 MV energy.

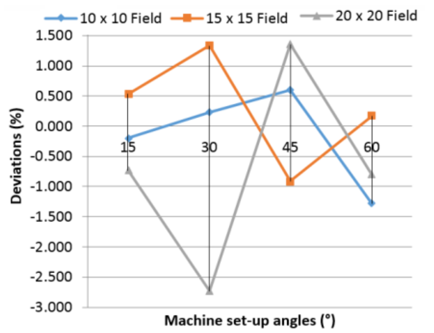

Fig. 2: Deviation between calculated and machine set-up angles at various field sizes for 15 MV energy.

The variation or deviation in 15 MV is lesser than 6 MV it is may be due to beam hardening effect in 6 MV, beam hardening is the effect when radiations passes through from metal low energy captured in metal. The previously study was done on PRIMUS3008 linear accelerator Siemens and the deviation between calculated and machine set-up angle is found to be within 1%.[9] In higher energies large field sizes has higher variation which implies that Siemens' computerize wedge use for fields less than 20 cm^2. Higher variations observed in case of 30 and 45 degrees of wedge angles which indicates that at these angles computerize wedge filed produced high inaccuracy due to the speed of collimator jaws. Our study has significance at 30 and 45 degrees of wedge angles, in which previous study on Elekta motorized wedge did not provide error at specific angles. This achievement is due to the shape of computerize collimator. The information obtained by recent study regarding the wedge angle confirmation for Elekta for 15 × 15 cm^2 field size is given in Table 4.[15]

Table 3: Percent deviations in the virtual wedge angle from machine set-up angles at 10 × 10 cm^2, 15 × 15 cm^2 and 20 × 20 cm^2 for 15 MV.

Field Sizes (cm^2)	Machine Set-up Wedge Angles (°)	Calculated Wedge Angles (°)	Deviation (°)	Percent deviation (%)
10 × 10	15	14.69	15.03	0.03
	30	29.16	29.93	0.07
	45	44.75	44.73	0.27
	60	58.42	60.77	0.77
15 × 15	15	15.15	14.92	0.08
	30	30.33	29.6	0.4
	45	46.35	45.41	0.41
	60	61.97	59.9	0.1
20 × 20	15	15.35	15.11	0.11
	30	30.64	30.82	0.82
	45	45.85	44.39	0.61
	60	59.9	60.48	0.48

Table 4: Effective wedge angles and Percent deviations in Elekta monitored wedge angle from machine setup virtual wedge angle for 15 × 15 cm^2 square field size.

Machine Set-up Wedge Angles (°)	Calculated Effective Wedge Angles (°)	Percent deviation (%)
15	12.35	2.65
30	26.29	3.71
45	41.12	3.88
60	57.10	2.9

Our study shows the deviations from original value within 3%, which is in satisfactory mode, this variation increases in higher fields due to the electron contamination with x-rays beam, deviation also increases with wedge angle as thickness increases energy decreases .As far as the effect of energy beam is concerned, in low energy deviation increases due to the beam hardening effect.

CONCLUSION

This study verified the treatment of using virtual wedge angle in Siemens' ONCOR linear accelerator. The effective wedge angles were calculated for various field sizes and energies that were required for TPS. The beam hardening and scatter of the wedge effect caused the difference between effective wedge angle and planned wedge angle.[15] Scattering of the wedge increased with field size and could be reduced by modification of the wedge shape and material. In high energy exposure large fields have significant variations and in high energy 30 and 45 degrees of wedge angles produce significant variations. The influence field size on effective wedge angle was not higher than proposed uncertainly 3%.[15] So this outcome in treatment planning system should not be considered. The required dosimetric characteristic of TPS for all field sizes could not be measured in the present study. This paper shows the variation in the effective wedge angles from machine setup angles as a function of the field size and beam energy. This algorithm was validated with measuring data successfully. The method was proved to calculate wedge angle based on factors of field method can be used as an alternative method for TPS by minimum required measurement.

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