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Moving Beam Technique with Narrow Field Electrons for Multiple Metastasis of Carcinoma of the Breast

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A moving beam technique with narrow field electrons was studied for the irradiation of multiple metastasis of carcinoma of the breast. The dose distribution was obtained by the film method, and the film density was calibrated by a thermoluminescent dosimeter. Inhomogeneous distribution of dose along the moving field was improved by changing the rotation speed of the source. New treatment cones were designed and produced to obtain a sharp-cut intensity of electron beam.

INTRODUCTION

The aim of rotation (or pendulum rotation) therapy by high energy X-rays or cobalt 60 gamma-rays is to deliver a homogeneous high dose in deep seated tumors in the body, without delivering an unnecessary dose to the surrounding normal tissues. The rotation therapy is applied to brain tumor, such as pituitary adenoma, mediastinal tumor, lung cancer, carcinoma of the esophagus, carcinoma of the urinary bladder and carcinoma of the uterine cervix. The rotation therapy by high energy electron beams of 20–42 MeV are also allowed for the therapy.

For the irradiation to the superficial tumors, electron beams of 4–15 MeV are desirable to use. The stational electron beams have been applied for the irradiation of the cutaneous and subcutaneous metastasis of the carcinoma of the breast; lymphnodes of sternum, axilla, supra and infra clavicular region. In the case of disseminated multiple subcutaneous metastasis, it is underirable to use stational fields of irradiation.
with electron beams for a large area. Although studies on moving electron beams of energies less than 20-MeV have been reported\(^{15,17,19,14}\), it is not well established. In this work, the moving beam technique with electrons was studied for the treatment of such a large area to obtain an uniform dose distribution for the target volume.

**MATERIALS AND METHODS**

A Toshiba 13-MeV linear accelerator (LMR-13, Toshiba Co.) was used in this study. The electron beams of 6 to 12 MeV were allowed for the experiments. To obtain a controlled rotation speed for the moving beam technique, an automatic rotation-therapy control unit (ARC) was developed and attached to the unit. For the moving beam irradiation, conventional treatment cones for electron beams were not used, and a narrow irradiation field of 2 cm width at the rotation center (100 cm from the quasi-source) was used. The narrow field was obtained collimating electron beams by collimators which were used for X-ray irradiation generally.

For the measurement of dose distributions, the film method was applied. A Kodac M-type film was sandwitched in the chest section of the Anderson phantom. The film density was calibrated by a BeO thermoluminescent dosimeter (Type 170-A, National Co.).

**RESULTS**

Fig. 1 represents a scheme of the experiments for the rotational moving beams. The radius of rotation was 100 cm. The pendulum rotation was 90° from the frontal irradiation to the lateral irradiation to the breast phantom. The depth of the rotation center in the phantom was at \( r_1 \) and \( r_2 \) from the surface frontally and laterally, respectively. The field of electron beams was \( 2 \times 20 \text{ cm}^2 \) at the rotation center. In Figs. 2a-c, dose distributions obtained by 8-MeV electrons are compared. The rotation center was at \( r_1 = 15 \text{ cm} \) and \( r_2 = 20 \text{ cm} \). Fig. 2a is of the stational beams of a 16×8 cm² field. A high dose area was observed at the center of the field. Fig. 2b shows the dose distribution with moving beams of the 2 cm-width field. The irradiated area was covered by a high dose region. But at the corner of the field, the dose distribution was not clearly cut. Five-milimeter thick
paltes of lead were covered on the surface on the phantom to shield outside of the irradiation field. The dose distribution with shielding lead plates is shown in Fig. 2c. The dose was rapidly decreased at the corner of the field.

The moving beams with 12-MeV electrons was examined. The rotation center was at \( r_1 = 10 \) cm and \( r_2 = 15 \) cm. The dose distribution of this condition is shown in Fig. 3. A high dose region was observed at the frontal part of the phantom. The dose at 1.5-cm depth along the surface is indicated as a function of the angle of the rotation (solid circles) in Fig. 4. The dose at the frontal was higher in 30% than that of the lateral.

The high dose at the frontal was analysed theoretically. The frontal part of the phantom is farer from the source than the lateral part (Fig. 1). The dose at the frontal is smaller than that of the lateral by the square law of distance. The irradiation period during the rotation of the beam is longer for the frontal than for the lateral, because the frontal is farer from the source than the lateral. The dose at the frontal, therefore, is larger than that at the lateral. The ratio of the dose at the frontal to that at the lateral can be calculated geometrically as follow,

\[
\frac{r_2 (100 - r_2)}{r_1 (100 - r_1)}
\]

where \( r_1 \) and \( r_2 \) are of Fig. 1. When \( r_1 = 10 \) cm and \( r_2 = 15 \) cm, the ratio calculated is 1.4, which is well agreed with 1.3 of Fig. 4.

In order to compensate the low dose at the lateral, the rotation speed of the source between 0° to 45° of the rotation angle was increased to 1.3 times that between 45° to 90°. The dose at 1.5-cm depth by this variable speed of rotation is show in Fig. 4 by a dotted curve with open circles.

To improve the sharpness of the dose distribution at the corner of irradiated field,
Fig. 3. Dose distribution by the moving beams with a 2-cm width field of 12-MeV electrons for $r_1 = 10$ cm and $r_2 = 15$ cm.

Fig. 4. Doses at 1.5 cm depth along the surface of the phantom which is indicated with the rotation angle. Solid circles; with a constant rotation speed; Open circles; with a variable speed of the rotation.

Fig. 5. Cross section of newly designed treatment cones. The width of the field at the edge of the cone is $2 \times 16$ cm$^2$. 
new treatment cones were designed and produced. The cross sections of the treatment cones are shown in Fig. 5. Two types, A and B, were produced. The beam field was collimated to $2 \times 16$ cm$^2$ at 80 cm from the source with 2-cm thick iron plate. The intensity of beam along a 16-cm field at 80 cm from the source was compared in Fig. 6. New designed treatment cones produced well defined beam intensity.

Fig. 6. Beam intensity by newly designed treatment cones. Solid curve; type-A cone; Broken curve; type-B cone; Dotted curve; 2-cm width field.

DISCUSSION

Two points have become clear in the moving beam technique of electrons. One is that the dose distribution was inhomogeneous along the field (Figs. 3 and 4). This was due to the unsymmetrical geometry along the rotation center. The changes of the rotation speed resulted in improvement of the dose distribution (Fig. 4). The other is that the dose distribution at the corner of the field was not clearly cut (Figs. 2b and 6). The lead plates made a well defined dose distribution (Fig. 2c). Newly designed treatment cones (Fig. 5) produced a sharp-cut intensity of beams (Fig. 6). It might be concluded that the moving beam technique of electron with controlled rotation speed and with well collimated beams produce a homogeneous dose distribution for a large area to be irradiated.

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REFERENCES


