DOSE CALCULATION FOR THE HALF BLOCKED FIELDS DEFINED BY INDEPENDENT JAWS

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ABSTRACT

A system of dose calculation of a 6 MV photon beam from a Clinac 1800 linear acce -lerator for the half blocked fields defined by independent jaws was designed. The dose is computed as the product of the field size factors, the off axis ratios and the percentage depth dose which are determined from a data set of symmetric fields. The dosimetric measurements of these parameters for asymmetric fields were performed to evaluate the calculation method. The field size factors for asymmetric fields are within 1.1% compared to those for symmetric fields corrected for off axis ratios. Asymmetric field percent depth doses differ from those of symmetric field with maximum of 7.5% for field sizes range 4x4 to 20x20 cm. and depth down to 20 cm. The measured isodose curves of asymmetric fields show about 4% reduction of dose near the field edge closed to the flattening filter center. Calculation of the doses for half beam by this method have been checked by the measurement of the dosage at 1.5, 5 and 10 cm depth, the result shows an agreement within 1.3% which is acceptable.

key words : dose calculation, half blocked fields, independent jaws, asymmetric fields.

INTRPDUCTION

An asymmetric x-ray collimator of Varian Clinac 1800 has one collimating jaw that can be moved independently of the corresponding opposed jaw. By blocking off one half of the field at the central axis, beam divergence can be eliminated at the junction of two fields. This characteristic is useful in the treatment field that is matched to the other fields such as the supraclavicular field and tangential breast field or other techniques which need no divergence of beams.

The characterestic of asymmetrical beams should be evaluated before using the beams to treat the patient. In this work the dose measurements were performed to evaluate that dosimetric data from symmetric collimators could be used for asymmetric collimators. The study of asymmetric and symmetric field dosimetric data, i.e. output factor, percentage depth dose and isodose curves are included.

METHODS AND MATERIALS

The study was done for half blocked fields defined by independent jaw system of 6 MV x-rays from Clinac 1800. First, to evaluate whether the calculation of monitor unit using the off axis ratios, the field size factors and the percentage depth dose of symmetric beams is suitable. The output at the center of the beam as a function of field sizes both for the symmetric and the asymmetric collimation were measured in water phantom at the depth of maximum dose (1.5 cm.) and at the depth of 5 cm. to calculate

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the field size factors. For routine calculation of monitor unit in asymmetric beam, the field size factors were obtained from the measurement of the output at 5 cm. in the water phantom and converted to the dose at depth of maximum dose. So in this study the measurement were done both in 1.5 and 5 cm. depth to verify the difference of two techniques obtaining the field size factors. The dosemeter used is Nuclear Enterprise limited (NE) Ionex Dosemaster (model NE 2590 A) with 0.6 cc. ion chamber (model NE 2571).

Next, the measurement of percent depth dose and the set of beam profile at 1.5, 6.5, 11.5, 16.5 and 21.5 cm depth for each square field have been performed using a Therados BDS 3 - water scanner system with a silicon detector. The field sizes were ranging from 4x4 to 20x20 cm. These data were filled to the software dialogue of the GE target planning system which generated the isodose curves.

Then, the output measurements were performed to confirm the dose calculation using the symmetrical beam data. The measurements were done in water phantom at fixed SSD (100 cm.), the field sizes of half blocked fields were ranged from 5x5 to 20x20 cm.. Output reading were taken at 1.5, 5 and 10 cm. depths for each square field.

RESULTS AND DISCUSSION

A. Field size factors

The field size factor (FS) for asymmetric field (1) of size (r x r) and a lateral displacement of field center (x cm) from the true central axis is given by (see fig 1)

$$FS(r, x) = \frac{FS(r,o) \times OAR(x)}{FS(10 \times 10,0)} \quad \text{.................} \; ①$$

where OAR (x) is the ratio of dose at off-axis points relative to dose at the true central axis of the beam measured at depth of maximum dose. Readings were taken in a profile of 40x40 cm. at depth of maximum dose relative to the dose at the center of beams. All dose measurements of the field were normalized to those measurements of the field of 10x10 cm. symmetric at 1.5 cm depth. Fig 2 shows the relative field size factors measured at the center of the beam both on the symmetric beam and asymmetric beam. The data plotted in Fig 2 indicates that field size factors for the half blocked fields generated by independent jaw closely approximate those for the symmetric fields of the same demension when each data point was corrected for the change in beam output for that off axis point. The data is shown in table 1 the maximum discrepancy is only 1.1%.

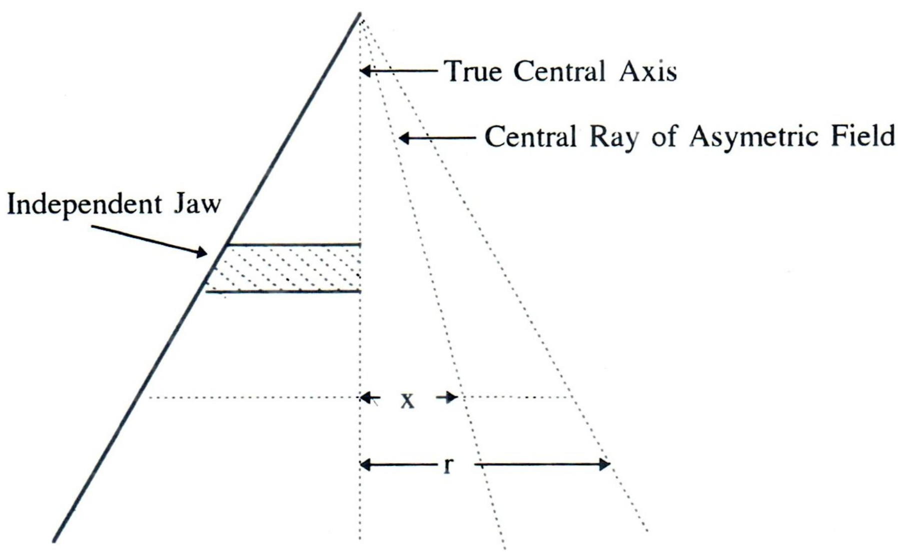


Fig 1. Geometry of half block field by an independent jaw

Table 1 **Comparison between field size factor of symmetric fields and half blocked asymmetric fields.**

Field size (cm)	5x5	8x8	10x10	16x16	20x20
Field size factor (FS) of symmetric fields	0.950	0.989	1.0	1.040	1.057
Off axis ratio (OAR) d_{max}	1.015	1.025	1.030	1.040	1.050
FS of symmetric fields x OAR	0.964	1.014	1.030	1.082	1.098
FS of asymmetric fields	0.960	1.013	1.041	1.094	1.107
$\frac{\text{FS sym x OAR}}{\text{FS Asym}}$	1.004	1.000	0.989	0.989	0.992

Table 2. **Comparison between central axis percentage depth dose of symmetric fields and half blocked asymmetric fields.**

Field size (cm.)	4x4			8x8			10x10			16x16			20x20		
Depth (cm.)	Sym (S)	Asym (A)	S/A	Sym (S)	Asym (A)	S/A	Sym (S)	Asym (A)	S/A	Sym (S)	Asym (A)	S/A	Sym (S)	Asym (A)	S/A
5	85.5	85.0	1.006	86.5	86.0	1.006	87.5	86.5	1.006	88.0	87.0	1.011	88.5	87.3	1.014
10	63.5	63.0	1.008	67.0	66.0	1.015	68.0	67.0	1.015	70.0	68.5	1.022	71.0	69.3	1.025
15	47.0	47.0	1.000	51.0	49.2	1.034	52.5	50.5	1.040	55.0	52.5	1.048	56.0	53.0	1.057
20	35.0	34.0	1.029	39.0	37.5	1.040	40.5	38.5	1.052	42.5	40.0	1.062	43.0	41.0	1.075

The field size factors measured at 1.5 cm in water are identical to field size factors obtained from the measurement at 5 cm. depth in water. The average discrepancy of field size factor by two methods is only 0.16%.

B. Percentage depth dose

The percentage depth dose along the central ray of the half blocked beams is expected to change due to significant change in beam quality at a point away from the true central ray (1,2,3). Percentage depth doses at 100 cm. SSD for field size 4x4 to 20 x20 cm. at 5, 10, 15, 20 cm depth are shown in table 2 both for symmetric and asymetric fields. The change in percentage depth doses for the depth less than 10 cm and field size smaller than 16x16 cm. is below 2.2%. The reduction in depth dose of asymmetric field is greater for larger field size and at greater depth. The percent depth dose of symmetric and asymmetric fields mostly differ by 7.5% as the field size is 20x20 cm and the depth is 20 cm. Beam quality is low when passing the thinner flattening filter comparing to beam passing the center of flattening filter (2). As field size get larger, the center of the field moves further from the flattening filter center. This causes the reduction of depth dose of asymmetric field compared to symmetric field. The effect is more when the depth is increased because the dose is contributed from primary and scattered interaction. At the superficial depths where the majority of dose is from primary interactions, these effects are small (2).

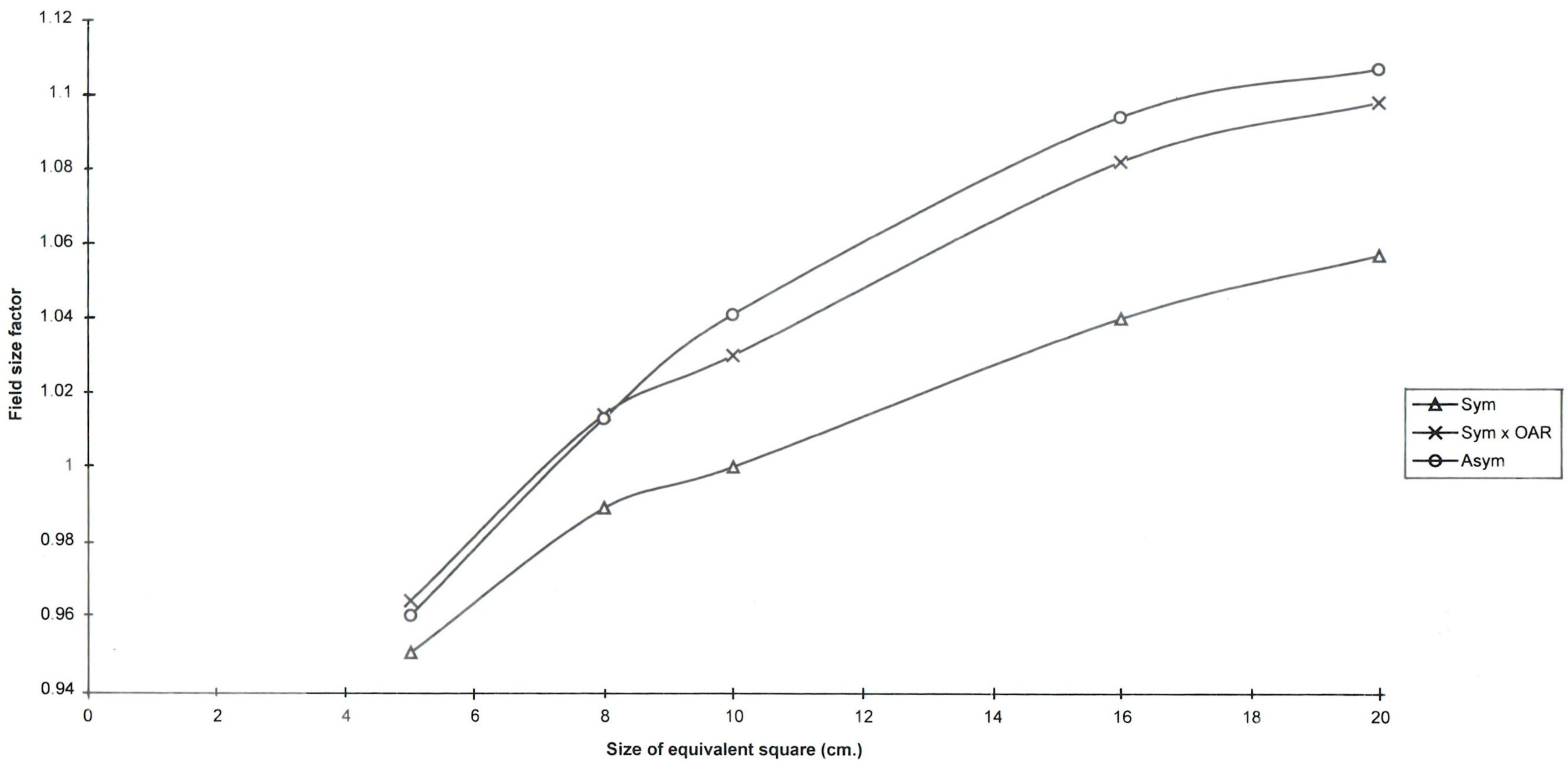
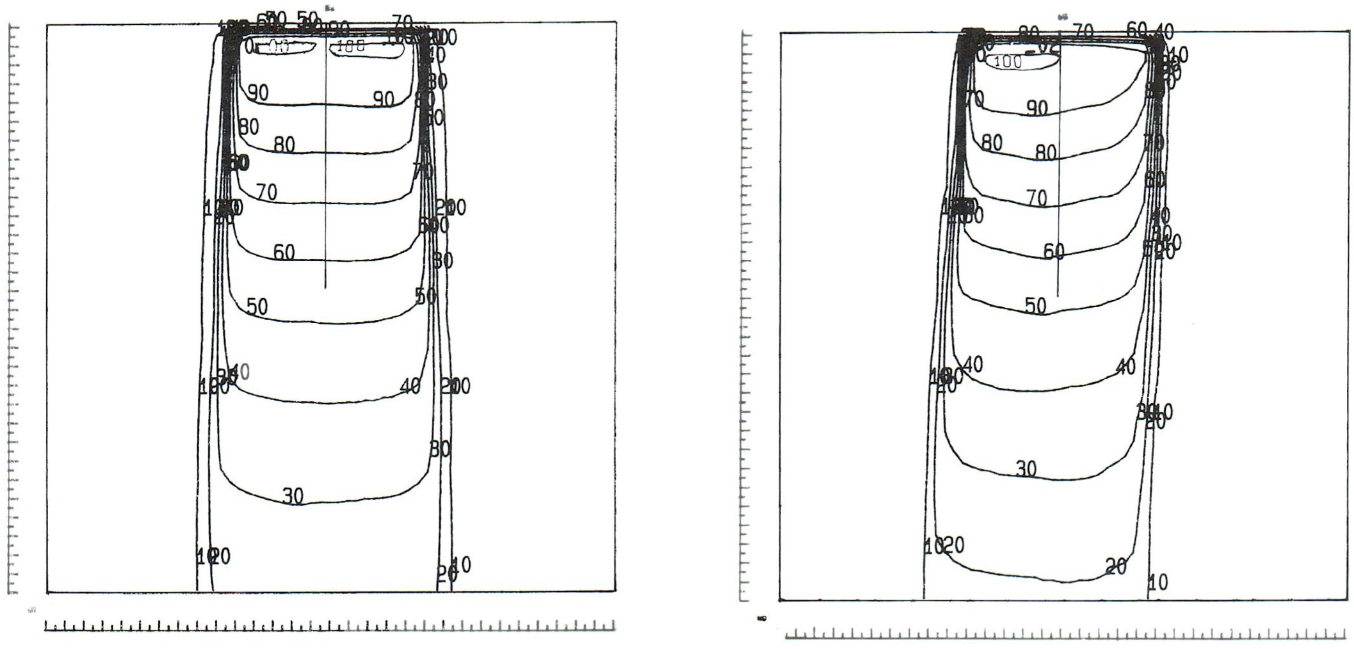


Fig 2. Field size factors measured on the center of symmetric and asymmetric beam

C. Dose distribution evaluation

Fig 3 shows the isodose distribution of 10x10 cm symmetric field "A" compared to 10x10 cm half blocked field "B" (5 cm off axis).

The shape of the isodose lines is altered by the asymmetric collimation. The shallower depth dose are shown on the left hand side of the field that is closer to the center of flattening filter. This is due to the attenuation by the flattening filter. Without the full scatter dose that would normally occur in this area of the field (2). The maximum decreasing of dose is 4%. Increasing depth diminized the reducing of isodose curves.



A. B.

Fig 3. Comparison of 10x10 cm. symmetric field (A) and half blocked field (B).

D. Dose to a point on the center of half blocked fields

Measurement of the dosage in a water phantom along the central ray of asymmetric fields at the reference depth (1.5 cm) verified the following equation (3).

$$D(d_m, x, r) = k\ MU\ FS(r, o)\ OAR_{dm}(x) \quad ②$$

where MU is the number of monitor unit and k is the dose per MU, which is 1 cGy per1 MU at the calibration point (at depth d_m) on the central axis of a symmetrical 10x10 cm. field. $OAR_{dm}(x)$ is the off oxis ratio at depth of maximum dose.

Similarly the dose to a point x at depth d on the central ray of a half blocked field is

$$D(d, x, r) = k\ MU\ FS(r, o)\ P(d, o, r)\ OAR_d(x) \quad ③$$

where $OAR_d(x)$ is the off axis ratio at depth d of symmetric field. For isocentric techniques

$$D(d, x, r) = k\ MU\ FS(r, o)\ TMR(d, o, r_d)\ OAR_d(x) \left(\frac{SCD}{SAD}\right)^2 \quad ④$$

Where SCD is the source to calibration point distance and SAD is the source to axis distance.

The doses measured at depth of 1.5, 5 and 10 cm. using 100 MU. were then compared to the calculated values from eq ② and ③, their results show in Table 3. The calculated and measured values show good correlation. The maximum difference between calculated values and measured values is 1.3%

Table 3. Comparison of measured dose and calculated dose for half blocked asymmetric fields

Depth in water (cm)	Measured dose / calculated dose				
	5x5 cm.	8x8 cm.	10x10 cm.	16x16 cm.	20x20 cm.
1.5	0.997	1.001	1.012	1.013	1.001
5.0	1.007	1.010	1.013	1.013	1.000
10.0	1.008	1.001	1.009	1.006	0.990

SUMMARY

The half blocked beam defined by asymmetric collimator causes certain dosimetric effects. Off axis factors can be used to calculate the monitor unit giving to the patient. The present of flattening filter causes the quality change of photon beam. Reduction in beam quality occurs because the thinner flattening filter allows lower energy photons to penetrate, reducing the percentage depth dose as off axis distance increases.

The agreement of dose calculation using off axis ratio, field size factor and symmetric percentage depth dose verifies that the data from symmetric beam can be used for the asymmetric beam. Correction for percentage depth dose is not neccessary unless the treatment field is at the depth greater than 10 cm. and field size greater than 16x16 cm.

For treatment planning system, the new set of isodose lines of asymmetric beam should be installed. Some commercial treatment planning system does not correct for off axis energy change. Therefore the error will be occurred and produce the misunderstood plan. However, the accurate isodose distribution by commercial treatment planning systems requires special dose calculation algorithms.

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