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Dosimetric investigation of dual energy photon beams with assymmetric collimator jaws

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Many modern linear accelerators are equipped with asymmetric collimators or jaws that can be moved independently. Asymmetric jaws have got many clinical applications in radiation therapy. In the present study, the dosimetric characteristics of asymmetric collimators from our linear accelerator with 6 and 18 MV X-rays were carried out. The field size factors (FSF) and half value layer (HVL) were measured in a water phantom using 0.6 cc Farmer chamber for symmetric and asymmetric fields for both 6 and 18 MV X-rays. Measurements of beam penumbra, percentage depth dose (PDD), cross beam profiles and calculated isodose curves were measured by RFA 300 for both asymmetric and symmetric fields. The FSF were found to agree with in 3% for symmetric and asymmetric fields. The HVL in water was found to be 15.8 cm and 14.4 cm for 6 MV photons and 26 cm and 22.9 cm for 18 MV photons at the central axis and at 20 cm off the central axis. At 30 cm depth the percentage depth dose for symmetric and asymmetric fields were found to differ as high as 6% for 6 MV and 4% for 18 MV fields. No observable difference in penumbra was noticed for symmetric and asymmetric fields of same dimensions. The constrictions of isodose curves at the edge nearer to central axis were noticed for asymmetrically placed fields. The observed differences could be due to the passage of primary beam through differential thickness of the flattening filter which alters the beam quality.

Key words: asymmetric field, half value layer, field size factor, percentage depth dose, beam penumbra.

Introduction

An asymmetric X-ray collimator has one or more collimating jaws that can be moved independently of the corresponding opposed jaws. This allows one to block a portion of the field from one side without affecting the opposite jaw setting. Asymmetric collimators have become the routine part of the latest generation of medical linear accelerators, and are being employed in an increasing number of clinical applications such as, (a) in the setup of boost fields, (b) to match adjacent fields, (c) the matching of opposed tangential, (d) in arc or rotation therapy. Asymmetric collimation allows countless possibilities to irradiate a target volume that surrounds the critical organs [4].

The dosimetric parameters of high energy photon beams such as the output factors and field penumbra are strongly dependent on the design of beam collimation system. Therefore, it is expected that asymmetric jaws will affect these beam characteristics. Also, the differential hardening of the beam which results in change of beam quality at off-axis points will influence the depth dose characteristics and shape of the isodose curves as the field opening is moved asymmetrically from the central ray. In this study we have analyzed these dosimetric characteristics of 6 and 18 MV X-rays produced using asymmetric collimators.

Materials and methods

This study used the independent jaw system provided with the Varian Clinac-DHX (S.No. 3172) linear accelerator. The variation of radiation dose rate with field size for the 6 and 18 MV photons were measured in a water phantom using 0.6 cc Farmer type chamber (FC65, Scanditronics, Wellhofer, Germany) for both asymmetric and symmetric fields. The change in beam quality can be indicated by a variation in Half-Value Layer (HVL) of the beam in water at off-axis points. The HVL of the 6 and 18 MV X ray beams were measured on the central and at off-axis points. Transmission measurements were made for varying thickness of white polystyrene phantom placed on the couch. The couch was rotated through 90° to obtain longer measurement distances and scatter free measuring conditions. The 0.14 cc ion chamber covered with brass build up cap was positioned at 2 meter distance from the source and the distance from the target to phantom was maintained as 1 meter. A narrow beam was used in this study and the chamber was positioned at a distance from the absorbers to avoid any scatter reaching the detector and the chamber was positioned away from any scattering medium to create 'good' geometry conditions. Asymmetric jaws were used to generate a narrow beam of 4×4 cm, which is just sufficient to cover the entire active volume of the chamber was used in this study. The measurements were carried out at various off-axis distances by positioning the chamber at the geometric centre of the asymmetric fields. The HVL thicknesses were obtained from the transmission curves and later converted into water equivalent thicknesses. Measurements of beam penumbra, percentage depth doses of asymmetric fields at off-axis, cross beam profiles and experimental isodose curves were measured by RFA 300 (Scanditronics, Wellhofer, Germany) in a water phantom.

Results and discussion

Field Size Factors (FSF)

The relative FSF measured on the central ray for the symmetric fields and for the asymmetric fields measured at the geometric centre are shown in Figure 1a and 1b for 6 and 18 MV photons. It has been suggested that (Patterson and Shragge [7]) the FSF is a

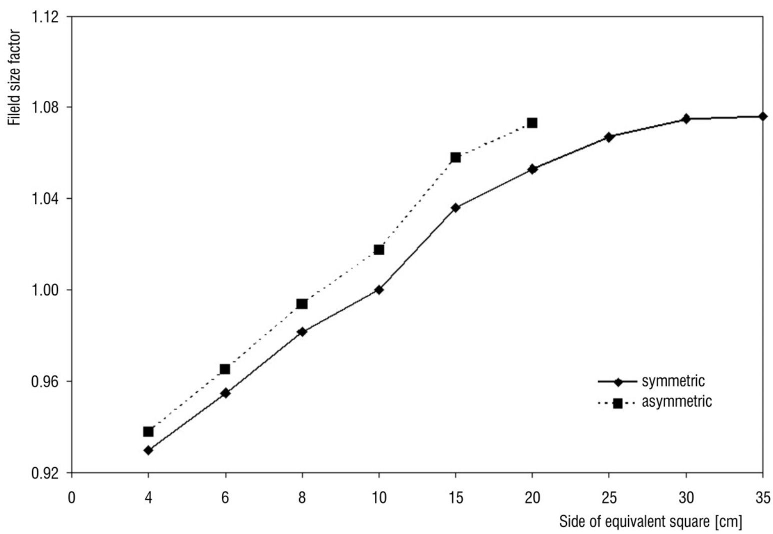

Figure 1a. Field size factors for 6 MV X-rays measured on the central ray of symmetric and asymmetric fields

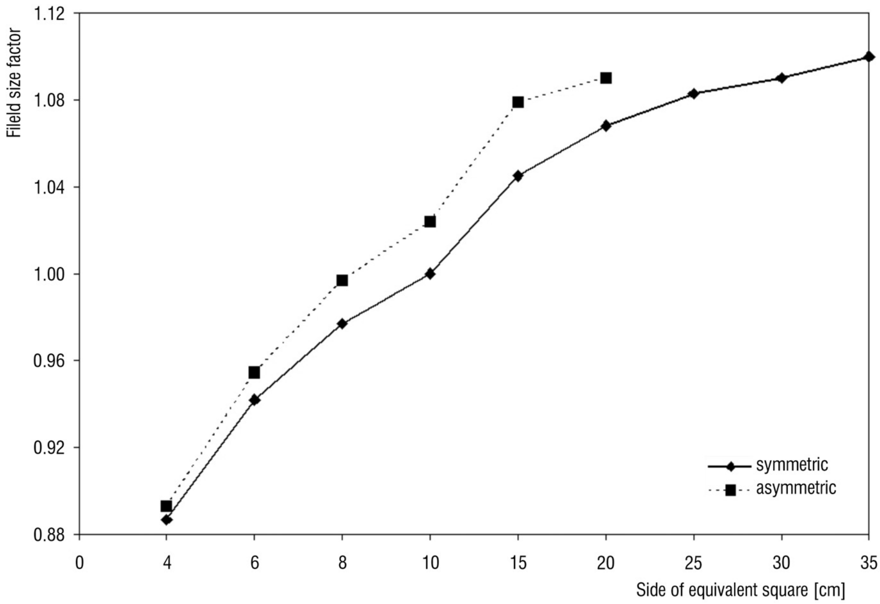

Figure 1b. Field size factors for 18 MV X-rays measured on the central ray of symmetric and asymmetric fields

complex phenomenon that may be expressed as a product of phantom scatter factor, collimator scatter factor and monitor chamber back scatter factor. Therefore, the relative FSF for an asymmetrically placed square field is expected to vary due to changes in any of these factors as the field is moved away from the central ray. Palta et al. [6] has previously measured the FSF for asymmetric field at the depth of dose maximum for a 6 MV beam. He found that the FSF's for asymmetric fields were identical to factors measured on the central axis when each data point is corrected for the change in beam output measured for that off-axis.

In this study, FSF were measured for asymmetric square fields ranging from 4×4 cm^2 to the maximum collimator opening possible, and the displacement of field center of 2 cm to a maximum of 10 cm from the collimator axis. All point measurement at the particular field centre offset were normalized to the centre of a 10×10 cm^2 field with the same field centre offset for both 6 and 18 MV X-ray fields. The FSF values for 6 and 18 MV asymmetrically placed fields were found to agree with the FSF values for a symmetrically placed fields at the same depth to with in 3%. The FSF results suggest the relative change in total scatter with field size is independent of the field centre offset along the principal axis for both 6 and 18 MV X-rays.

Half Value Layer in water (HVL)

The change in beam quality is indicated by a variation in HVL of the beam in water at off-axis points. The HVL was estimated for 6 and 18 MV photons along the central axis and at off-axis points. Asymmetric jaws were used to generate a narrow beam at various off-axis distances.

The variation in HVL across the beam is shown in Figure 2a and 2b for 6 and 18 MV X-rays. Hanson et al. [1] have measured the HVL for photon energies ranging between 4 to 10 MV from different linear accelerators. It was found that the beam energy decreased with the increasing distance from the central axis to the periphery of the beam. Hortons et al. [2] measured the HVL of the beam in water on the central axis and at points along the diagonal at 7, 14 and 21 cm off-axis at a distance of 100 cm from the source and reported that the HVL on the central axis is 14.7 cm and decreased to 13.3 cm at 21 cm off the central axis.

In our present study, it was observed that the HVL in water was found to be varying from 15.8 cm at the central axis to 14.4 cm at 20 cm off the central axis for 6 MV photons. For 18 MV, HVL in water at central axis was 26 cm and decreased to 22.9 cm at off-axis

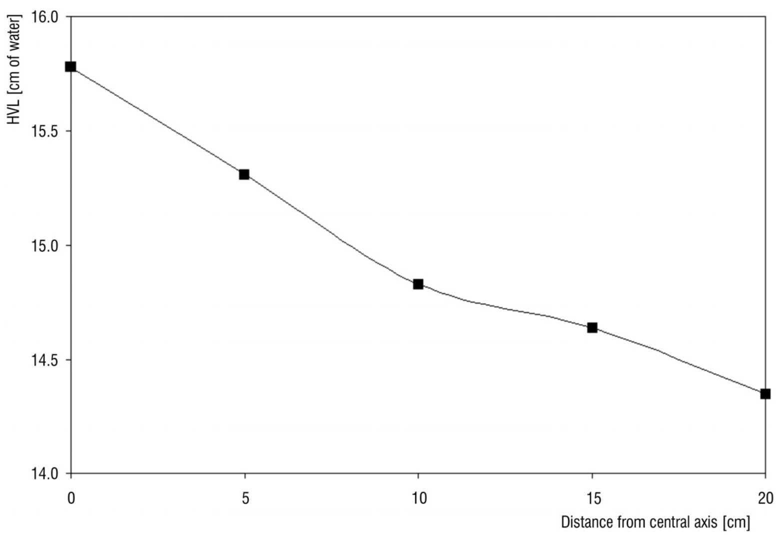

Figure 2a. HVL in water at various off-axis distances for 6 MV X-rays

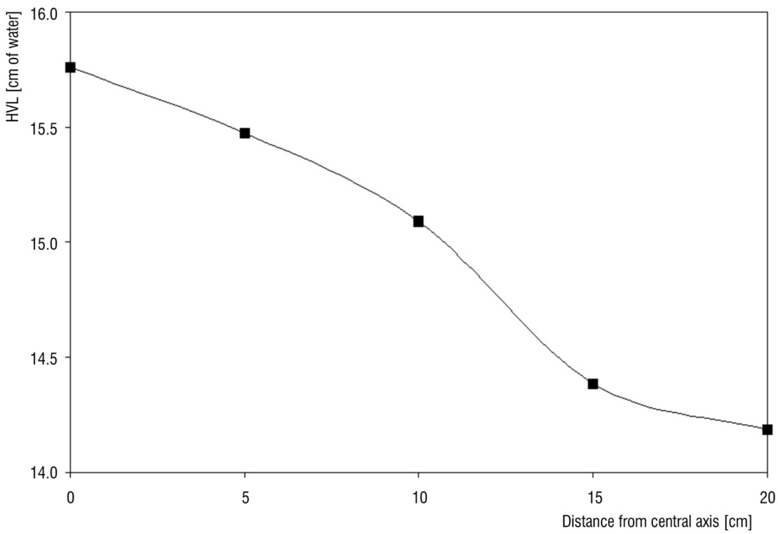

Figure 2b. HVL in water at various off-axis distances for 18 MV X-rays

distance of 20 cm. These results demonstrate some radial softening of the beam by the cone shaped flattening filter as studied earlier.

Percentage Depth Dose (PDD)

The PDD in the centre of asymmetrically placed field is expected to change if there is significant change in beam quality at points away from the central ray. Palta et al. [6] measured the central ray depth doses for several field sizes with different field offsets. The change in PDD up to 7 cm off-axis and depths up to 15 cm was found to be less than 2.5%.

In this study, we have measured the depth doses for symmetric and asymmetric square fields of 10×10 and 20×20 cm^2 at the field centre for both 6 and 18 MV photon fields. The asymmetric fields were obtained by placing the X and Y jaws at different locations ($x_1 = 0, x_2 = 10, y_1 = 5$ and $y_2 = 5$ for 10×10 cm^2 and $x_1 = 0, x_2 = 20, y_1 = 10$ and $y_2 = 10$ cm for 20×20 cm^2).The variation in PDD values are shown in Table 1a and 1b. At greater depths the PDD differences between symmetric and asymmetric field centre were more significant and are as high as 6% for 6 MV and 4% for 18 MV fields.

Table 1a. Measured central ray depth doses from symmetric and asymmetric fields for 6 MV photons

Depth [cm]	Symmetric 10×10 field [cm^2]	Asymmetric 10×10 field [cm^2] (X_1=0; X_2=10)	Symmetric 20×20 field [cm^2]	Asymmetric 20×20 field [cm^2] (X_1=0; X_2=20)
2	99.3	99.1	98.8	98.4
4	91.1	91.0	91.6	90.7
5	86.9	86.4	87.7	86.9
8	74.6	73.9	76.7	75.4
10	67.0	66.2	70.0	68.4
15	50.9	50.1	54.9	53.0
20	38.5	37.7	42.7	40.7
25	29.1	28.3	33.0	31.4
30	22.2	21.4	25.6	24.1

Table 1b. Measured central ray depth doses from symmetric and asymmetric fields for 18 MV photons

Depth [cm]	Symmetric 10×10 field [cm^2]	Asymmetric 10×10 field [cm^2] (X_1=0; X_2=10)	Symmetric 20×20 field [cm^2]	Asymmetric 20×20 field [cm^2] (X_1=0; X_2=20)
4	99.4	99.1	97.7	97.2
5	96.7	96.6	94.4	94.0
8	86.4	86.1	84.7	83.8
10	79.8	79.3	78.5	77.7
15	64.9	64.4	65.0	63.8
20	52.8	52.1	53.7	52.2
25	43.1	42.4	44.4	43.1
30	35.3	34.6	36.6	35.4

Beam penumbra

Measurements of beam penumbra width at depth of d_{max}, 5 cm, 10 cm for different combination of collimator jaw position symmetric and as well as asymmetric fields were presented in the Table 2a and 2b, which exhibited no observable differences for symmetric and asymmetric fields of same dimensions. Asymmetrically placed field exhibit similar degradation in sharpness of the beam edge with depth as the symmetric field. This is primarily because of increasing phantom scatter.

Isodose curves

The cross line beam profiles were measured for a 10×20 cm^2 field defined at 100 cm source-surface-distance of both symmetric and asymmetric fields at depths of 5, 10, 15 and 20 cm for both 6 and 18 MV X-ray fields. From the measured profiles the calculated

Table 2a. Beam penumbra width at 1.5, 5 and 10 cm depth for asymmetrically set fields of 6 MV photons

Field size				Penumbra [mm]		
X [cm]		Y [cm]		1.5 cm depth	5 cm depth	10 cm depth
x_1	x_2	y_1	y_2	(80−20%)	(80−20%)	(80−20%)
0	10	5	5	8	9	10
5	5	0	10	8	9	10
0	10	10	10	8	9	10
10	10	0	10	8	9	10
0	20	10	10	8	10	11
10	10	0	20	8	9	11
5	5	5	5	7	8	9
5	5	10	10	7	8	10
10	10	5	5	8	9	10
10	10	10	10	8	9	11

Table 2b. Beam penumbra width at 1.5, 5 and 10 cm depth for asymmetrically set fields of 18 MV photons

Field size				Penumbra [mm]		
X [cm]		Y [cm]		3.3 cm depth	5 cm depth	10 cm depth
x_1	x_2	y_1	y_2	(80–20%)	(80–20%)	(80–20%)
0	10	5	5	8	8	9
5	5	0	10	10	10	10
0	10	10	10	10	10	11
10	10	0	10	10	10	11
0	20	10	10	10	11	13
10	10	0	20	10	10	11
5	5	5	5	9	9	10
5	5	10	10	9	9	10
10	10	5	5	9	10	10
10	10	10	10	10	10	11

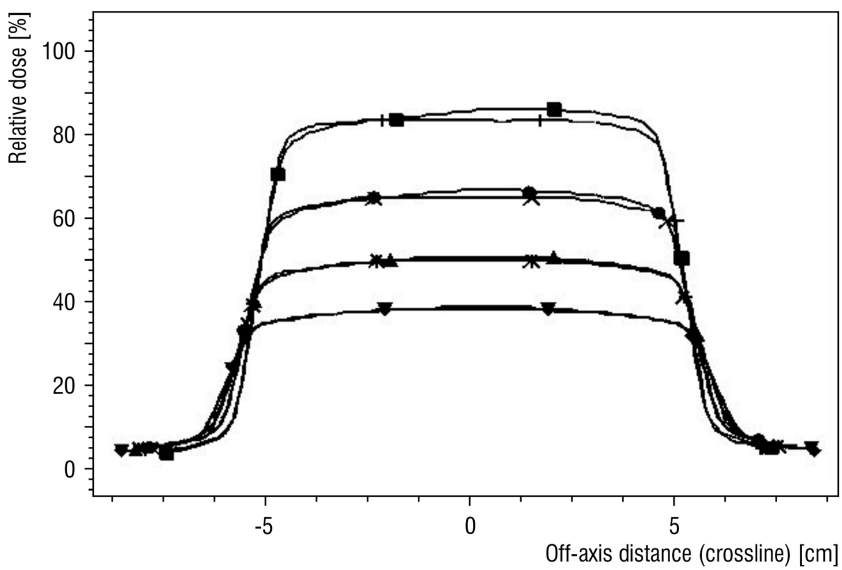

Figure 3a. Comparison of symmetric and asymmetric field crossline profiles for 6 MV X-rays

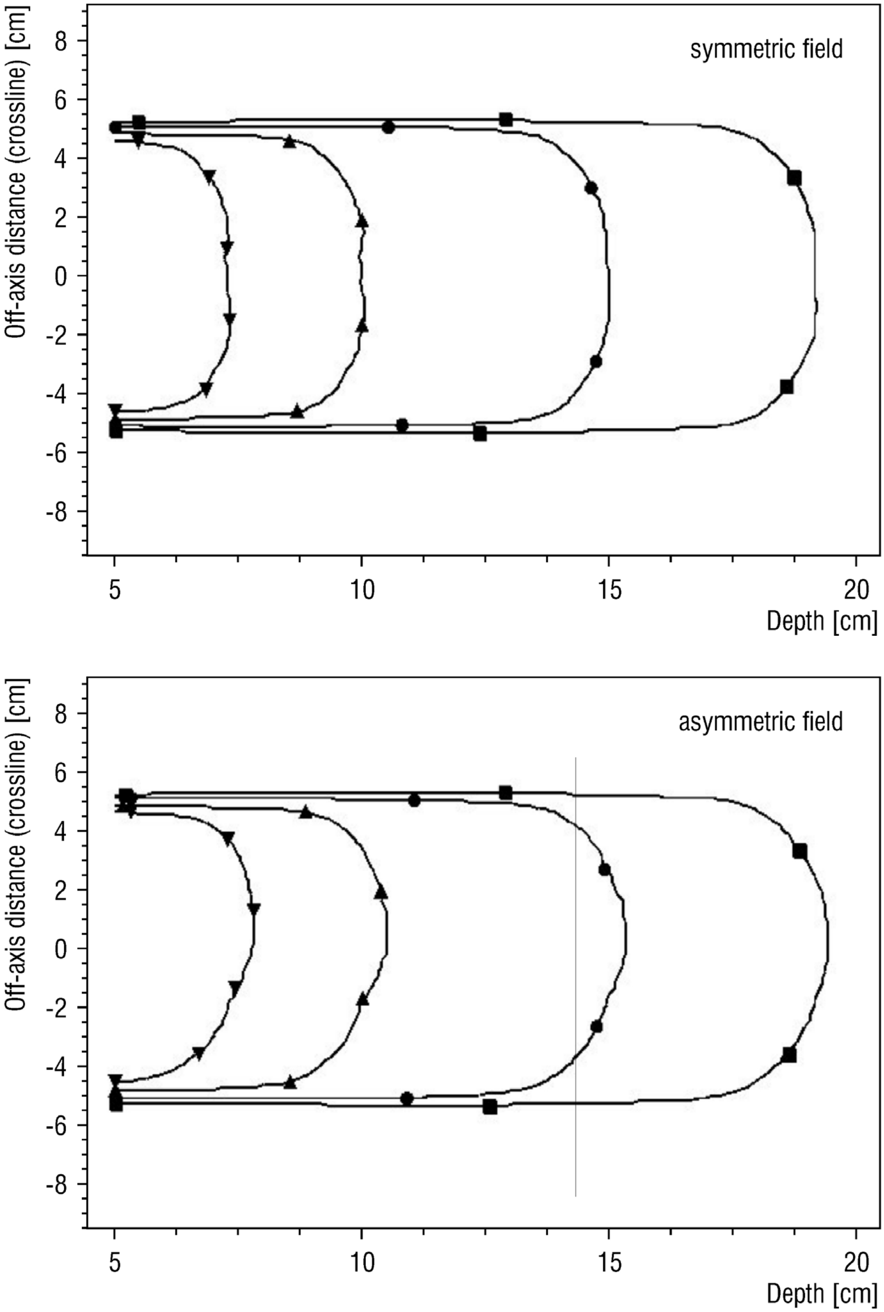

Figure 3b. Comparison of symmetric and asymmetric field calculated isodose curves for 6 MV X-rays

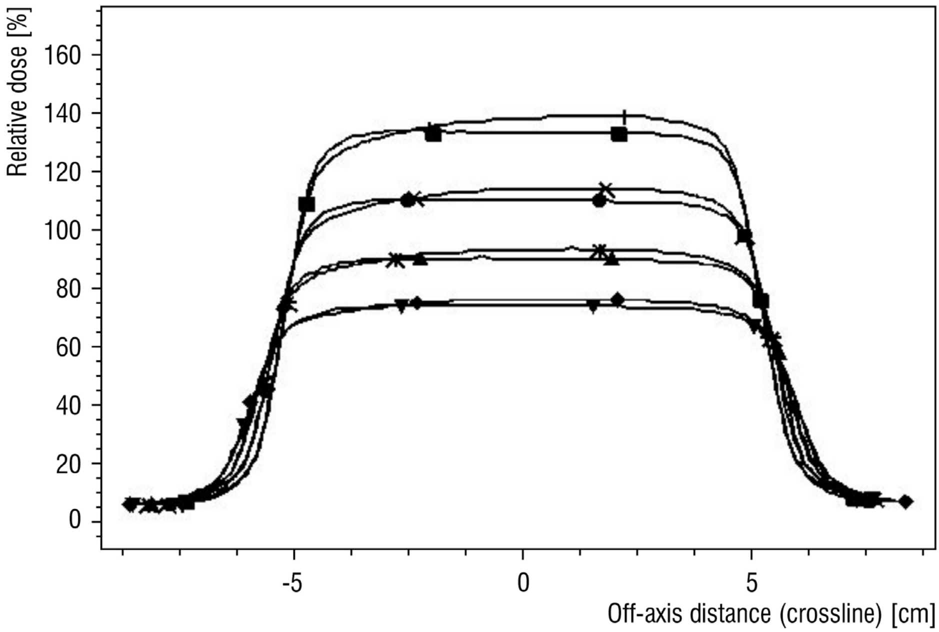

Figure 3c. Comparison of symmetric and asymmetric field crossline profiles for 18 MV X-rays

isodose curves were drawn for both symmetric and asymmetric fields. Figure 3a and 3b shows the comparison of cross beam profiles and isodose curves for symmetric and asymmetric fields of 6 MV X rays and the Figure 3c and 3d shows the comparison of the same for 18 MV X rays.

The constrictions of isodose curves at the edge nearer to central axis for asymmetrically placed fields are obvious. This is attributed to the decrease of primary and side scattered radiation caused by geometrical non-divergence of the beam at that edge. Another characteristic of isodose curves for asymmetrically placed fields are wedging of these curves distal to central ray. This is clearly visible on isodose curves generated on machines that exhibit significant 'horns' on beam intensity cross profiles [3, 5]. In our case this was more pronounced in 18 MV than for 6 MV photon fields.

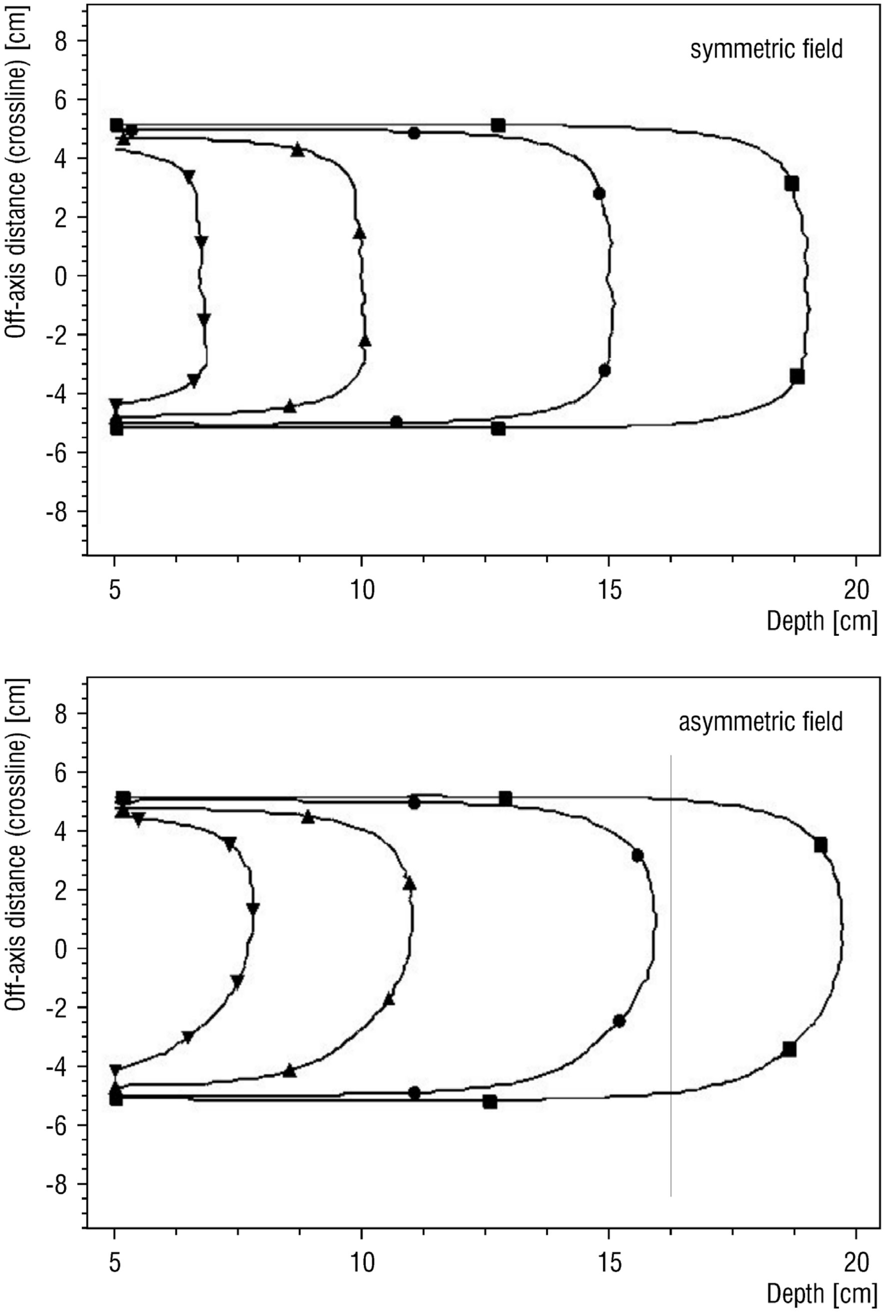

Figure 3d. Comparison of symmetric and asymmetric field calculated isodose curves for 18 MV X-rays

Conclusion

The dosimetric characteristics of 6 and 18 MV photon beams with asymmetric collimation have been investigated. Experimental measurements show that some characteristics of asymmetrically placed fields are qualitatively different from symmetrically placed fields. These were primarily for field size factors and shape of isodose distributions. Most of these differences can be attributed to the beam hardening effect due to the passage of primary beam through differential thickness of the flattening filter.

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