

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

Akira ASHIZAWA, Akihisa NAKASHIMA, Hirofumi MAEDA,
Satomi HAKARIYA*, Koji FUJISE**

Department of Radiology, Medical College of Oita

**Department of Radiology, Nagasaki University
School of Medicine*

***Technical Service & Maintenance Department,
Toshiba Medical Systems Co. Ltd.*

Received for publication, July 26, 1982

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 cervix¹³⁾¹⁹⁾. The rotation therapy by high energy electron beams of 20–42 MeV are also allowed for the therapy^{3)4)8)9)11)15)16)~18)}.

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 region¹⁾¹²⁾²⁰⁾. In the case of disseminated multiple subcutaneous metastasis, it is underirable to use stational fields of irradiation

芦澤 昭, 中島 彰久, 前田 宏文, 計屋 慧実*, 藤瀬 郊二**

with electron beams for a large area. Although studies on moving electron beams of energies less than 20-MeV have been reported⁽²⁾⁽⁵⁾⁽⁷⁾⁽¹⁰⁾⁽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 sandwiched 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 2×20 cm² at the rotation center. In Figs. 2a-c, dose distributions obtained by 8-MeV electrons are compared. The rotation center was at $r_1=15$ cm and $r_2=20$ cm. Fig. 2a is of the stationary 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

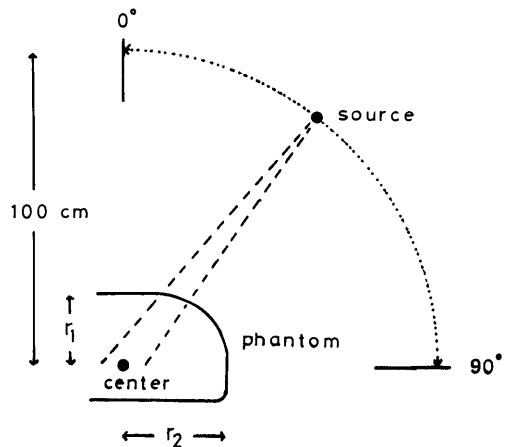


Fig. 1. Position of the phantom for the moving beam technique.

plates 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 foantal 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,

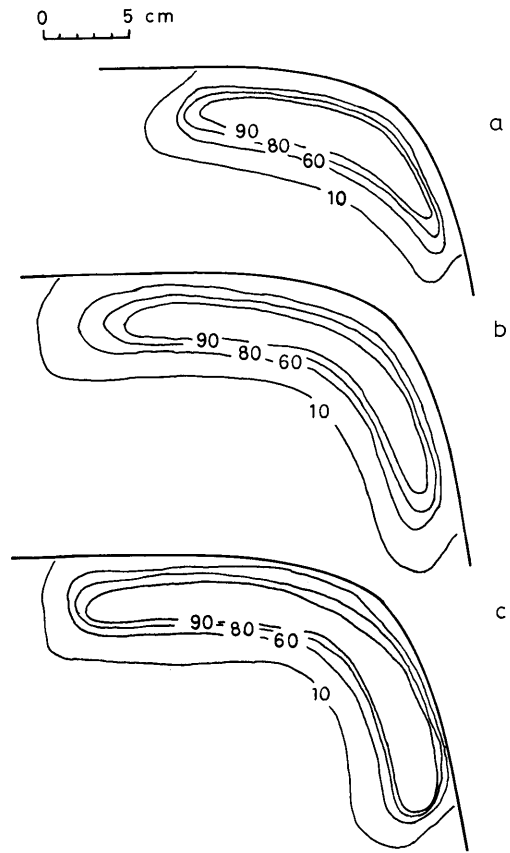


Fig. 2. Dose distributions by the moving beam technique with 8-MeV electrons for $r_1=15$ cm and $r_2=20$ cm. a; stationary beams of a 16×8 cm²; b; moving beams with a 2-cm width field; c; moving beams of a 2-cm width field with 5-mm thick plates at the edge of the irradiation field.

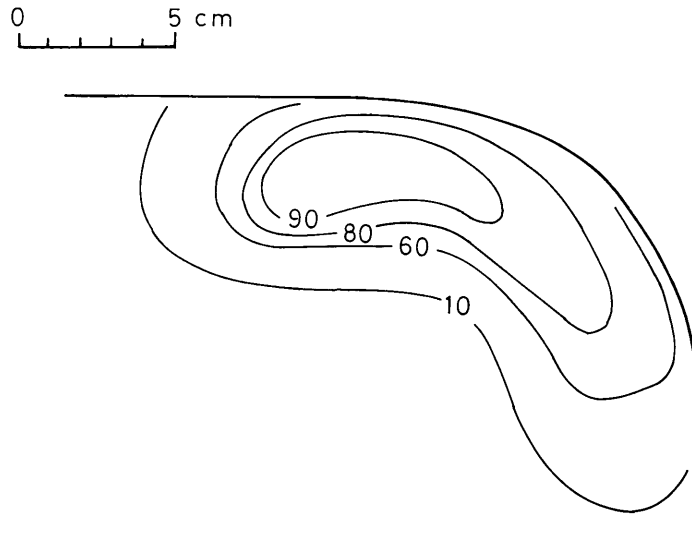


Fig. 3. Dose distribution by the moving beams with a 2-cm width field of 12-MeV electrons for $r_1=10$ cm and $r_2=15$ cm.

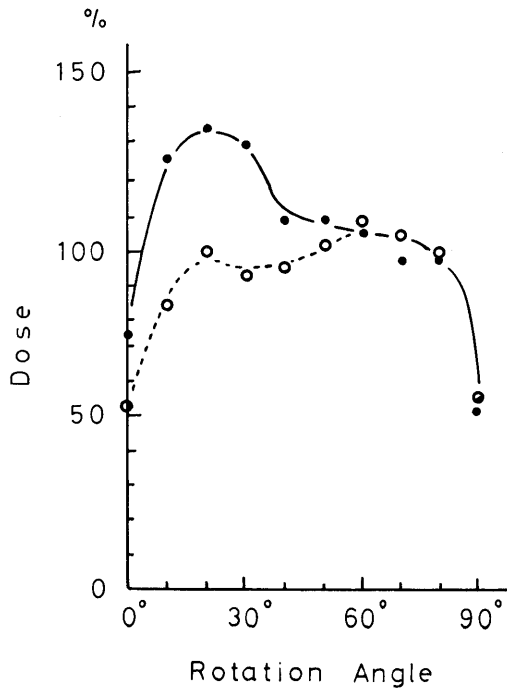


Fig. 4. Doses at 1.5cm depth along the surface of the phantom which is indicated with the rotation angle. Solid circles; with a constant rotation speed; Open circles; with a variable speed of the rotation.

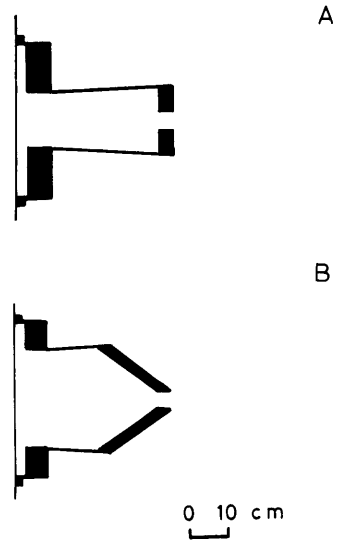


Fig. 5. Cross section of newly designed treatment cones. The width of the field at the edge of the cone is 2×16 cm².

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 2×16 cm² at 80 cm from the source with 2-cm thick iron palte. 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.

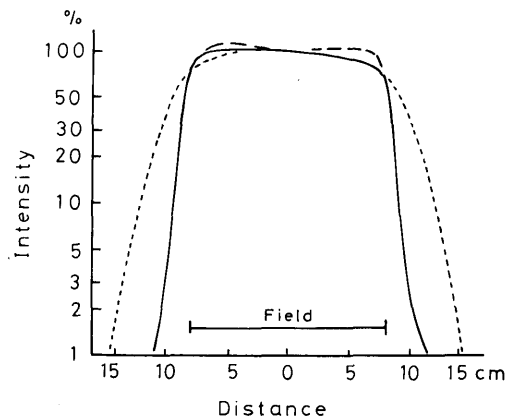


Fig. 6. Beam intensity by newly designed treatment cones. Solid curve; type-A cone; Broken curve; type-B cone; Dotted curve; 2-cm width field.

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.

ACKNOWLEDGMENT

The authors are grateful to Prof. Z. Hombo for his encouragement to the study, and Mr. S. Matsushima for his technical assistance. They also thank Dr. Y. Okumura for his valuable comments on the manuscript.

REFERENCES

- 1) FLETCHER, G. H.: Textbook of Radiotherapy, 2nd ed. p. 484, Lea & Febiger, Philadelphia, 1973.
- 2) FOURNIER, D. V., KUTTING, H. und CURLAND, St.: Zur Elektronen Pendelbestrahlung der Thoraxwand. *Strahlentherapie* 144: 393-397, 1972.

- 3) GÜRTLER, K. F., DARAI, S., SCHNABEL, K. und KUTTIG, H.: Elektronen-Tiefentherapie im Thoraxbereich. V. Dosimetrische Untersuchungen mit telezentrischer Kleinwinkelpendelbestrahlung. *Strahlentherapie* 153: 143–148, 1977.
- 4) HEUSS, K. und HOEFFKEN, W.: Zur Anwendung exzentrischer Pendelbestrahlungen mit einem 42-MeV-Betatron in der Tiefentherapie. *Strahlentherapie* 143: 485–493, 1972.
- 5) HÜDEPOHL, G. und RASSOW, J.: Beitrag zur Elektronentiefentherapie mittels Pendelbestrahlung. VII. Mitteilung: Dosimetrie und Anwendungsbeispiel für die telezentrische Pendelbestrahlung mit Elektronen von 5–10 MeV (Schalenbestrahlung) bei Fokus-Haut-Abstrandsänderungen. *Strahlentherapie* 146: 546–558, 1973.
- 6) KIKUCHI, A.: Radiation therapy of the mammary cancer. *Jap. J. Cancer Clinics* (Supplement) 214–222, 1978.
- 7) KIKUCHI, A., and TAKAHASHI, H.: Post-operative electron beam irradiation of the mammary cancer: Therapeutic results viewed from the early recurrence rate. *Jap. J. Cancer Clinics* 22: 203–208, 1976.
- 8) KOISCHWEITZ, D., FROMMHOLD, H. und WINKEN, R.: Lungen und Rückenmarkbelastung bei der telezentrischeexzentrischen Pendelbestrahlung des Ösophagus-Karzinoms mit dem 42-MeV-Betatron. *Strahlentherapie* 151: 183–191, 1976.
- 9) KUTTIG, H., BRANDS, K. und SCHNABEL, K.: Elektronentiefentherapie im Thoraxbereich Dosimetrische Untersuchungen. *Strahlentherapie* 142: 621–628, 1971.
- 10) KUTTIG, H., NEMETH, G. und POSER, H.: Die Elektronen-Pendelbestrahlung der beidseitigen Halslymphabflussgebiete mit Jalusietubus. *Strahlentherapie* 145: 396–400, 1973.
- 11) KUTTIG, H., SCHNABEL, K. und SCHEFFZEK, M. J.: Elektronen tiefentherapie im Thoraxbereich. IV. Pendelbestrahlung mit asymmetrischem Pendelwinkel. *Strahlentherapie* 148: 74–79, 1974.
- 12) MANSFIELD, C. M., AYYANGAR, K. and SUNTHARLINGAM, N.: Comparison of various radiation techniques in treatment of the breast and chest wall. *Acta Radiol.* 18: 17–24, 1979.
- 13) MCEWAN, A. C. and WHEELER, T. K.: Dose measurements in esophagus in cobalt 60 rotation therapy. *Acta Radiol.* 9: 618–621, 1970.
- 14) POSER, H., NEMETH, G. und KUTTIG, H.: Die Anwendung der Elektronen-Pendelbestrahlung im Bereiche der Halslymphknoten. *Strahlentherapie* 145: 277–281, 1973.
- 15) POSER, H., NEMETH, G. und KUTTIG, H.: Telezentrische Kleinwinkel-Pendelbestrahlung der Harnblase mit schnellen Elektronen. *Strahlentherapie* 145: 390–395, 1973.
- 16) RASSOW, J. und SACK, H.: Beitrag zur Elektronentiefentherapie mittels Pendelbestrahlung. V. Mitteilung: Anwendung der telezentrischen Kleinwinkel Pendeltechnik zur Strahlentherapie von Tumoren im Abdominalbereich. *Strahlentherapie* 141: 5–12, 1971.
- 17) SACK, H. und RASSOW, J.: Beitrag zur Elektronentiefentherapie mittels Pendelbestrahlung. VI. Mitteilung: Strahlenbehandlung von Nierentumoren mit schnellen Elektronen und 42-MV-Bremstrahlen. Methodik und erste Erfahrungen. *Strahlentherapie* 144: 641–648, 1972.

- 18) SCHNABEL, K., OEFTERING, T., PEREYRA, J. und KUTTIG, H.: Elektronen-Tiefentherapie im Thoraxbereich. III. Dosimetrische Untersuchungen mit symmetrischer Pendelbestrahlung über die laterale Brustwand. *Strahlentherapie* 148: 69–72, 1974.
- 19) SCHRADER, R., WÜRTHNER, K. und SCHRÖDER, B.: Die Dosierung bei der tangentialen Co-60-Pendelbestrahlung der Thoraxwand beim operierten Mammakarzinom und die Bestrahlung der parasternalen Lymphknoten. *Strahlentherapie* 155: 237–242, 1979.
- 20) UEDA, T. and KIMURA, C: Dose distributions modified by narrow field scanning method in high-energy electron-beam therapy. *Strahlentherapie* 147: 185–188, 1974.