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Research Article

Effect of Isodose Symmetry of Wedge-shaped Beam Profile for External Radiation Therapy

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Abstract: Accurate determination of dosimetric parameters is vital in radiotherapy to avoid normal-tissue damage. For accurate delivery of dose to the target volume, uniform dose distribution is achieved by the use of wedge filters. It is important to measure all parameters of photon beam profile before calibrating linear accelerator (LINAC). Quality assurance of radiotherapy treatment planning procedure depends largely on symmetry parameter, which determines quality of radiation beam produced by LINAC. To make analysis of beam profile parameter, symmetry, for 6 MV and 15 MV beam energies is attained by varying different factors such as depth, field size and wedge angle. We measured photon beam profile for dual photon energies using DHX Clinic and PTW array detector. Data management, analysis and processing of isodose curves were carried out by PTW MP3-M water tank and PTW MEPHYSTO version 7.3 software. By the use of this software, dosimteric parameters for wedged beam profiles were calculated at different depths and field sizes for 6 MV and 15 MV energy for quality assurance and commissioning. Variation in symmetry was analyzed with parameters, such as field size, depth, wedge angle and beam energy, to match acceptance criteria as recommended by American Association of Physicists in Medicine (AAPM) protocols**.** This article describes symmetry parameter test of wedge-shaped beam profile. For treatment planning purpose this parameter can be treated as being independent of depth and field size for wedged shape beam profile. Values of symmetry were in good agreement with AAPM protocol and symmetrical radiation beam is useful in treating tumors.

Keywords: Wedge, beam symmtery, dose distribution, isodose curves

1. INTRODUCTION

Isodose distribution of beam with wedges are required for clinical purpose in radiotherapy treatment planning process. The simplest method for producing wedge-shaped isodose distribution is the use of physical wedges, others being Universal Wedges UW and Enhanced Dynamic Wedges EDW. To improve dose inhomogeneity compensation in high energy photon beam therapy, wedges tilt isodose curves by attenuating the beam more on thicker side then on thinner side. Separate wedge filters are optimally designed and inserted in the path of radiation beam for each beam width. Wedge filters made of high density material such as lead or steel are mounted on a tray and inserted at specified distance from the source. Physical wedges attenuate the beam and are characterized by their wedge angle [1]. Wedges are of considerable importance in clinical situations when dealing with irregularly shaped target volumes and sloped patient surfaces to avoid irreparable damage to subcutaneous tissues. Physical wedges are available for wedge angles of 15°, 30°, 45° and 60° [2].

The quality of radiation beam is determined by a parameter called symmetry. Treatment outcome is highly dependent on this parameter. Recommendations from World Health Organization WHO reports on quality assurance suggests that optimal value of deviation for symmetry should fall within ±3%. This parameter should be checked once a year as reported by several national and international associations [3]. Beam symmetry is an important parameter for assessment of beam uniformity and is usually calculated at Z_{max}. Z_{max} is most sensitive depth for estimation of beam symmetry. Symmetry specification is that beam profile at Z_{max} should be

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equidistant from the central axis on each left and right side and are within 2% of each other. Water tanks scanning systems can automatically plot isodose curves for calculation of areas under Z_{max} beam profiles. Different manufacturers adopt different criterion to calculate symmetry. Varian has a tolerance limit of ±2% for photon beams. The American Association of Physicists in Medicine AAPM TG-40 approves the symmetry to be within ±3% [4].

To reduce probability of harm to a patient proper quality assurance is necessary in radiotherapy process. Change of about few percent in dose to tumor may result in increased probability of treatment failure and hence increased exposure to personnel. For individual patient setup different treatment modalities are required. This necessitates the detailed measurement of dosimteric parameters, which is carried out during the process of commissioning a linear accelerator (LINAC). This process also includes entry of specific machine data into the treatment planning software and testing its accuracy [5]. Many clinical situations require the use of wedge-shaped isodose distributions. Insertion of physical wedges result in undesirable dosimteric characteristics such as hardening of beam, limited field size and fixed wedge angle [6]. Besides Physical wedges have numerous unfavorable dosimteric attributes i.e. they are heavy and limited in size. Furthermore low energy photon scattering increases because of the use of high density and high atomic number material in these wedges [2]. With the development of modern treatment technique such as Intensity Modulated Radiation Therapy IMRT, physical wedges are replaced by soft wedges. However they are still widely used in external beam radiotherapy because clinical use of IMRT is limited for several reasons. Some of which are increased treatment time, sparse manpower, and limited clinical outcome data [7]. Major factor which defines beam homogeneity is beam symmetry. In radiotherapy it is required that radiation beam be as uniform as possible, since heterogeneities may cause under dosing of the target volume resulting in treatment failure. Homogeneous beams are represented by straight isodose curves. However, in practice it is desirable to achieve isodose curves as straight and perpendicular to beam direction as possible [8].

2. MATERIALS AND METHODS

Symmetry requirement is fulfilled if the ratio between measured doses for each pair of points that are symmetrical along central axis lies between 0.97 and 1.03 within the flattened area [9].

$$symmetry\,\% = \left[\frac{D(x,y)}{D(-x,-y)}\right] 100\,\%$$

For maintenance of accuracy level in radiotherapy process, national and international agencies recommend several procedures, which give tolerance limit of physical parameters. The recommended Z_{max} depth is 10cm and beyond this depth under flattening of beam profile is observed.

In this study Varian Clinac DHX (Varian Medical Systems Inc. Palo Alto, CA) linear accelerator was operated with standard blue water phantom, which act as human tissue, to obtain scans. During measurements pressure and temperature of room were kept constant. Measurements of commissioning beam data were performed with cylindrical ion chamber N30001/PTW FREIBURG. Values of symmetry were expressed in percentage. In present work data management, analysis and processing of isodose curves was carried out by PTW (PTW, Freibereg, Germany) MP3-M water tank and PTW MEPHYSTO version 7.33 advanced software. By the use of this software, dosimteric parameters such as central axis deviation, left and right penumbras, field 50%, Dmax, Dmin, symmetry and homogeneity, for wedged beam profiles were calculated at different depth and field sizes for 6 MV and 15 MV energy for quality assurance and commissioning. Each scan automatically generates standard values of symmetry. Physical wedges (15°, 30°, 45° and 60°), made of lead and steel, were inserted into radiotherapy unit. For the measurement of dose in mGy, ionization chamber in water was connected to electrometer. Wedges have constant width of 20x40 cm^2. Data was obtained for all wedge angles at different depths from 50 mm, 100 mm, 200 mm and 300 mm and field sizes of 5 x5 cm^2, 10 x 10 cm^2, 15 x 15 cm^2, 20 x 20 cm^2, 25 x 25 cm^2 and 30 x 30 cm^2.

3. RESULTS

Symmetry values, to check uniformity of isodose curves, were tabulated and then graphically

Table 1. Percentage difference in symmetry 6 MV and 15 MV for Field Size 5x5 cm^2.

Wedge Angle	Symmetry			
	Depth (mm)	**6 MV**	**15 MV**	**% Diff.**
15	50	105.4	104.2	1.14
30	50	111.03	108.7	2.10
45	50	116.48	115.85	0.54
60	50	129.89	131.94	-1.58
15	100	105.62	104.46	1.10
30	100	110.5	108.09	2.18
45	100	115.85	116.23	-0.33
60	100	131.2	133.07	-1.43
15	200	105.3	104.46	0.80
30	200	110.29	109.16	1.02
45	200	116.18	116.46	-0.24
60	200	132.46	133.94	-1.12
15	300	105.14	104.41	0.69
30	300	110.58	109.4	1.07
45	300	116.53	116.89	-0.31
60	300	131.97	135.06	-2.34

Table 2. Percentage difference in symmetry 6 MV and 15 MV for wedge angle 45◦.

Depth	Symmetry			
	Field size	**6 MV**	**15 MV**	**% Diff**
50	5x5	116.48	115.85	0.54
100	5x5	115.85	116.23	-0.33
200	5x5	116.18	116.46	-0.24
300	5x5	116.53	116.89	-0.31
50	10x10	137.35	136.4	0.69
100	10x10	136.44	135.68	0.56
200	10x10	132.52	134.08	-1.18
300	10x10	130.96	133.31	-1.79
50	15x15	163.33	160.41	1.79
100	15x15	160.16	159.24	0.57
200	15x15	154.11	156.2	-1.36
300	15x15	151.9	156.74	-3.19
50	20x20	194.38	190.09	2.21
100	20x20	188.17	190.6	-1.29
200	20x20	180.12	187.66	-4.19
300	20x20	176.82	184.55	-4.37

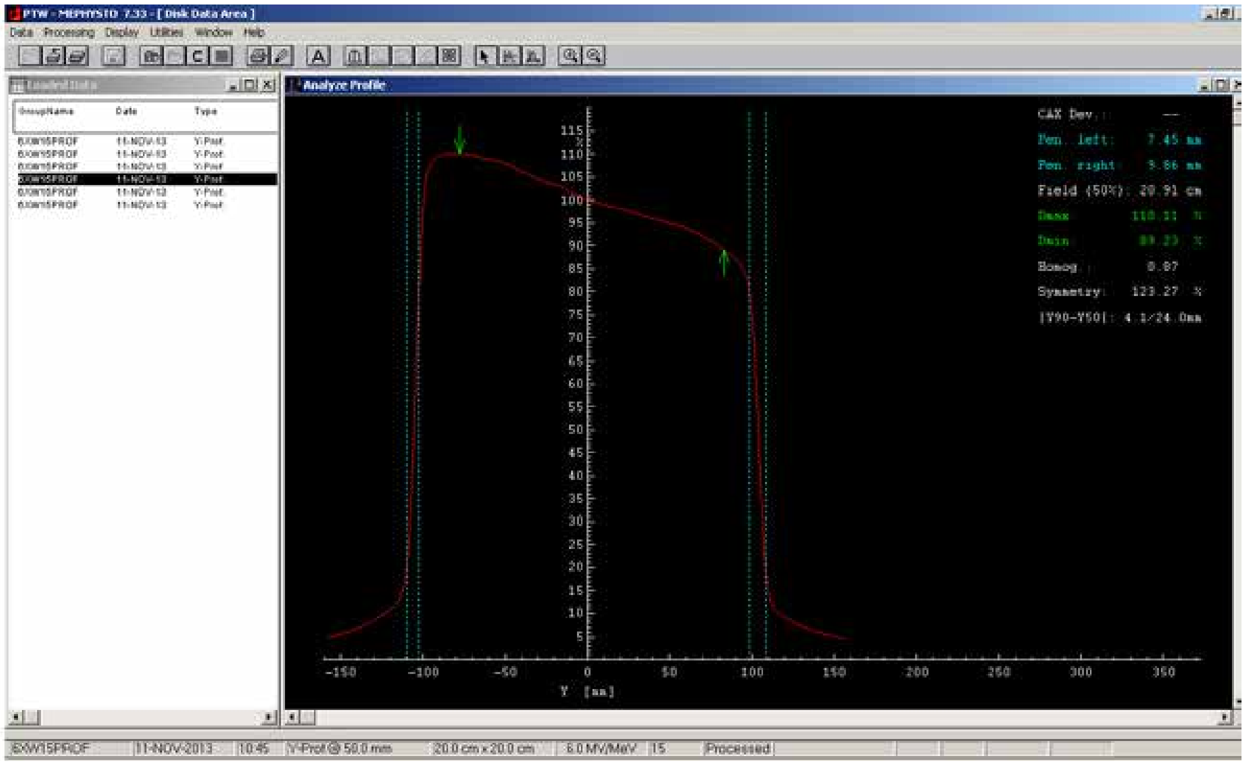

Fig. 1. Wedge shaped isodose curves for 6 MV photon beam and field size of 20x20 cm^2 and wedge angle of 15°.

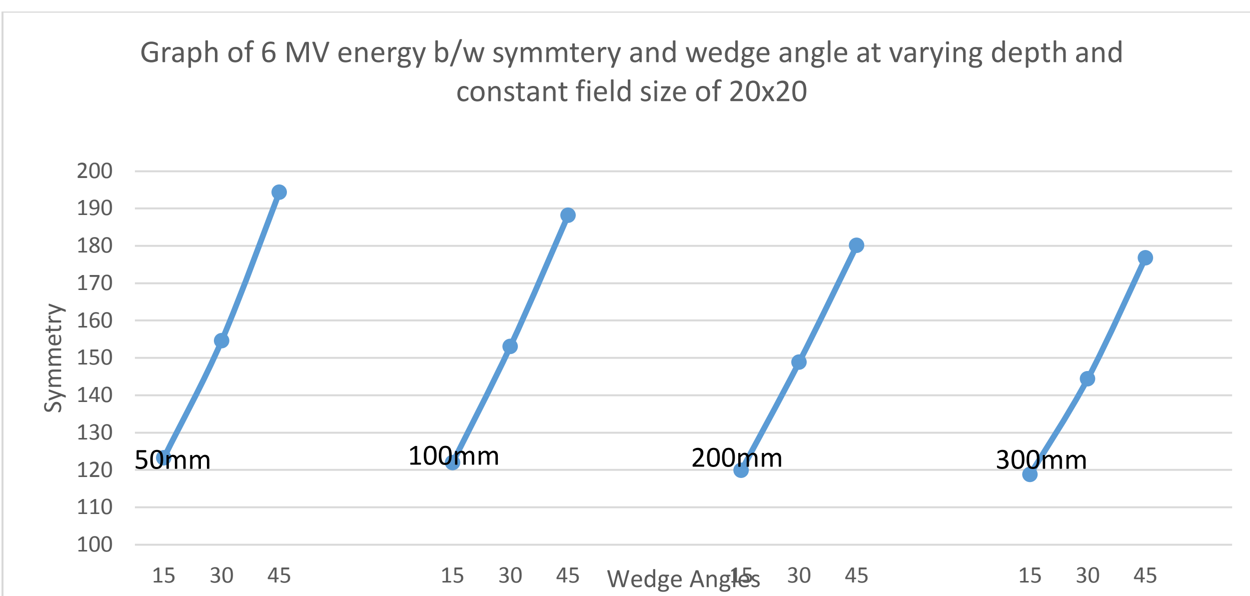

Fig. 2. Relationship between symmetry and wedge angle at varying depth and constant field size of 20x20 cm^2 using 6 MV photon energy.

analyzed. Comparison between symmetries at 6 MV and 15 MV energies were explored and are presented in Table 1 and Table 2. Results were obtained for energy of 6 MV and 15 MV in three different ways. Firstly by studying the effect of depth on symmetry at different field sizes and for all wedge angles. Secondly graphs of symmetry vs. wedge angle were drawn at varying depth keeping field size constant. Lastly variation in symmetry with field size was reported at constant depth and different wedge angles. Comparison between symmetries at 6 MV and 15MV energies was also explored in this paper. The baseline values obtained during acceptance testing and commissioning are shown in Fig. 1.

Data was analyzed for following square field sizes: 5, 10, 15, 20, 25, 30 cm^2, however few results are represented here. Results obtained showed that symmetry negligibly increases with wedge angle at constant depth. Also it was observed that symmetry parameters negligibly decreases at greater depths compared to smaller depths. Values of symmetry are less for 100 mm depth as compared to 50 mm depth, except at 5 x 5 cm^2 field size, for same wedge angle and field size as presented in Fig. 2 and Fig. 3. Symmetry increased as wedge angle increased from 15 to 45 at constant depth, irrespective of the fact that depth taken was 50 mm, 100 mm, 200 mm or 300 mm (Fig. 2, Fig. 3).

In Fig. 4 and Fig. 5, Graphs of depth vs. symmetry at varying field sizes and constant wedge angle of 15°, 30°, 45° and 60° proved that there is very slight decrease in symmetry with depth for 6 MV and 15 MV photon beams. However decrease in symmetry with depth was more pronounced for larger field size then for smaller field sizes.

Effect of symmetry on field sizes for 6 MV and 15 MV photon beams and wedge angle studied at particular depth as illustrated in Fig. 6 and Fig. 7. Symmetry linearly increases with increase in field size for 50mm, 100 mm, and 200 mm and 300 mm depths. Similar behavior is shown for all wedge angles. For 15 MV beam, graph show nonlinear behavior for small field sizes. No discontinuity in values of symmetry were observed at different depths for all field sizes. So values of symmetry for 6 MV and 15 MV were quiet similar.

4. DISCUSSION

Symmetry is specified obliquely at several field sizes for a particular depth and for number of gantry angles. Computer controlled water phantom scanning systems were used for the measurement of symmetry. This parameter is not dependent on the depth of measurement and is a maximal ratio of doses on both symmetrical points of the field relative to central axis [10]. Physicists should check symmetry for all major planes containing collimator axis following the presentation of isodose lines [11]. Central axis of the chamber was taken as the point of measurement in cylindrical chamber as is mentioned in AAPM's TG-51 protocol [12].

By graphical investigation of beam profiles, beam distribution was found to be symmetrical. However it is recommended to make thorough analysis of all beam parameters during commissioning. This will improve the reproducibility of dose delivery procedure. This exploration revealed that there was negligibly slight difference in values of symmetry for 6 and 15 MV beam. Field size has a direct connection with the number of photons entering the phantom or the patient. Larger field sizes allow more photons to penetrate through them as well as they generate more scattered photons, thus leading to greater dose at specified points. This increase of symmetry with increasing field size is due to the fact that the scattering of radiation beam becomes large for larger field size [13].

Similarity of symmetry values for 6MV and 15 MV dose beam profiles can be precisely modeled by approximating 6MV beam to 15 MV beam. Published results revealed that for 6 MV and 15 MV beams primary and scattered components of radiation beams are altered by the presence of wedges. Increase in wedge angle results in increase in beam hardening. As is obvious from graphical analysis, there was very slight or no deviation in symmetry values for different energies. So this can be considered as a constant parameter and did not have much dependence on field sizes, depth, and energy of photon beam and wedge angle [10]. For wedged beam profiles, measured results were generally good and did not exceed the criterion for symmetry i.e. ±3% [3-4].

In conclusion, values of symmetry by DHX Clinac were in good agreement with AAPM

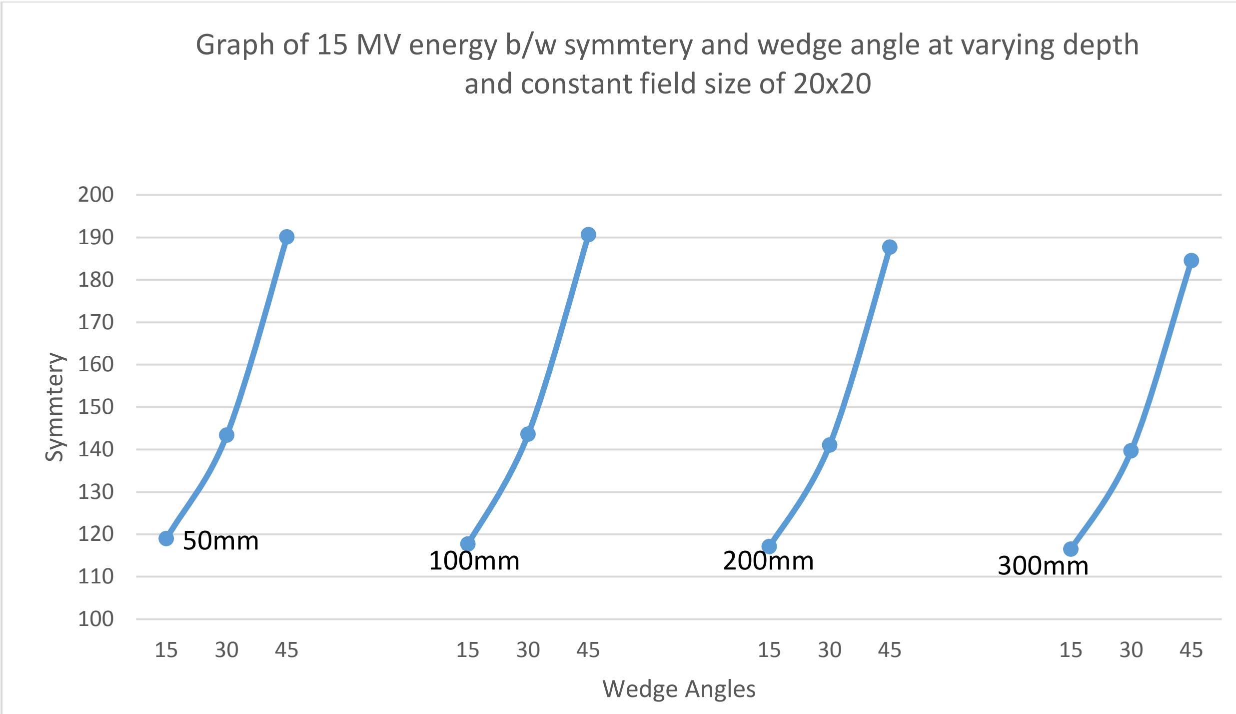

Fig. 3. Relationship between symmetry and wedge angle at varying depth and constant field size of 20x20 cm^2 using 6 MV photo energy.

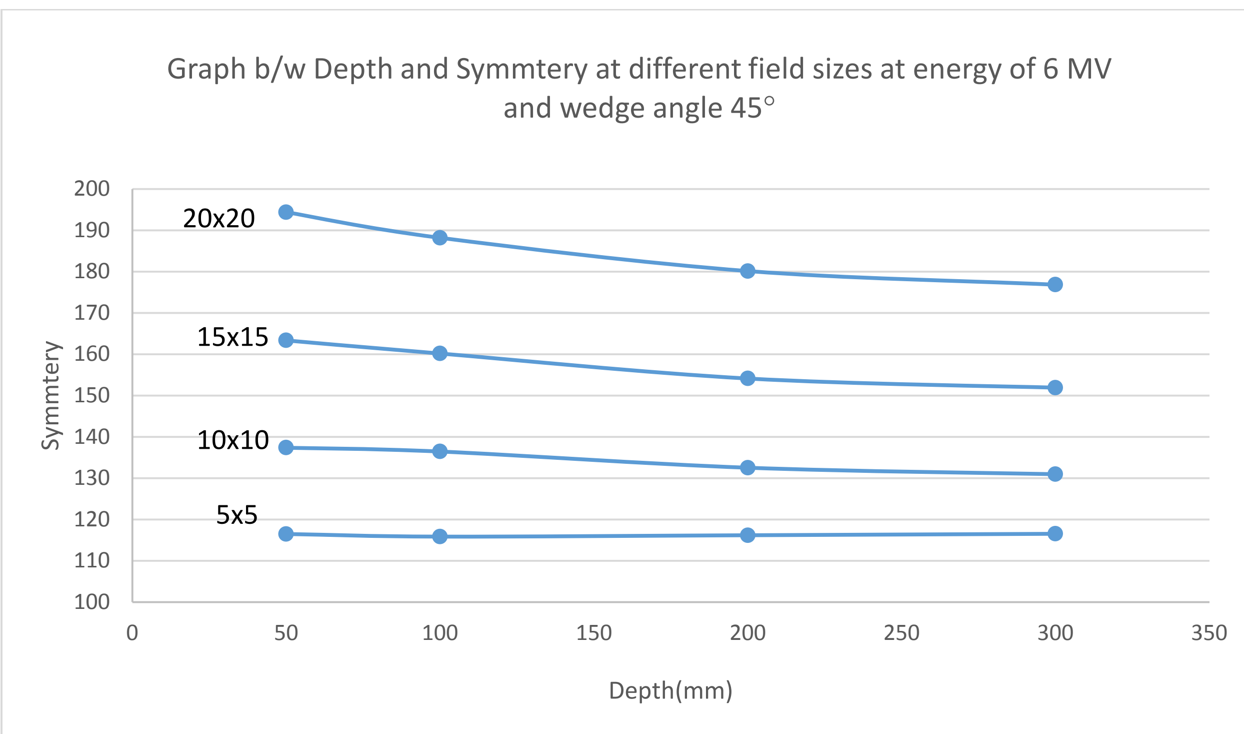

Fig. 4. Relationship between depth and symmetry at different field sizes using 6 MV photon energy for 45° wedge angle.

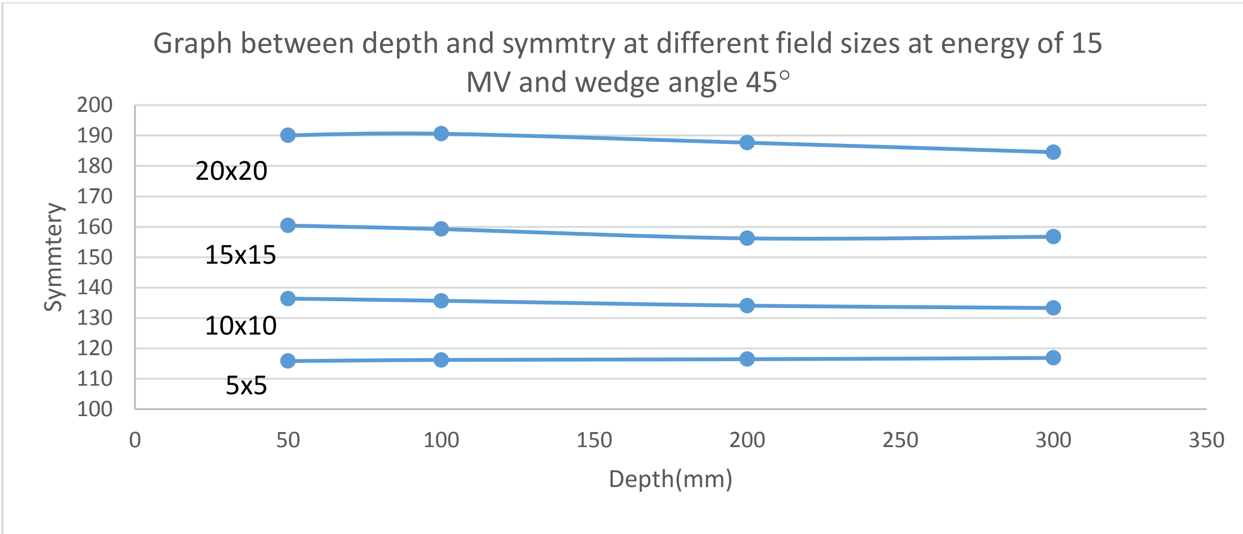

Fig. 5. Relationship between depth and symmetry at different field sizes using 15 MV photon energy for 45° wedge angle.

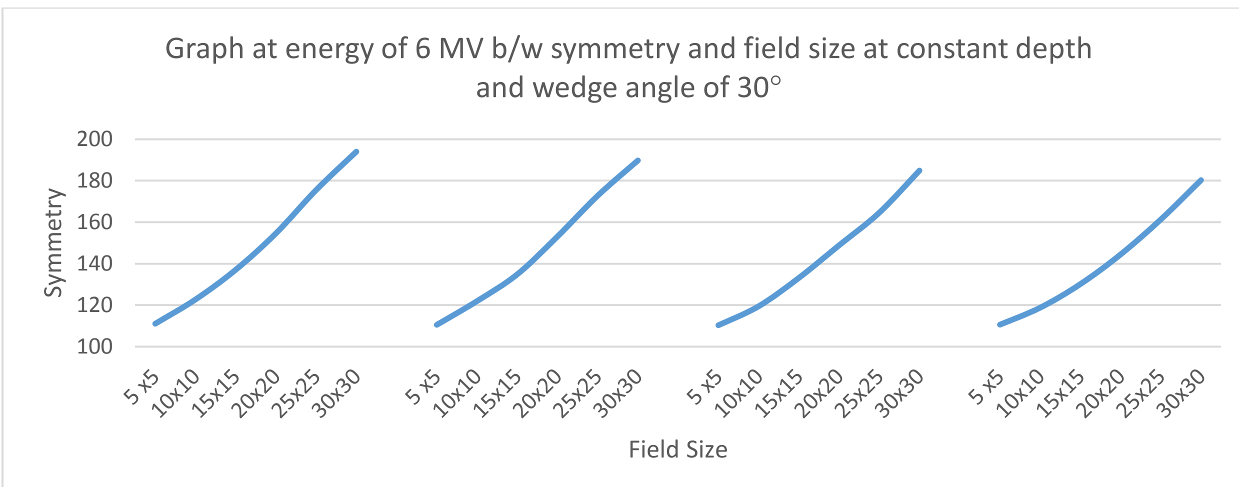

Fig. 6. Symmetry and field size at constant depth and wedge angle of 30° using 6 MV photon beam.

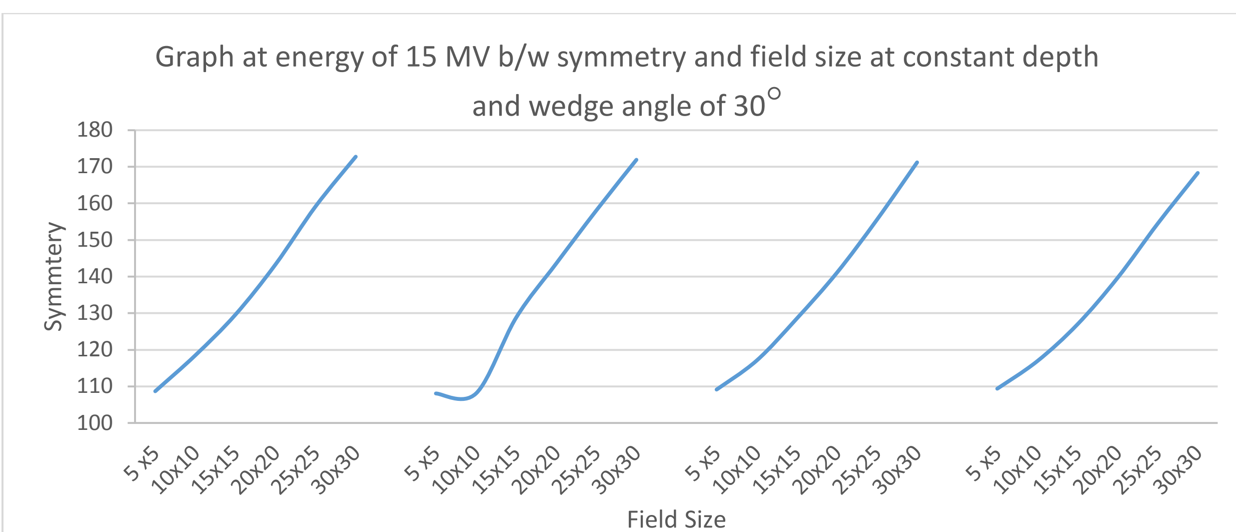

Fig.7. Symmetry and field size at constant depth and wedge angle of 30° using 15 MV photo beam.

protocol and radiation beam being symmetrical is useful in treating tumors.

5. CONCLUSIONS

Isodose distribution of beam with wedges is required for clinical purpose in radiotherapy treatment planning process. To reduce probability of harm to a patient proper quality assurance is necessary in radiotherapy process. This necessitates the detailed measurement of dosimteric parameters, which is carried out during the process of commissioning a LINAC. The quality of radiation beam is determined by a parameter called symmetry. Treatment outcome is highly dependent on this parameter. Results were obtained for energy of 6 MV and 15 MV by analyzing effect of depth, field size, beam energy and wedge angle on symmetry. Comparison between symmetries at 6 MV and 15 MV energies had also been explored in this paper. Implication was that for treatment planning purpose this parameter can be treated as being independent of depth and field size for wedged shape beam profile. Values of symmetry by DHX Clinac were in good agreement with AAPM protocol and radiation beam being symmetrical was useful in treating tumors. This can be considered as a constant parameter and does not have much dependence on field sizes, depth, and energy of photon beam and wedge angle. For wedged beam profiles, measured results were generally good and did not exceed the standard criteria for symmetry. This study can be extended to investigate and analyze the effect of other beam parameters, such as homogeneity and flatness, on depth, field size and wedge angle. Also wedge shaped beam characteristics can be compared to open field dosimetric parameters.

6. ACKNOWLEDGMENTS

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