Perturbation of electron beam doses as a function of SSD due to the use of shielding blocks on the Clinac-18[a)]

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Many radiotherapy linear accelerators use electron beam applicators which extend close to the patient's surface when treating at the regular distance. The relatively large size of these applicators often necessitates the use of a larger SSD than that designed by the manufacturer. In such cases, the addition of shielding blocks to the applicator can significantly alter the factors which should be used to calculate the dose rate at the new SSD as compared with the unshielded beam condition. In some typical clinical situations, errors of greater than 60% may result from failure to account for this perturbation. This paper presents the proper correction of the dose vs SSD function for the presence of such shielding blocks for the Clinac-18 linear accelerator.

Key words: dosimetry, electron beams, shielding blocks

I. STATEMENT OF THE PROBLEM

Two problems frequently complicate the dosimetry of electron beam radiotherapy: shielding of areas not to be included in the radiation field, and treating at nonstandard distances. Most accelerators collimate the electron beam with standard circular or square applicators only, necessitating additional beam modifying diaphragms to be used with most patients. A convenient method of manufacturing custom-made diaphragms was described by Goede *et al.*[1] using low temperature alloys such as Lipowitz's metal. The use of such diaphragms perturbs the central ray dose, and thus an additional correction factor must be used in patient calculations.[1-4]

The applicators on most accelerators extend very close to the patient's surface. On the Varian Clinac-18, the end of the applicator is 5 cm from the skin. A shielding diaphragm attached to the base of the applicator leaves only 4 cm to the patient's surface. The lack of space often results in the inability to set the patient at the standard treatment distance. Two methods are commonly used to calculate the dose rate at extended distances, (1) a graphical or tabular presentation of the actual dose rate measured as a function of distance, and (2) inverse square law calculations, using an "effective source location" derived from the measured values.[5] Used properly, either method is adequate over the range of treatment distances commonly used.

An error in the dose delivered to a patient results if field shaping diaphrams are used at extended distances, and the dose rate is calculated by multiplying the aperture corrections for the shielding block by the distance correction factor for the unshielded applicator. Choi *et al.* reported a 28% error for a Clinac-35 resulting from such practice.[6]

II. EXPERIMENTAL METHOD

To establish the effect of the shielding block on the function relating dose with treatment distance, a series of diaphragms were made of Lipowitz's metal with circular apertures in the center of the field, ranging in diam from 1 to 6 cm with $\frac{1}{2}$ cm increments, and from 6 to 10 cm with 1 cm increments. Each diaphragm block was 1 cm thick, and slid onto tracks on the base of the regular treatment applicators.

Initially measurements were made using a Farmer chamber in a polystyrene phantom, but while making depth dose scans with the Varian Therados RAF-III Scanning Diode System, it was noted that the position of maximum dose changes with both the addition of shielding diaphragm and changes in the treatment distance. This effect has been reported by Biggs *et al.*[4] Subsequently, all measurements were made using the Therados System. As an additional advantage, the very small sensing element of the Therados System allowed measurements to be made on smaller apertures than would the use of the Farmer chamber. All measurements were at the true position of peak dose.

The peak dose rate varies with the electron beam energy, E, the applicator used, C, the treatment distance, D, and the size of the aperture in the diaphragm, A. The distance function describes how the dose rate, normalized to the standard treatment distance (STD), for a given combination of beam energy, applicator, and aperture varies with treatment distance. This function is defined as:

$$\text{Distance Function} = R(E,C,D,A,)/R(E,C,STD,A), \quad (1)$$

where R is the reading at the depth of peak dose.

Expressing the error incurred by assuming that the distance function is unaffected by field-shaping apertures in terms of the desired dose (i.e., that dose prescribed) assists in evaluating the clinical significance of this problem, as given by:

% Error

$$= \frac{Q(A)DF(\text{open}) - Q(A)DF(A)}{Q(A)DF(\text{open})}\Bigg|_{E,C} \times 100\%, \qquad (2)$$

$$= \left(1 - \frac{DF(A)}{DF(\text{open})}\right)\Bigg|_{E,C} \times 100\%, \qquad (3)$$

where $DF(A)$ and $DF(\text{open})$ refer to the distance functions for the given aperture and the unshielded applicator, respectively, and $Q(A)$ denotes the correction factor, measured or calculated, for the given aperture size at the standard treatment distance, defined as:

$$Q(A) = \frac{R(E,C,STD,D,A)}{R(E,C,STD,D,\text{open})}\,. \qquad (4)$$

III. RESULTS

Figure 1 shows the percent error, as defined above, for selected combinations of electron energy and applicator. The errors all result in under doses.

The curves appear to take on a shape similar to a saturation function, with the error increasing with both increased treatment distance and decreased aperture size. The absolute value of the error decreases with increasing electron beam energy. However, the error for the same aperture size increases with increasing size of the unshielded applicator. This is particularly important in view of Goede's recommendation to use the large applicators with shielding diaphragms to decrease the necessary aperture correction at the standard distance.[1] By using the large applicators at extended distances, a greatly increased error may result if proper correction is not made for the added diaphragm.

The absolute magnitude of the errors involved are alarming. Whereas the very small aperture sizes commonly do not find much use in radiotherapy, the error involved with moderate size apertures at reasonable distances, even for the higher energies, could make an appreciable difference in treatment results.

IV. CONCLUSIONS

(1) Large errors in delivered dose in electron beam therapy at extended distances result if the dose rate is calculated by multiplying the aperture correction factor at the standard distance by the distance function used for the unshielded applicator. This error decreases with aperture size and electron beam energy, but increases with the size of the unshielded applicator.

(2) The data included with this report apply to the Varian Clinac-18 for diaphragms with circular apertures centered in the treatment field. Comparison with some information on a Varian Clinac-35 tends to indicate that the value of the error for that unit would be very similar. However, these figures should not be blithely used on any other treatment unit. In addition, some more recent information indicates that irregularly shaped apertures, or apertures off the central ray of the treatment beam, may have dose rates different from that which would be expected by an "equivalent field" approach.

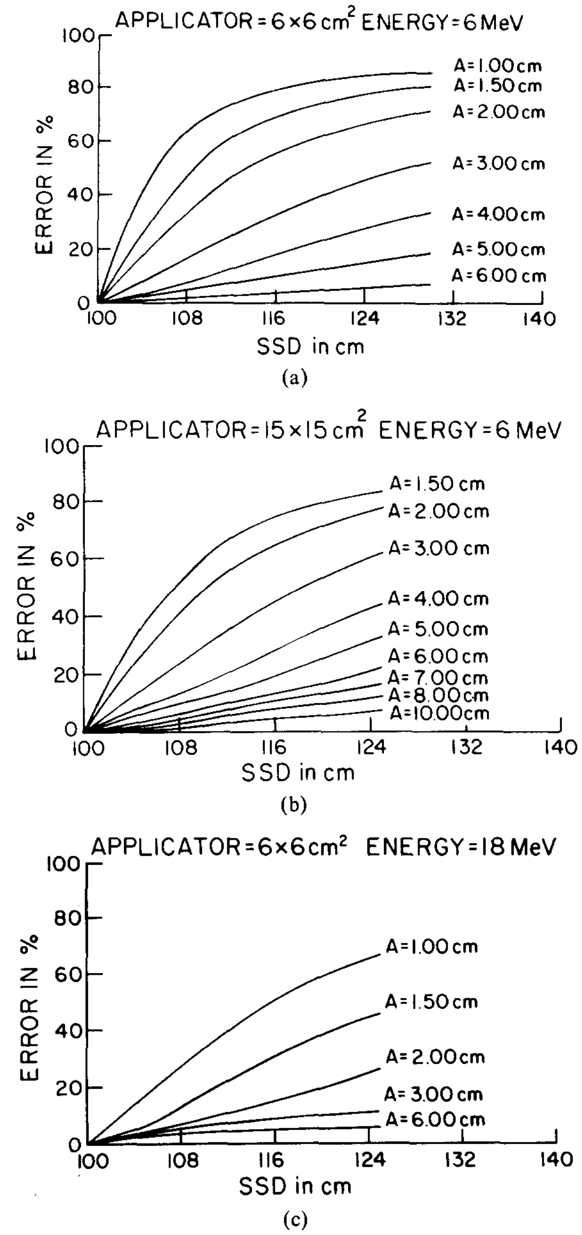

FIG. 1. (a, b, and c) The error in peak dose expressed as a percentage of the prescribed dose as a function of nominal SSD for various aperture sizes.

(3) Given the stage of knowledge at this time, the dose rate for any field using an auxiliary diaphragm at an extended distance on an electron beam treatment accelerator should be measured.

A complete set of graphs for all five electron energies, and applicators up to 15 × 15 cm² on the Clinac-18 is available upon request.

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