AN ANALYSIS OF MATCHLINE DOSIMETRIC PROBLEMS ASSOCIATED WITH A BEAMSPLITTER AND CUSTOM BLOCKS FOR A THREE-FIELD TECHNIQUE FOR BREAST TREATMENT

A Thesis

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by
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Dedicated to

My Family

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ABSTRACT

Conservative surgery combined with radiotherapy can produce survival rates similar to those obtained by more radical surgical procedures in selected cases of breast cancer. A three-field technique is commonly used for the radiation therapy treatment. Mary Bird Perkins Cancer Center (MBPCC) in Baton Rouge, Louisiana, has devised a technique that uses two opposing tangential fields with custom blocks and a beam splitter. An anterior field treats the axilla and supraclavicular area, with a gantry rotation of 12-15 degrees. To achieve a uniform dose distribution when treating the breast with the three-field technique, it is essential that the supraclavicular field join together properly with the tangent field, not only on the skin but at all depths. In radiotherapy, an important step in the development of treatment techniques is the comparison between the desired dose to be delivered to the patient during a sequence of treatments and the actual absorbed dose distribution in the patient. This study was undertaken to investigate the matchline dosimetry of the three-field technique currently in use at MBPCC. An anthropomorphic phantom was constructed and Kodak XV-2 films were placed sagittally along the matchline area. The film was read and data prepared into graph form for a no wedge and thirty degree wedge technique. The current technique displayed significant peak doses at the matchline. Modifications to the present technique along with continued investigations have been proposed.

INTRODUCTION

Amongst women breast cancer is the most common and most dreaded malignancy. It often strikes at the prime of life, for no known reason, and there is no known method of prevention. The American Cancer Society reports that breast cancer is slowly increasing in incidence and prevalence at a rate of .09% more new cases diagnosed per year. In the United States, approximately 100,000 new cases of breast cancer will be diagnosed this year (Harris, J., 1983). Overall in the United States one out of every eleven females will develop breast cancer at sometime in life. Breast cancer accounts for 27% of all cancers in females (ACS, 1981).

Originally, operable breast cancer was treated with radical mastectomy surgery developed by Halsted (1894). This procedure includes the removal of the entire breast and the two muscles underlying the breast: the pectoralis major and pectoralis minor. A very thin chest wall with skin on top of the ribs is left after surgery. Because these muscles are removed, swelling, skin breakdown and limited arm motion are all possible complications of this surgical procedure.

The first attempts to treat breast cancer conservatively were in Europe and are associated with Francois Baclesse (1939). At the Foundation Curie in Paris he showed that it was possible to cure breast cancer without surgery, using radiation therapy alone. Later, Baclesse (1960) proved that the combination of surgical resection of the tumor (tumorectomy) and radiation therapy could produce cure rates comparable to mastectomy alone. However, unsatisfactory cosmetic results were obtained because of the late side effects caused by orthovoltage equipment. Fibrosis and retraction were common late effects then.

After 1955, with the advent of high energy machines (telecobalt and betatrons) for external beam treatment, new radiotherapy techniques were developed. Supervoltage techniques significantly improved the cosmetic and functional results of radiotherapy. The increased depth dose and skin sparing reduced skin thickening, cutaneous discoloration and fibrosis that had been observed earlier. Since results from combined conservative treatment were identical to those obtained using surgery alone at 5 years as well as 10 years follow-up, surgeons worked together with radiotherapists to further develop new therapeutic approaches to breast cancer (Pierquin et al, 1986).

Today for treating potentially curable breast cancer, a local excision with radiotherapy has become an important alternative to mastectomy. There are two approaches for the excision of the primary tumor: a lumpectomy (total excision or tylectomy) and segmental resection (segmental or quadrantectomy). A lumpectomy involves excision of the tumor with a 1 cm or 2 cm margin of normal breast tissue around the lesion. A segmental resection implies a wider excision, with approximately one fourth of the total breast tissue removed. How and where the excision is performed will have a definite effect on the cosmetic results. The basis of the combination of surgery and irradiation is that radiation is effective with subclinical disease, but not as well with large tumors unless larger doses are given which can cause complications and poor cosmetic results. Fletcher (1980) proved that 5000 rads in 5 weeks eradicates close to 100% of epithelial tissue subclinical disease. Since surgery is limited in the sense that it primarily removes gross disease, the two treatments combine well as another option for patients.

The goals of irradiation to surgically operable breast carcinoma are to obtain short-term and long-term survival results equaling those of radical or modified mastectomy and to obtain a long-term cosmetically satisfactory appearance of the breast. High local tumor control, a long-term good cosmetic appearance and maximum sparing of underlying normal tissues (i.e. lung and spinal cord) are technical goals of a course of radiation therapy. Meticulous attention to detail is required of the technique of treatment of the intact breast following surgery. In breast cancer, the treatment volume presents a complex three-dimensional structure. The breast target area may include the breast itself, the internal mammary chain, the supraclavicular fossa and the axilla. The actual area treated is dependent upon the individual clinical situation.

Currently Mary Bird Perkins Cancer Center (MBPCC) in Baton Rouge, Louisiana treats approximately 30-40 conservative, intact breast patients a year. A three-field technique is commonly used for the radiation therapy treatment. Two opposing tangential fields treat the breast, chest wall and often the internal mammary lymph nodes (Fig. 1-A). An anterior field treats the axilla and

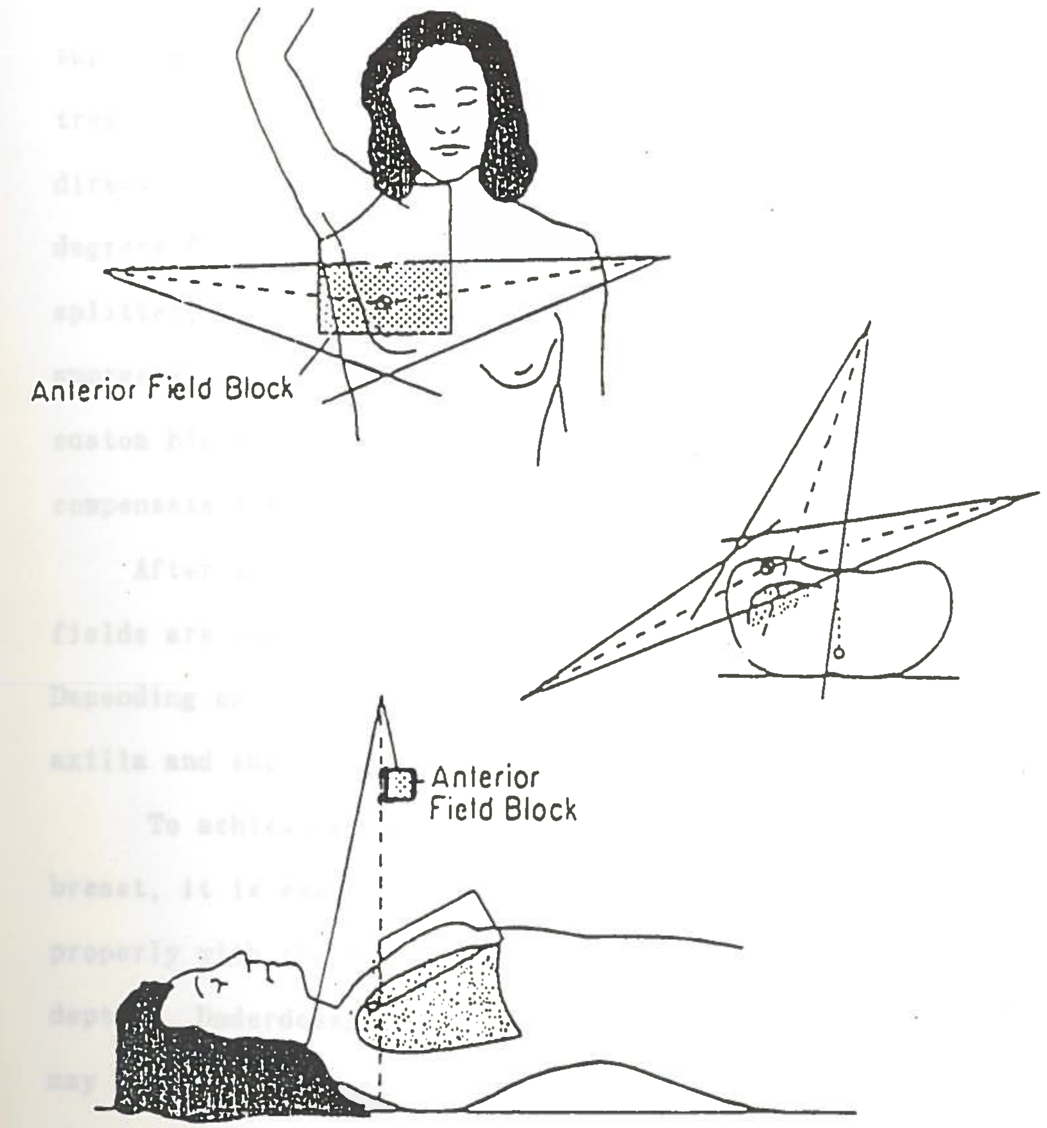


FIG. 1. Set up geometry in the coronal, transverse and sagittal planes. The opposing tangential fields and the anterior supraclavicular are indicated on the diagram. The beam splitter on the anterior field and custom blocks of the tangential fields are shown by the labelled shaded areas in the coronal and sagittal views.

supraclavicular area not only for lymph node coverage, but also to treat any breast tissue extending up into that area. To avoid direct irradiation of the spinal cord, the gantry is rotated 12-15 degrees from the vertical incidence (Fig. 1-B). A fixed beam splitter, 1.5 cm off the central axis (CAX), is utilized in the supraclavicular field as a block. For the tangential fields, a custom block is used to shield the lung and a wedge is employed to compensate for the tissue gradient along the breast.

After surgery to remove all gross disease, the two tangential fields are treated with 4 Mv x-rays to 45-50 Gy in 5 weeks. Depending on the clinical situation, 40-50 Gy are delivered to the axilla and supraclavicular area.

To achieve a uniform dose distribution when treating the breast, it is essential that the supraclavicular field join together properly with the tangent fields, not only on the skin but at all depths. Underdosage and a potential decrease in local tumor control may result from geometric gaps, whereas geometric overlaps result in overdosage and a decrease in cosmetic results. The hot spot, a high dose region, is caused by the divergence of the supraclavicular beam superiorly into the tangential fields or the divergence of the tangential beams inferiorly up into the supraclavicular field or both (Fig. 2). With Co^{60} the penumbral characteristic are such that at the matchline the hot region is probably not intense or large enough to cause significant late effects (Bedwinek, 1981). However, the sharp beam and the horns at the edge of the beam of a linear accelerator will produce a marked increase in dose beneath

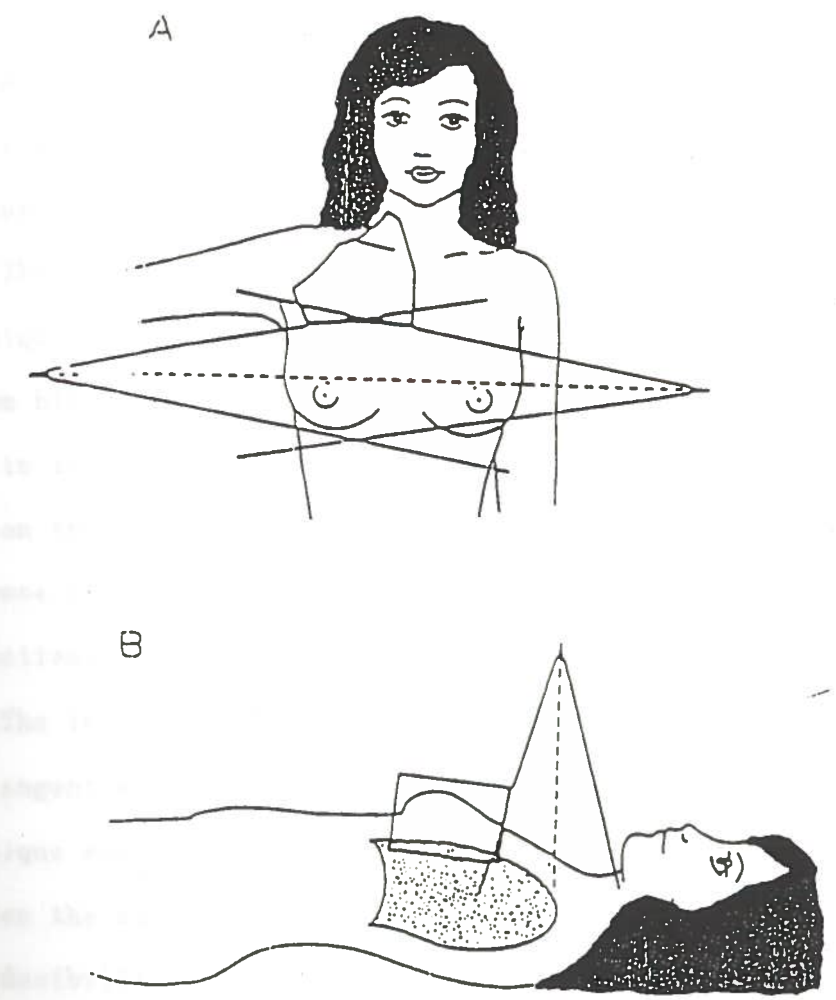


FIG. 2. Beneath the skin surface a hot spot at the junction of the tangential and supraclavicular fields may be caused by: A. Tangential fields diverging into the supraclavicular field B. Supraclavicular beam diverging into the tangential field.

the matchline if the divergence of the three fields is not corrected. Severe matchline fibrosis or rib fractures may result from an increase of dose in this region. Therefore, when using a linear accelerator it is important to eliminate the divergence of the supraclavicular and tangential beams.

The physicians and physics staff at MBPCC have designed a technique of matching the three field lines using a beam splitter, custom blocks and table rotation. In radiotherapy, an important step in the development of treatment techniques is the comparison between the desired dose to be delivered to the patient during a sequence of treatments and the actual absorbed dose distribution in the patient.

The intent of this study was to investigate the dosimetry of the tangent-supraclavicular field matchline using the current technique employed at MBPCC. The study investigated differences between the choice of an ideal wedge verses an open field, and the reproducibility of the set up each day. The present thesis outlines the method used to treat breast cancer conservatively which was reproduced on an anthropomorphic phantom. The phantom was put through all phases of the radiation treatment planning cycle including simulation, contouring, computer treatment planning, and a weeks treatment with an accelerator. Absorbed doses were obtained using the phantom and film dosimetry.

MATERIALS AND METHODS

PHANTOM CONSTRUCTION

A patient was contoured from the superior border of the neck to the inferior border of the ribs. Two-centimeter-wide plaster bandage strips were moistened and stylized 360 degrees around the patient every two centimeters. The strips were allowed to dry and the field margins were traced from the patient, numbered, and then removed (Fig. 3). The plaster strip contour was then transferred to graph paper. A two-cm-thick sliced computerized axial tomograph (CT) scan was then matched to the contours of the patient. Each CT slice was enlarged to the size of the traced plaster contour. The enlarged CT was then photographed and the actual size of the lungs were traced onto graph paper. Two cm slices of cork were then cut to the full dimensions of the lung.

Melted bees wax was then poured into the individual plaster strips with the cut cork pieces in the appropriate position of the lungs. The wax slice was allowed to harden overnight.

After the wax hardened, the plaster strip was removed from the solid slab. This procedure was repeated from the superior border of the neck to the inferior border of the ribs. A total of twenty-four, 2 cm thick slabs were stacked on top of each other to produce a female anthropomorphic phantom. The phantom was kept intact by two boards connected by strings at each corner.

Seven sagittal cuts were made 4 cm deep into the wax phantom beginning 3 cm superior to the supraclavicular-tangential field

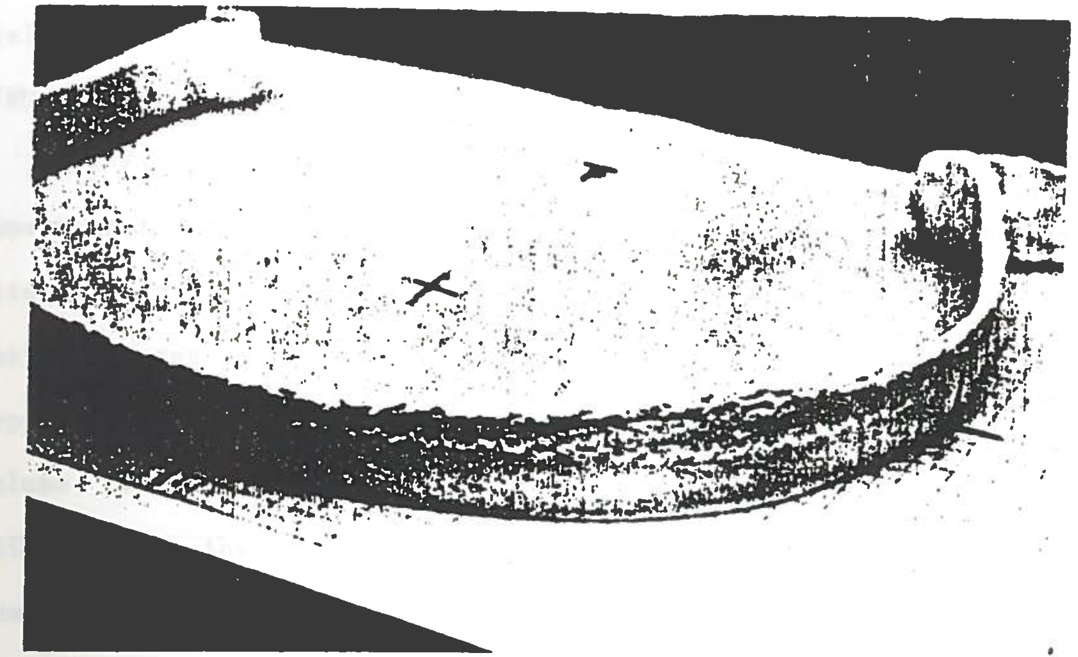


Fig. 3. Diagram of the construction of the wax phantom. Bee's wax was poured into the individual plaster strip contours.

matchline and extending 3 cm inferior to the matchline. The sagittal cuts extended from the medial to the lateral tangential field borders.

SIMULATION

The fields were set up using the Toshiba LX30A simulator in the same manner patients are simulated. Treatment beam geometry was determined with the phantom lying supine on the simulator table. The advantages of the supine position are that it is easily reproducible and permits precise dosage throughout the target volume. A patient's ipsilateral arm rests on an armboard device which secures the arm extended 90 degrees perpendicular from the chest wall to the elbow. Below the elbow, the forearm is held vertically by the fist handle of the armboard. The armboard allows for added reproducibility of the set up each day.

The desired borders of the supraclavicular field were first determined. The CAX of this field was placed 1.5 cm cephalic to the matchline, and the caudad half of the beam was shielded by a beamsplitter (Fig. 4). The supraclavicular field was angled from its vertical direction by 15 degrees to avoid direct irradiation of the spinal cord and esophagus. A target-skin-distance of 80 centimeters was then obtained and the borders and CAX of the supraclavicular field were marked on the phantom surface. An AP verification film was then taken.

To avoid dose heterogeneity at the matchplane, the superior borders of the two tangential fields were then precisely matched to the inferior border of the supraclavicular field by rotating the

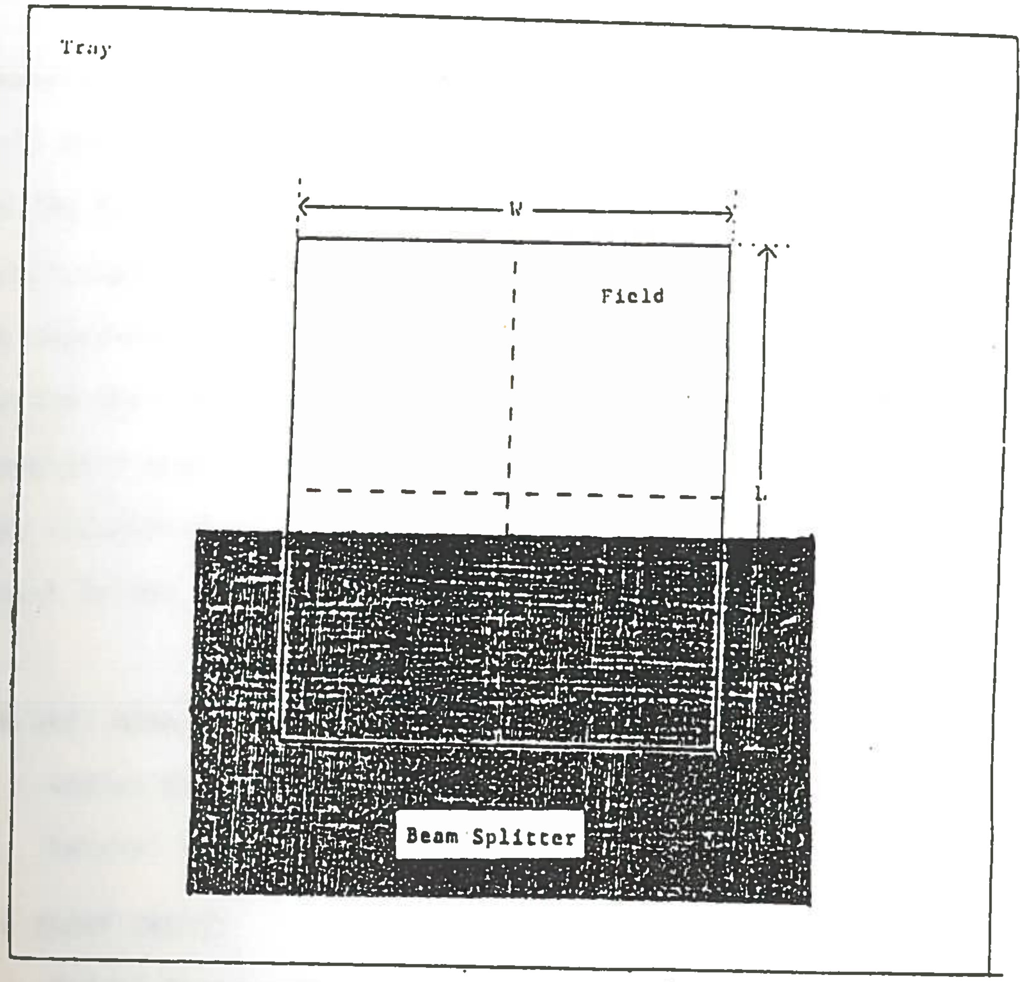


Fig. 4. **Illustration showing the 1.5 cm off CAX beam splitter. With the beam splitter in the tray holder, the view is from the x-ray target to the isocenter. The supraclavicular field used to treat the phantom measured width : 14 cm and length : 17 cm.**

treatment table. Due to the armboard, only the medial tangential field was set up on the simulator. The lateral tangential field was set 180 degrees from the medial field on the treatment table. The dorsal edges of the tangential beams were marked on the phantom by the physician. A breast bridge was placed on the phantom extending between the two dorsal lines and a breast bridge angle was read. The gantry angles for the medial and lateral tangential field were then calculated by inserting the breast bridge angle read from the breast bridge into the following formula:

FOR LEFT BREAST:

Medial Field = 270 - BBA = TA

Lateral Field = TA of medial field - 180 = TA

For RIGHT BREAST:

Medial Field = 90 + BBA = TA

Lateral Field = 270 + BA = TA

*BBA = Breast Bridge Angle

**TA = Tangent Angle

The gantry was then rotated according to the calculation and an 80 target-skin-distance was set. The field lines were remarked again on the phantom surface. A B-B chain was taped along the phantom's medial field border and a thin wire was placed along the dorsal edge of the lateral field in order to visualize the fields under fluoroscopy. The gantry rotation should make the posterior geometric edges of the tangential fields coplanar. The radiotherapist may desire to change the gantry angle slightly to align the tangent fields coplanarly. Fluoroscopy was then repeated to assure the proper alignment of the tangent fields. The CAX was then marked on the phantom surface and a medial film was taken of the tangent field. The physician drew in a custom block on the medial film in order to avoid any treatment of the lung. Custom blocks of Cerrobend were then cut for treatment.

The treatment set up was recorded on a standard patient chart. Physician's treatment orders were recorded into the chart. Orders included: supraclavicular field: 200 GD X 25 fractions with 4 MV photon beam, breast: parallel opposed tangent fields using 4 MV photon beams to 4500 TD in 25 fractions. The phantom's patient chart included the following field description:

DATE	UNIT	FIELD NO	COLLIMATOR SETTING L/W	FIELD DESCRIPTION	SSD TSD / SAD TAD	COLL ∠	GANTRY ∠	COUCH ∠	WEDGE #	MONITOR UNITS TIME	LAST TX	COMMENTS
	4Mv	A	17/14	AP SCF	80	-	195	-	-	204		Beamsplitter gantry 15
	4Mv	B	15.5/15	Med Tang	80	-	242	rot	30W	154 113		Rotate couch Custom block
	4Mv	C	15.5/15	Lat Tang	80	-	62	rot	30W	154 113		" "

DOSE PLANNING

A moistened plaster bandage strip was placed transversely across the CAX of the tangent fields. The strip was allowed to shape to the phantom's contours. Field margins and CAXs of both fields were traced onto the plaster strip. After drying the strip was removed and traced onto graph paper with field margins and CAX also being transferred onto the paper. Isodose calculations were produced by the Artronix Model 12/7. Plans were run for all wedges available, and the best distribution for the phantom was chosen. A thirty degree wedge plan was chosen to treat the phantom. A plan utilizing no wedge was also used to compare the accuracy of the wedge in the treatment. Dose calculations were calculated for both a thirty degree wedge and no wedge. Dose calculations were predicted upon empirically derived data including field size correction factors, backscatter factors, wedge attenuation factors and shadow tray attenuation factors. The prescription was to the 100% isodose line. A reference dose was obtained from the individual computer plans for both dose calculations.

Dose orders for the supraclavicular field were converted to monitor units using the following equation :

$$\frac{GD}{BSF \times FSCF \times STA} = MU$$

The tangential field monitor units were derived for both the unwedged and 30 degree wedged fields using the following equation:

$$\frac{TD}{RD \times BSF \times FSCF \times STA \times WF} = MU$$

TD = Tumor Dose
GD = Given Dose
RD = Reference Dose from individual computer plan
BSF = Backscatter Factor
FSCF = Field Size Correction Factor
STA = Shadow Tray Attenuation Factor
MU = Monitor Units

IRRADIATION TECHNIQUE

All measurements were taken at MBPCC in Baton Rouge, Louisiana on a Varian Clinac 4, model 824014, serial # 115 . The Clinac 4 is a radiofrequency powered linear accelerator that produces a maximum of 4 MV x-ray at an average dose of 250 monitor units/minute.

A standard dose response curve for Kodak XV-2 film was obtained using the Clinac 4. A polystyrene phantom was placed in calibration conditions: 10 X 10 cm field size at 80 cm TSD. Strips of Kodak XV-2 film, batch # 114-15-1, were placed at 81.2 cm within the phantom. Each strip was given a set amount of monitor units ranging from 0 monitor units to 340 monitor units in increments of 10 monitor units. An unirradiated strip was also set aside for background subtraction. All of the film was developed at the same time. A MacBeth TD-504 densitometer was used to obtain optical density readings. Before each set of readings, calibration of the densitometer was performed using Kodak Calibration Step Tablet No. 706ST121. Optical density readings were read from the film at the center of the radiation field for each dose given using a 1 mm reading-area insert. From these readings, a standard dose response curve (sensitometric curve) for Kodak XV-2 batch # 114-15-1 on the Clinac 4 was prepared. This curve was used to convert optical density to dose for the treatments.

In the anthropomorphic phantom, Kodak XV-2 batch #114-15-1 film was sandwiched between and contoured to the seven sagittal slits from the medial to lateral tangential field borders. The film extended 3 cm cephalic of the matchline and 3 cm caudad of the matchline.

In order to produce readings on the linear portion of the dose response curve, all calculated monitor units for each field were divided by four. Five treatments were performed with the 30 degree wedge treatment plan. The film was taken out after each treatment, marked and new film put in and repositioned for the next treatment. A zero rad film was set aside for each treatment. The supraclavicular field was treated first with the beam splitter 1.5 cm caudad from the CAX (Fig. 4). Next, the medial tangential field was treated with the 30 degree wedge and medial custom block in place. The gantry was rotated 180 degrees and the lateral tangent was treated using the 30 degree wedge and the lateral custom block (Fig. 5).

Five treatments were then performed without any wedges. The treatment procedure was the same as for the 30 degree wedge, excluding the wedge.

The film was then developed and read using the MacBeth TD-504 densitometer. The films were scanned in the cephalad-caudad direction, beginning in the supraclavicular field through the matchline and into the tangent field in a direction perpendicular to the matchline and parrallel to the phantom surface. Each scan was read at 0.5 cm depth intervals as measured from the phantom surface at the matchline.

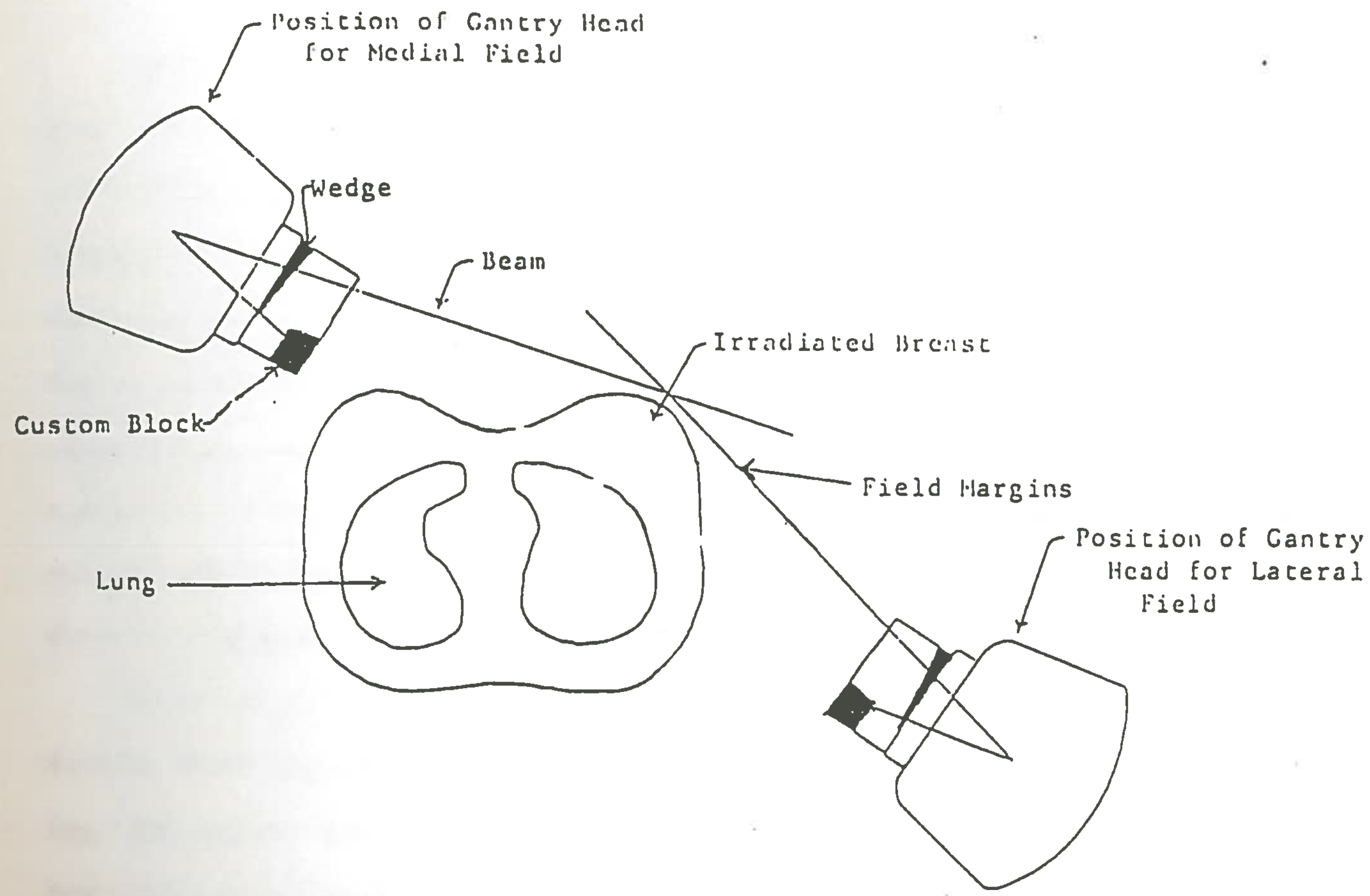


Fig. 5. A transverse thoracic section showing the tangential beams with custom blocks and 30 wedge.

RESULTS

Since the TD-504 densitometer is a manually-operated and manually-calibrated instrument, it is necessary to perform periodic calibration checks to insure that the instrument is performing properly. Before each use the control setting was checked and the potentiometer on back of the instrument was adjusted until the digital display corresponded to the density value for the calibration step tablet. The histogram in Fig. 6. demonstrates the similarity between the density value for the calibration step tablet and the actual densitometer readings. This calibration allowed direct reading of optical density with a densitometer.

In dosimetry, the quantity of interest is usually net optical density which was obtained by subtracting the reading for the base fog, the optical density of an unexposed processed film, from the measured optical density. The net optical density was converted to dose using the standard dose response curve for XV-2 film in Fig. 7.

The optical density of a film depends on the exposure, but it also depends very critically on the development of the film. The development of the film must be carefully controlled using the correct chemicals, time, temperature, and agitation (Johns and Cunningham, 1983). Therefore, for consistent results an automatic processor was used and all films were processed simultaneously; accuracy can be expected to be ±3% between series of films (Dutriex and Dutriex, 1969).

The data plotted in Fig. 8 through 14 represent the dose

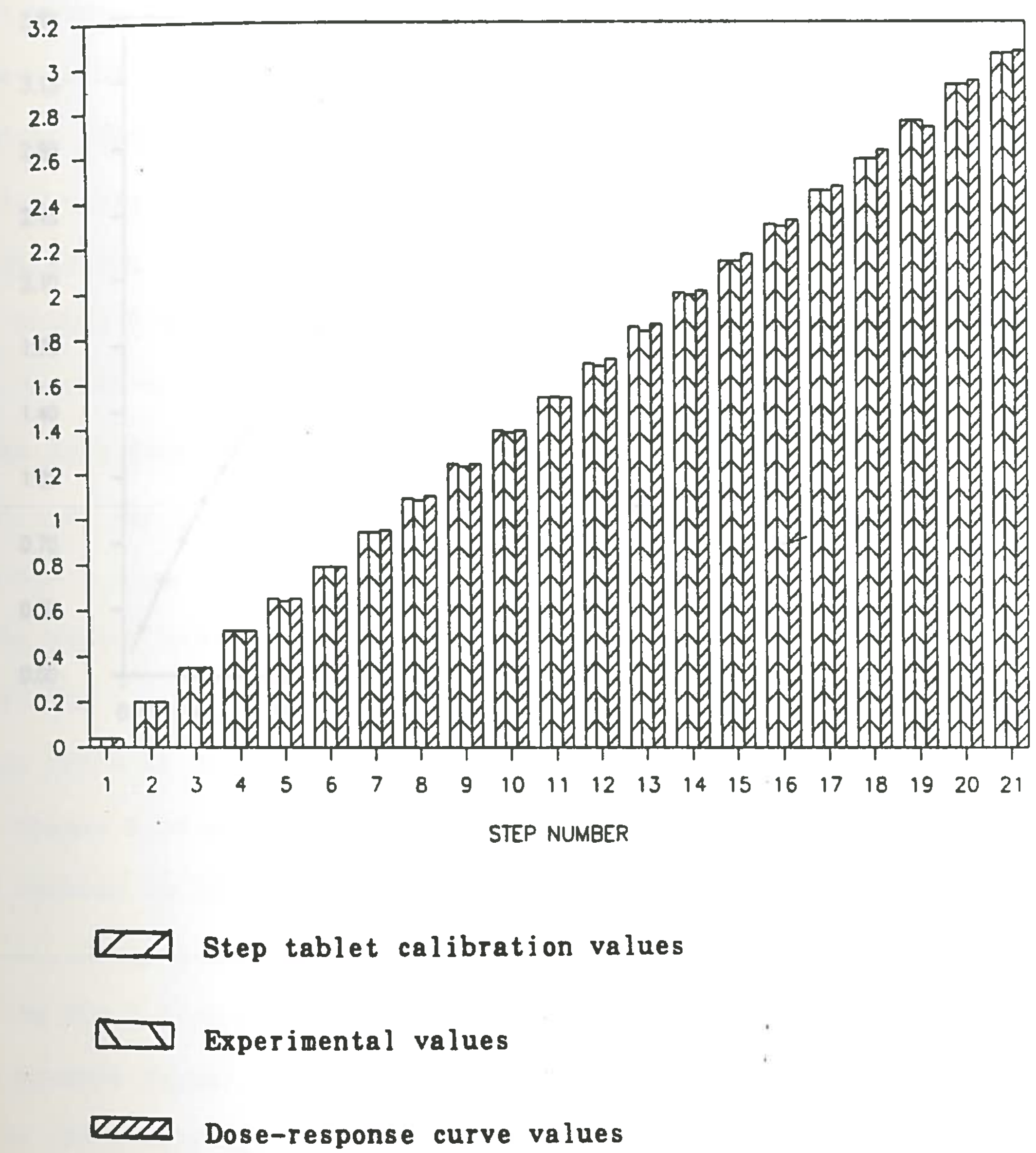


Fig. 6. The density value histogram demostrates the simularity between the density value for the calibration step tablet and the actual direct densitometer reading. Before each use a calibration was performed to allow direct reading of optical density with the densitometer.

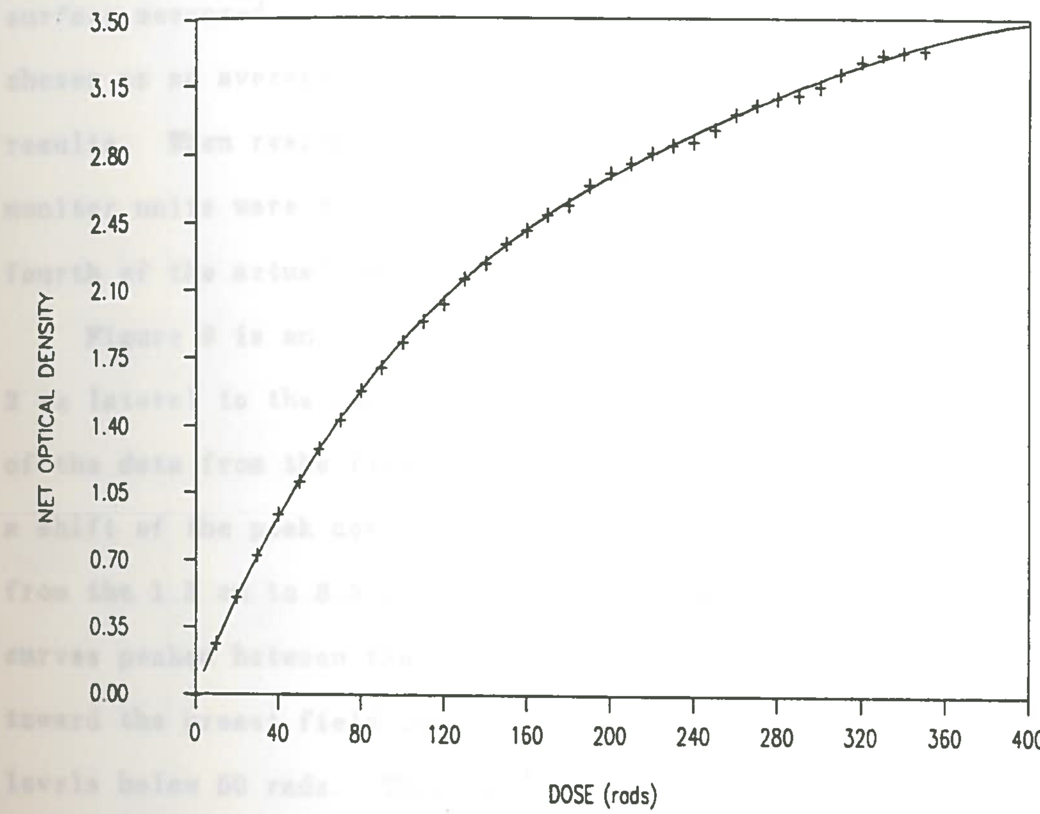


Fig. 7. A standard dose response curve for XV-2 film. Film was exposed on the Clinac 4 under calibration conditions: 10 X 10 field size at 80 cm TSD. All data was background subtracted.

distribution for the three-field technique. Films were read at depths of 1.5 cm, 2.0 cm, 2.5 cm, 3.0 and 3.5 cm from the anterior surface measured at the level of the matchline. The data were chosen as an average representation of the five separate treatment results. When reading data, it should be kept in mind that all monitor units were divided by four, therefore dose responses are one fourth of the actual treatment results.

Figure 8 is an illustration of data read in the sagittal plane 2 cm lateral to the supraclavicular medial field border. An average of the data from the five treatments in the same scan plane reveals a shift of the peak dose toward the supraclavicular field of 8.8 mm from the 1.5 cm to 3.5 cm depth curves. The 3.0 cm and 3.5 cm curves peaked between the 60 and 70 rad measured dose. Furthermore, toward the breast field the 2.5, 3.0 and 3.5 cm curves drop to levels below 50 rads. These points are in the cork (lung) region.

Figure 9 is an illustration of data read in the sagittal plane 4 cm lateral to the supraclavicular medial field border. For five treatments in the same sagittal scan plane and average shift of 8.2 mm from the 1.5 cm hot spot to the 3.5 cm hot spot was observed. High dosages appear at the edge of the film. These are artifacts due to the border of the film being exposed to light.

Figure 10 is a comparison of the doses at different depths read in the sagittal plane 6 cm lateral to the supraclavicular field. The average of the data from the five treatments at the same sagittal plane indicate a superior shift of 6.0 mm from the 1.5 cm curve to the 3.5 cm curve peak dose.

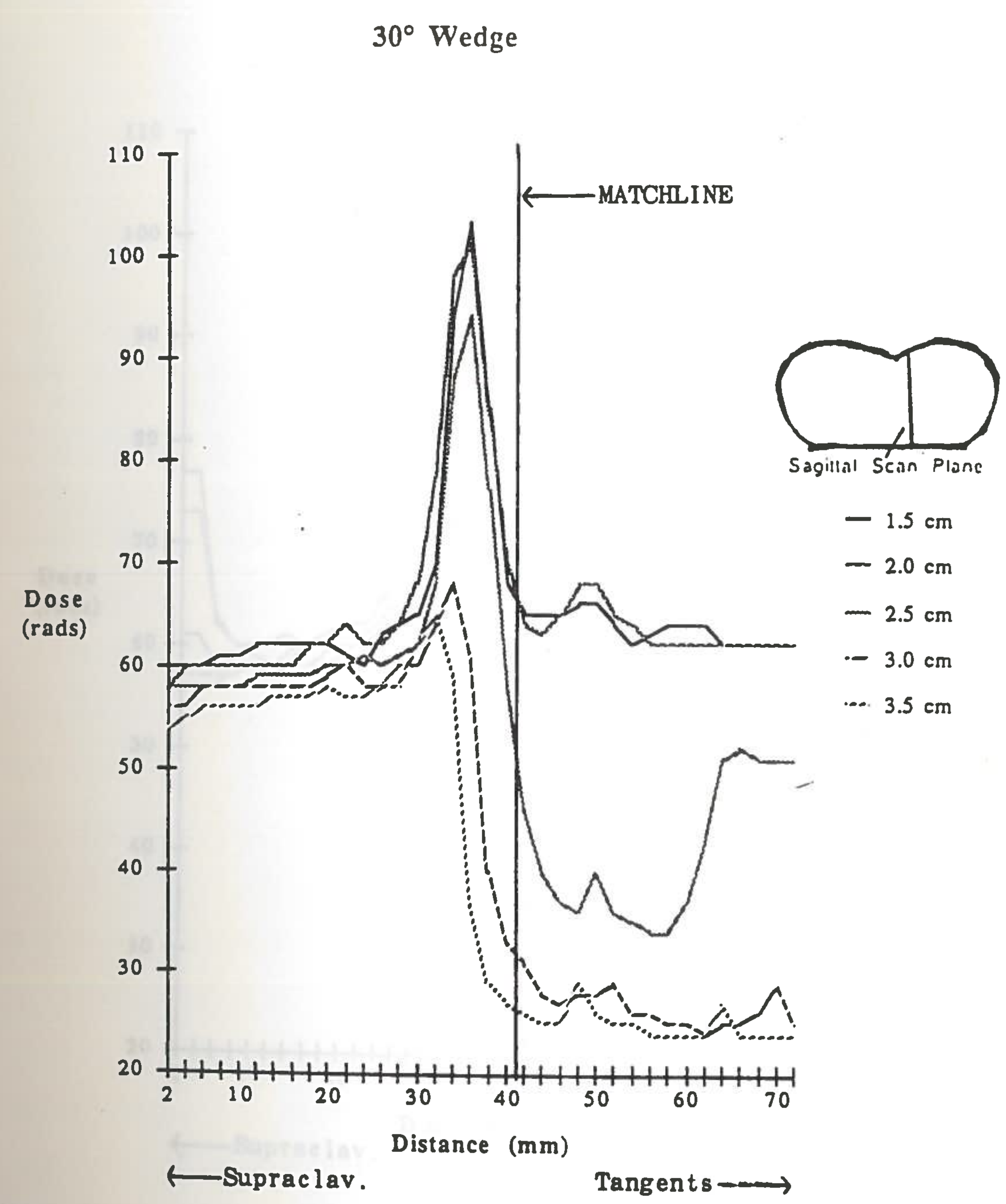


Fig. 8. Matchline dose distributions for the three-field technique used at MBPCC in the sagittal plane 2.0 cm lateral to the supraclavicular medial field border. The distributions are at depths of 1.5 cm, 2.0 cm, 2.5 cm, 3.0 cm and 3.5 cm from the anterior surface measured at the level of the matchline.

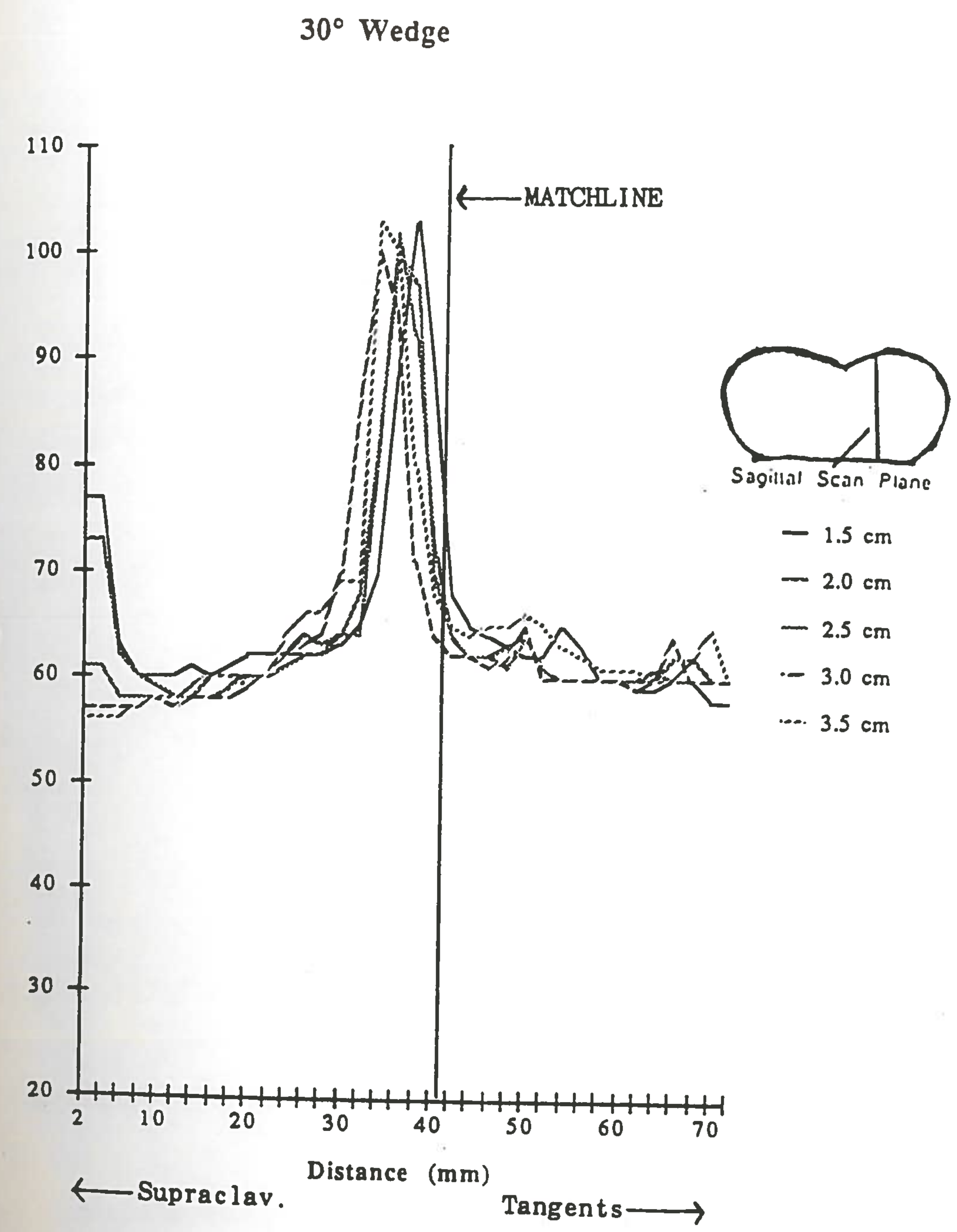


Fig. 9. **Matchline dose distributions for the three-field technique used at MBPCC in the sagittal plane 4.0 cm lateral to the supraclavicular medial field border. The distributions are at depths of 1.5 cm, 2.0 cm, 2.5 cm, 3.0 cm, and 3.5 cm from the anterior surface measured at the level of the matchline.**

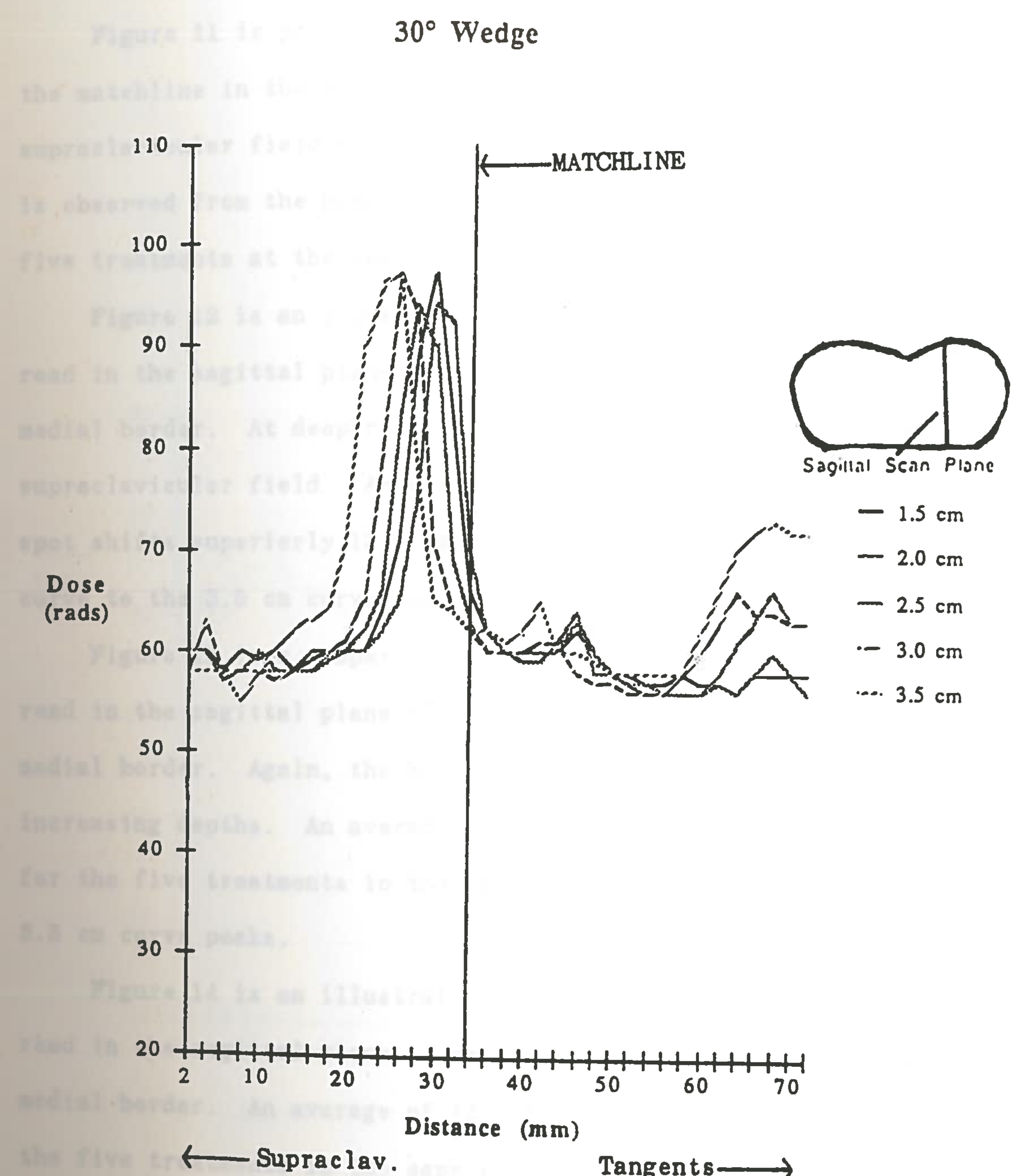


Fig. 10. **Matchline dose distributions for the three-field technique used at MBPCC in the sagittal plane 6.0 cm lateral to the supraclavicular medial field border. The distributions are at depths of 1.5 cm, 2.0 cm, 2.5 cm, 3.0 cm and 3.5 cm from the anterior surface measured at the level of the matchline.**

Figure 11 is presented to illustrate the dose distribution at the matchline in the sagittal plane 8 cm lateral to the supraclavicular field border. An average superior shift of 7.0 mm is observed from the peak doses 1.5 cm to 3.5 cm depth curves in the five treatments at the same sagittal plane.

Figure 12 is an illustration of the doses at different depths read in the sagittal plane 10 cm lateral to the supraclavicular medial border. At deeper depths the hot spot shifts toward the supraclavicular field. An average of the five treatments, the hot spot shifts superiorly 13.8 mm from the peak point of the 1.5 cm curve to the 3.5 cm curve peak point.

Figure 13 is a comparison of the different depth dose curves read in the sagittal plane 12 cm lateral to the supraclavicular medial border. Again, the hot spots shift superiorly with increasing depths. An average superior shift of 13.8 mm is found for the five treatments in the same sagittal plane from 1.5 cm to 3.5 cm curve peaks.

Figure 14 is an illustration of the doses at different depths read in the sagittal plane 14 cm lateral to the supraclavicular medial border. An average of 13.4 mm superior shift is observed of the five treatments in the same plane from the 1.5 cm curve peak point to the 3.5 cm curve peak point.

A comparison of matchline peak doses at varying depths is presented in Table 1. Each value represents an average of all sagittal planes from five treatments at each depth. The 30 degree wedge treatments were between 4.7 and 10.8% higher than the no wedge

30° Wedge

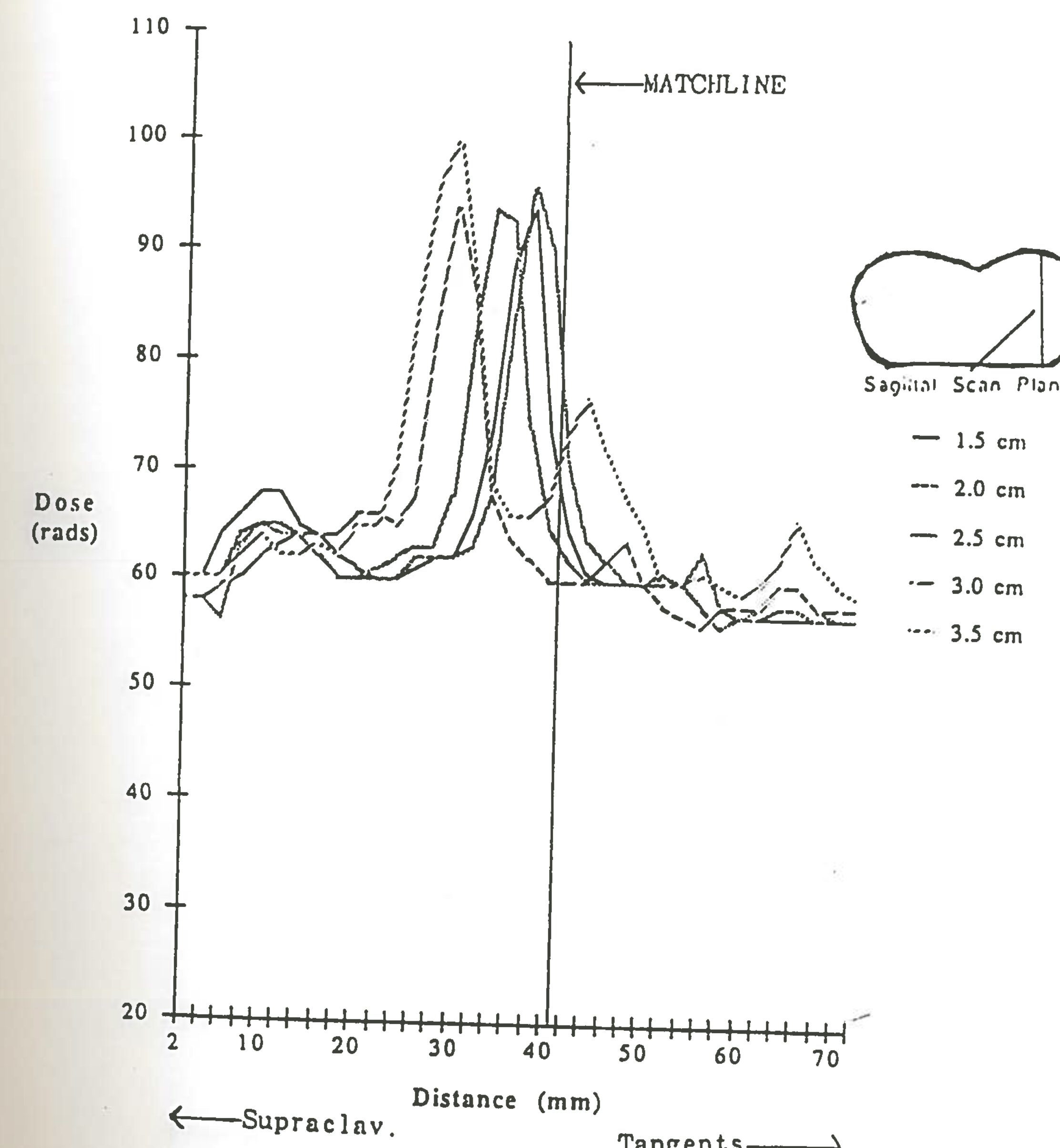


Fig. 11. Matchline dose distributions for the three-field technique used at MBPCC in the sagittal plane 8.0 cm lateral to the supraclavicular medial field border. The distributions are at depths of 1.5 cm, 2.0 cm, 2.5 cm, 3.0 cm and 3.5 cm from the anterior surface measured at the level of the matchline.

30° Wedge

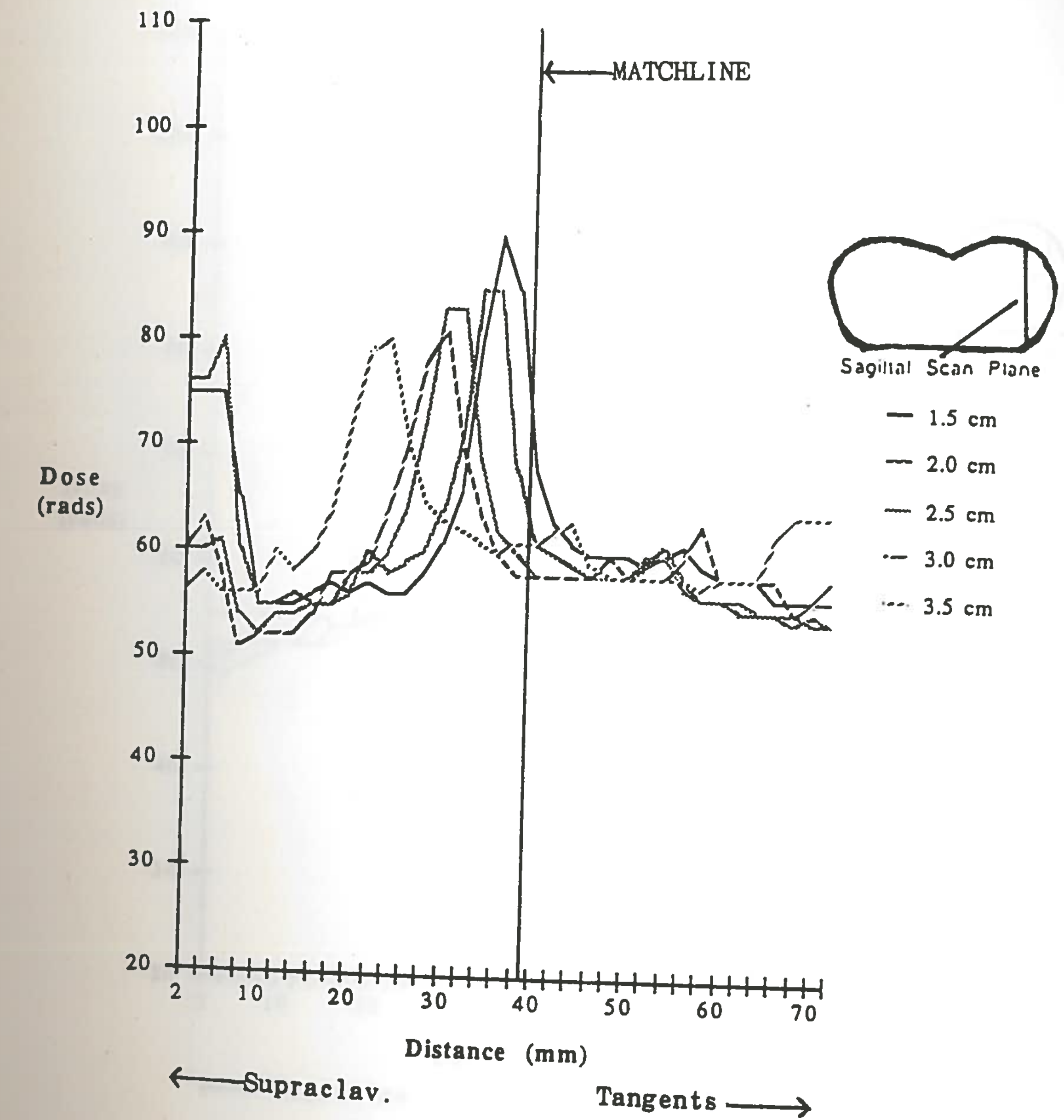


Fig. 12. Matchline dose distributions for the three-field technique used at MBPCC in the sagittal plane 10.0 cm lateral to the supraclavicular medial field border. The distributions are at depths of 1.5 cm, 2.0 cm, 2.5 cm, 3.0 cm and 3.5 cm from the anterior surface measured at the level of the matchline.

30° Wedge

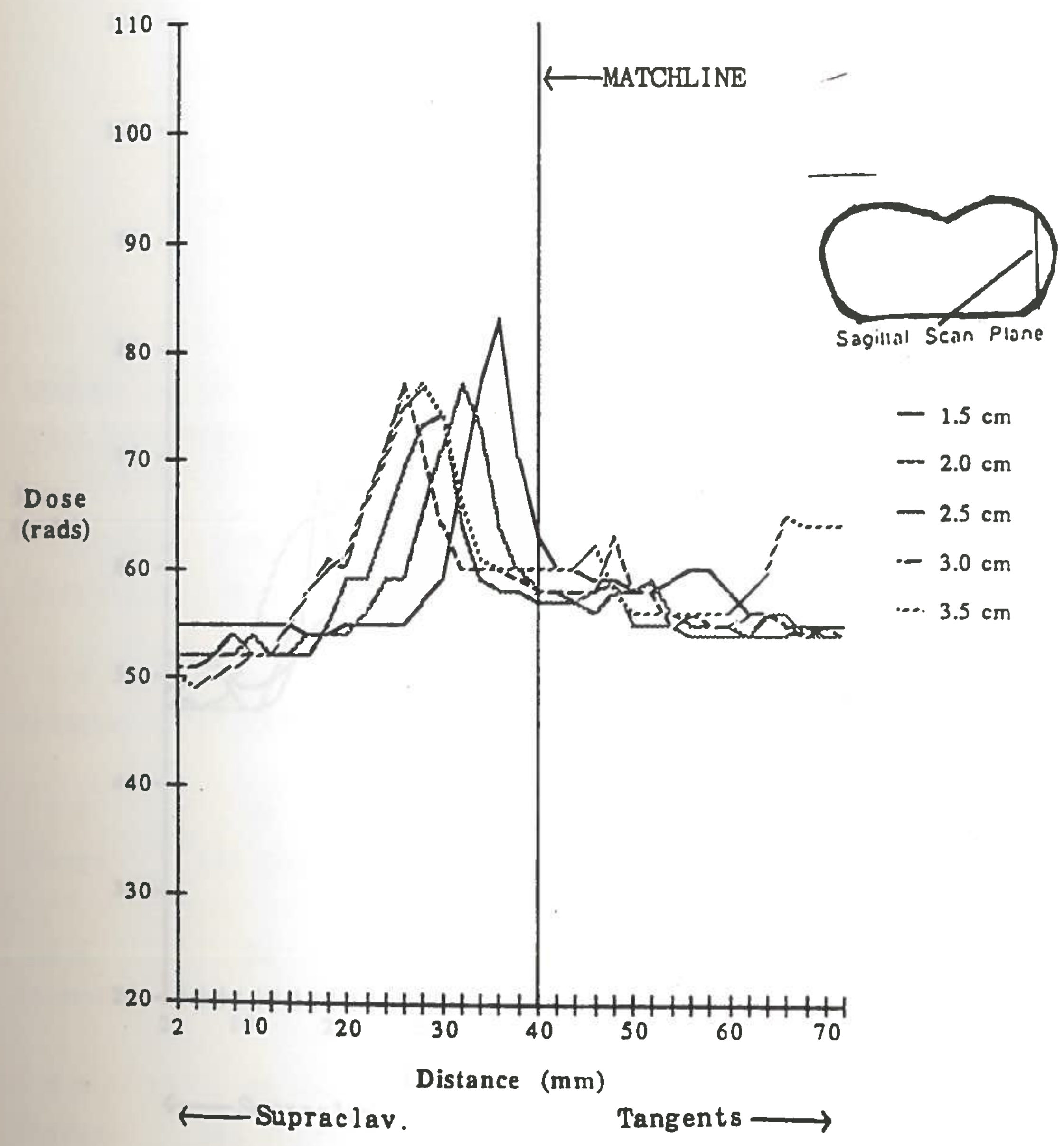


Fig. 13. Matchline dose distributions for the three-field technique used at MBPCC in the sagittal plane 12.0 cm lateral to the supraclavicular medial field border. The distributions are at depths of 1.5 cm, 2.0 cm, 2.5 cm, 3.0 cm and 3.5 cm from the anterior surface measured at the level of the matchline.

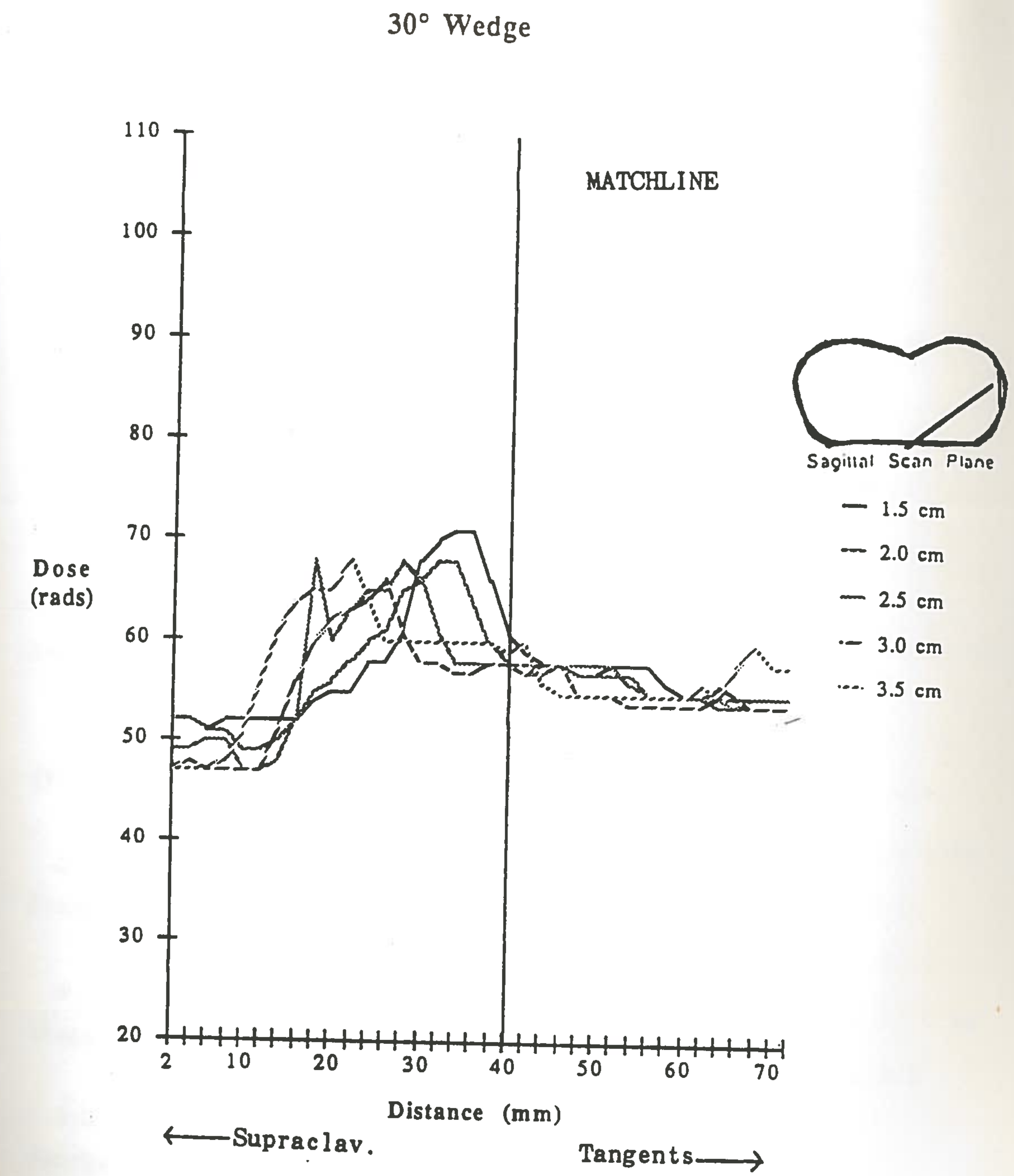


Fig. 14. Matchline dose distributions for the three-field technique used at MBPCC in the sagittal plane 14.0 cm lateral to the supraclavicular medial field border. The distributions are at depths of 1.5 cm, 2.0 cm, 2.5 cm, 3.0 cm and 3.5 cm from the anterior surface measured at the level of the matchline.

Table 1. A comparison of matchline peak doses at depths 1.5 cm, 2.0 cm, 2.5 cm, 3.0 cm and 3.5 cm from the anterior surface measured at the level of the matchline. Each value represents an average of all sagittal planes in five treatments at each depth. The ranges of each plane are displayed in parenthesis.

Depth (cm)	30 Wedge Treatment	No Wedge Treatment	% Difference Between Treatment Techniques
1.5 (range)	91 (76-103)	85 (76-94)	7.1%
2.0 (range)	89 (72-102)	85 (71-93)	4.7%
2.5 (range)	90 (71-100)	82 (65-92)	9.8%
3.0 (range)	84 (69-100)	80 (59-92)	5.0%
3.5 (range)	82 (64-99)	74 (60-90)	10.8%

treatments at varying depths.

Table 2 represents a comparison between peak doses from the 1.5 cm curve to the 3.5 cm curve. Each value is an average percent difference in peak doses for each sagittal plane. With the no wedge treatments, the difference between the 1.5 cm curve and the 3.5 cm curve peak doses is greater than the treatment with the wedge in place at each sagittal plane along the matchline.

Matchline scans for the no wedge technique are presented in Figures 15 through 21. Each figure shows variation in matchline doses with depth. Since no wedges were used on the tangential field, this dose inhomogeneity can be expected. As dose curves get deeper peak doses appear more superior.

Figure 15 is an illustration of the depth dose curves in the sagittal plane 2.0 cm lateral to the supraclavicular field border. There are marked decreases in dose with depth due to the data fields being in the cork (lung) region. At deeper depths the hot spots appear to be more superior. An average of the data from the five separate treatments at the same sagittal plane reveal that a 17.0 mm superior shift in the curves from 1.5 cm curve peak point to 3.5 curve peak point was detected.

Figure 16 represents matchline dose distributions in the sagittal plane 4.0 cm lateral to the supraclavicular medial field border. Dosages extending into the supraclavicular field are 1.2% higher than dosages extending into the tangents. At deeper depths the hotspots shift more superiorly. Five seperate treatments at the same sagittal plane reveal an average shift in the curve of 9.2 mm

Table 2. A comparison of matchline peak dose from the 1.5 cm curve to the 3.5 cm curve. All five experiments, for each type treatment, gave the same relationship between the 1.5 cm depth and the 3.5 depth. This % variability is given for each sagittal plane.

*Sagittal Plane (cm. lat. to medial border)	30 Wedge Treatment	No Wedge Treatment
2.0	3.4%	8.8%
4.0	1.5%	1.9%
6.0	0.9%	1.8%
8.0	0.8%	1.2%
10.0	1.5%	2.1%
12.0	0.8%	2.5%
14.0	1.8%	1.9%

No Wedge

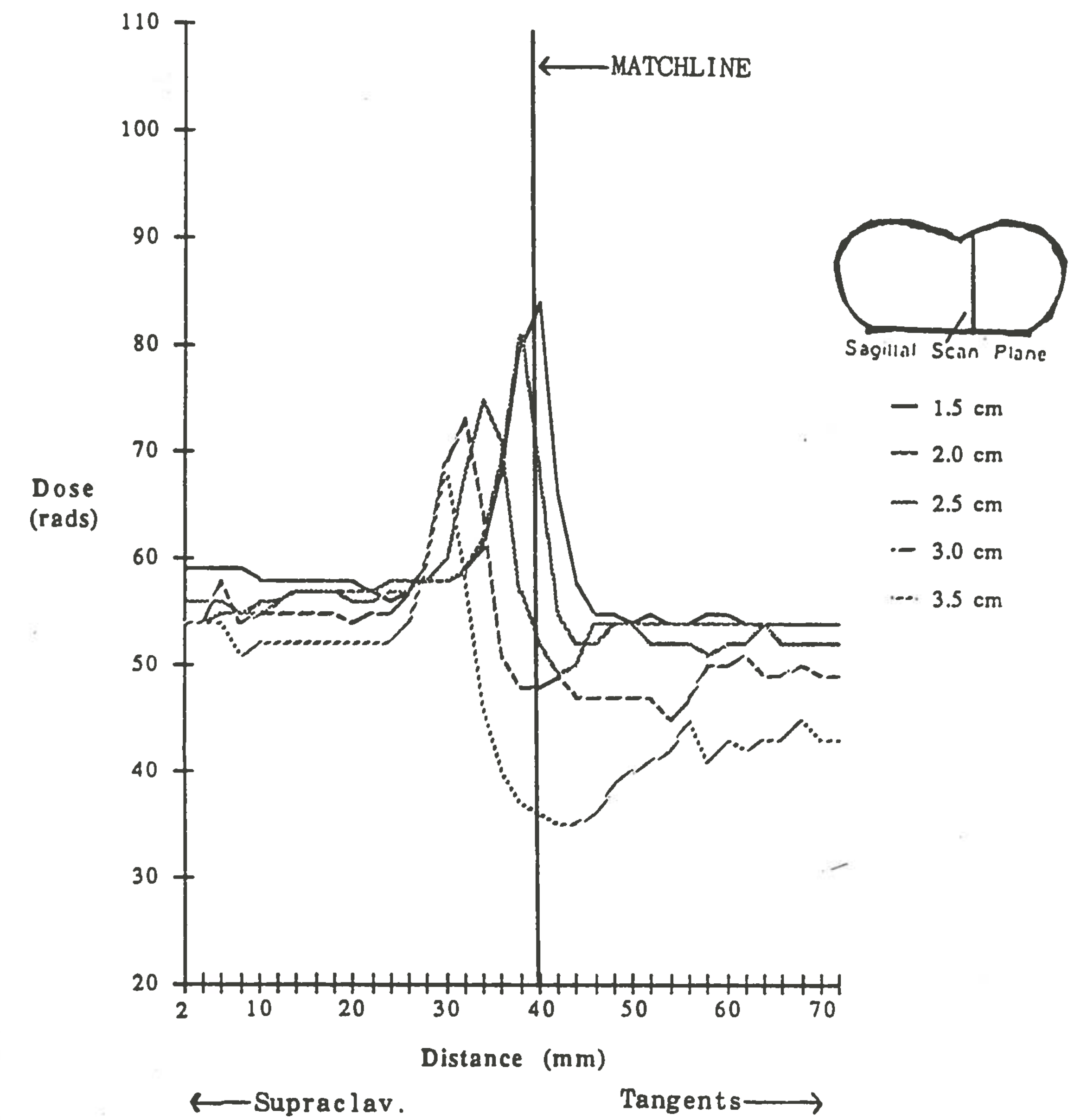


Fig. 15. Matchline dose distributions for the three-field technique used at MBPCC in the sagittal plane 2.0 cm lateral to the supraclavicular medial field border. The distributions are at depths of 1.5 cm, 2.0 cm, 2.5 cm, 3.0 cm and 3.5 cm from the anterior surface measured at the level of the matchline.

No Wedge

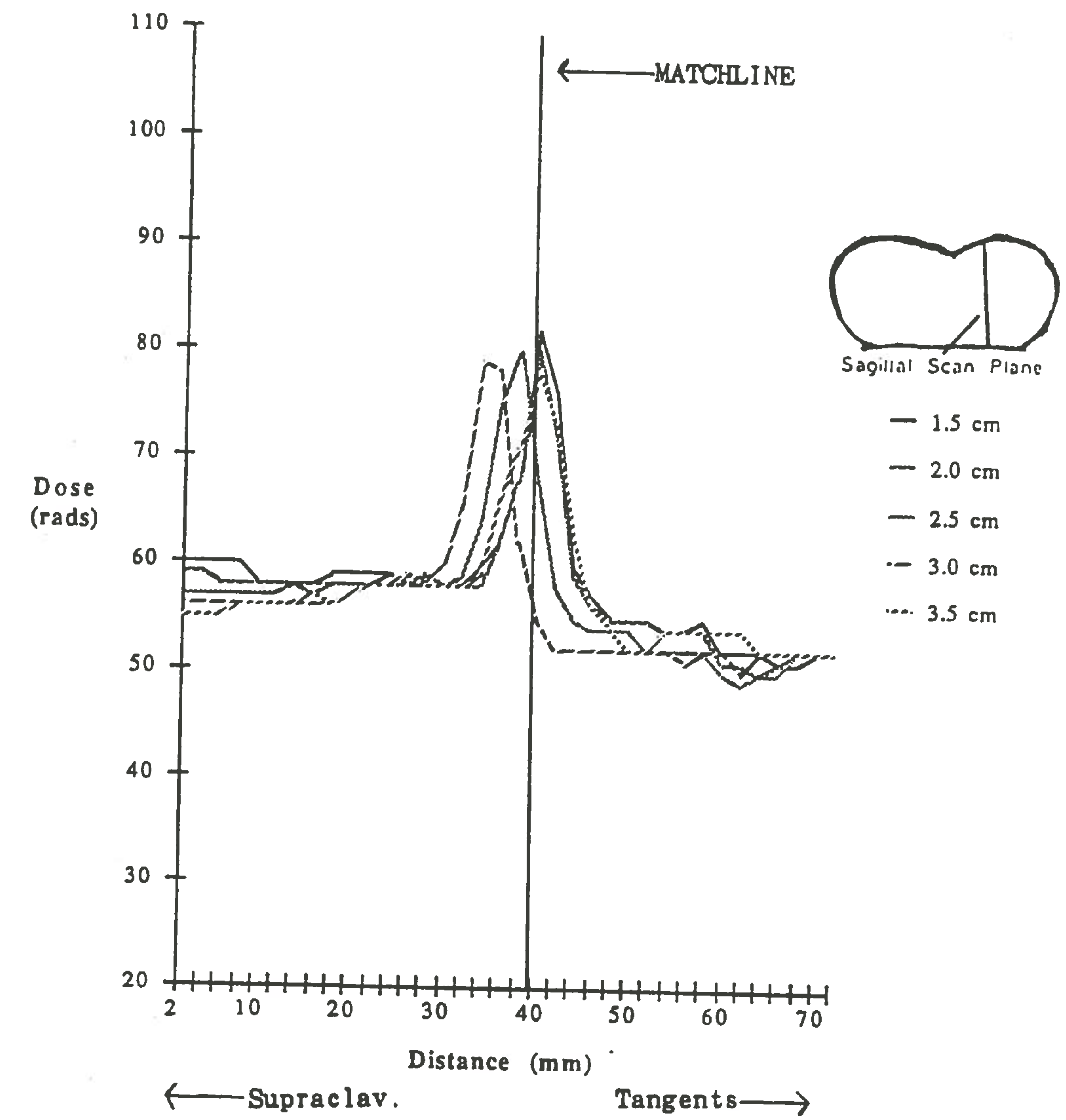


Fig. 16. Matchline dose distributions for the three-field technique used at MBPCC in the sagittal plane 4.0 cm lateral to the supraclavicular medial field border. The distributions are at depths of 1.5 cm, 2.0 cm, 2.5 cm, 3.0 cm and 3.5 cm from the anterior surface measured at the level of the matchline.

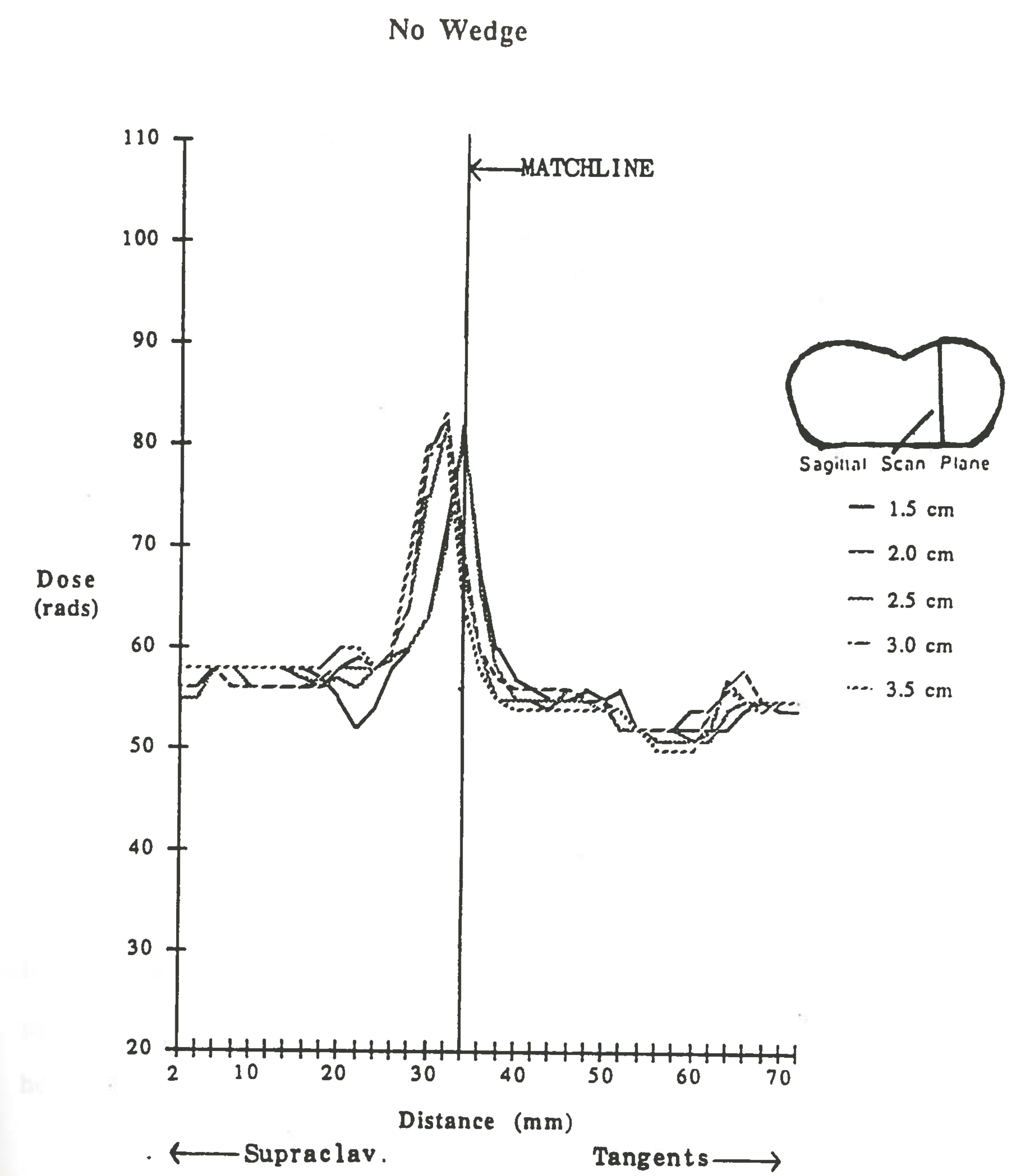


Fig. 17. Matchline dose distributions for the three-field technique used at MBPCC in the sagittal plane 6.0 cm lateral to the supraclavicular medial field border. The distributions are at depths of 1.5 cm, 2.0 cm, 2.5 cm, 3.0 cm and 3.5 cm from the anterior surface measured at the level of the matchline.

from depths of 1.5 cm curve hot peak to 3.5 cm curve hot peak.

Figure 17 is an illustration of matchline dose distribution in the sagittal plane 6.0 cm lateral to the supraclavicular medial field border. A 3.0 mm shift is noted in dose peaks as the curve deepen. However, an average of the five treatments at the same plane reveal a 7.0 mm shift.

Figure 18 is a comparison of doses at different depths in the sagittal plane 8.0 cm lateral to the supraclavicular field border. At deeper depths the hot spots shift superiorly. An average shift in the curve of 9.6 mm from the peak points of the 1.5 cm and 3.5 cm curves is found from five different treatments.

Figure 19 is an illustration of the sagittal plane 10.0 cm lateral to the supraclavicular meidal field border. In the same plane the average of five treatments revealed a 7.0 mm shift in the dose peaks from the 1.5 cm curve to the 3.5 cm curve.

Figure 20 represents matchline dose distributions in the sagittal palne 12.0 cm lateral to the supraclavicular medial field border. An average shift in the curve of 9.6 mm was found from peak points at the 1.5 cm curve to 3.5 cm curves. At deeper depths the hot spot shifts superiorly.

Figure 21 is an illustration of the matchline dose distributions in the sagittal plane 14.0 cm lateral to the supraclavicular medial field border. An average superior shift in the curve of 14.6 mm was found in peak points from 1.5 cm to 3.5 cm curves for the five different treatments in the same plane.

The illustration in Fig. 22 is a diagram of the divergence from the supraclavicular field. The calculation shows that the contribution from divergence of the supraclavicular field is only 0.6 mm at a depth of 3.5 cm below the matchline.

No Wedge

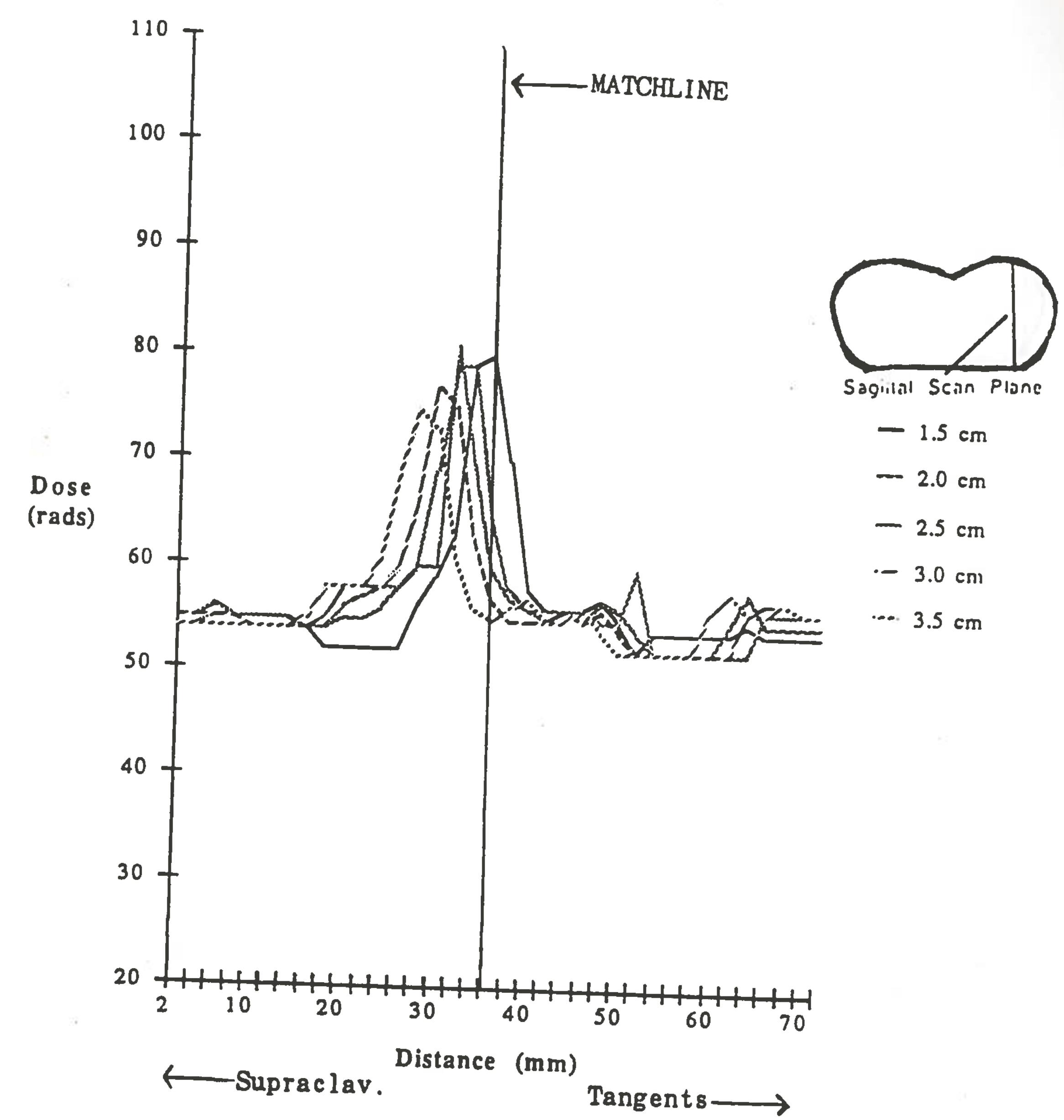


Fig. 18. Matchline dose distributions for the three-field technique used at MBPCC in the sagittal plane 8.0 cm lateral to the supraclavicular medial field border. The distributions are at depths of 1.5 cm, 2.0 cm, 2.5 cm, 3.0 cm and 3.5 cm from the anterior surface measured at the level of the matchline.

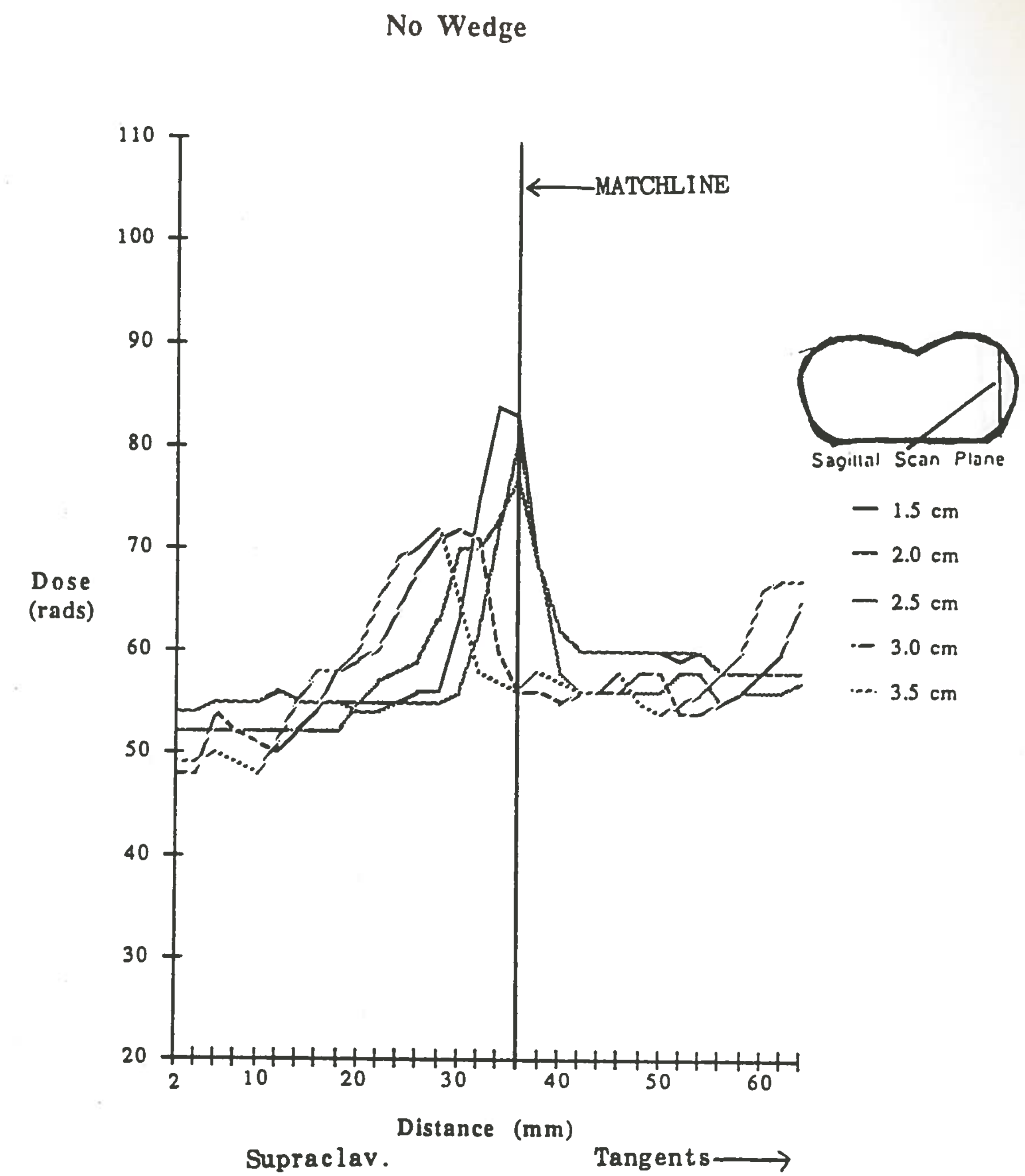


Fig. 19. Matchline dose distributions for the three-field technique used at MBPCC in the sagittal plane 10.0 cm lateral to the supraclavicular medial field border. The distributions are at depths of 1.5 cm, 2.0 cm, 2.5 cm, 3.0 cm and 3.5 cm from the anterior surface measured at the level of the matchline.

No Wedge

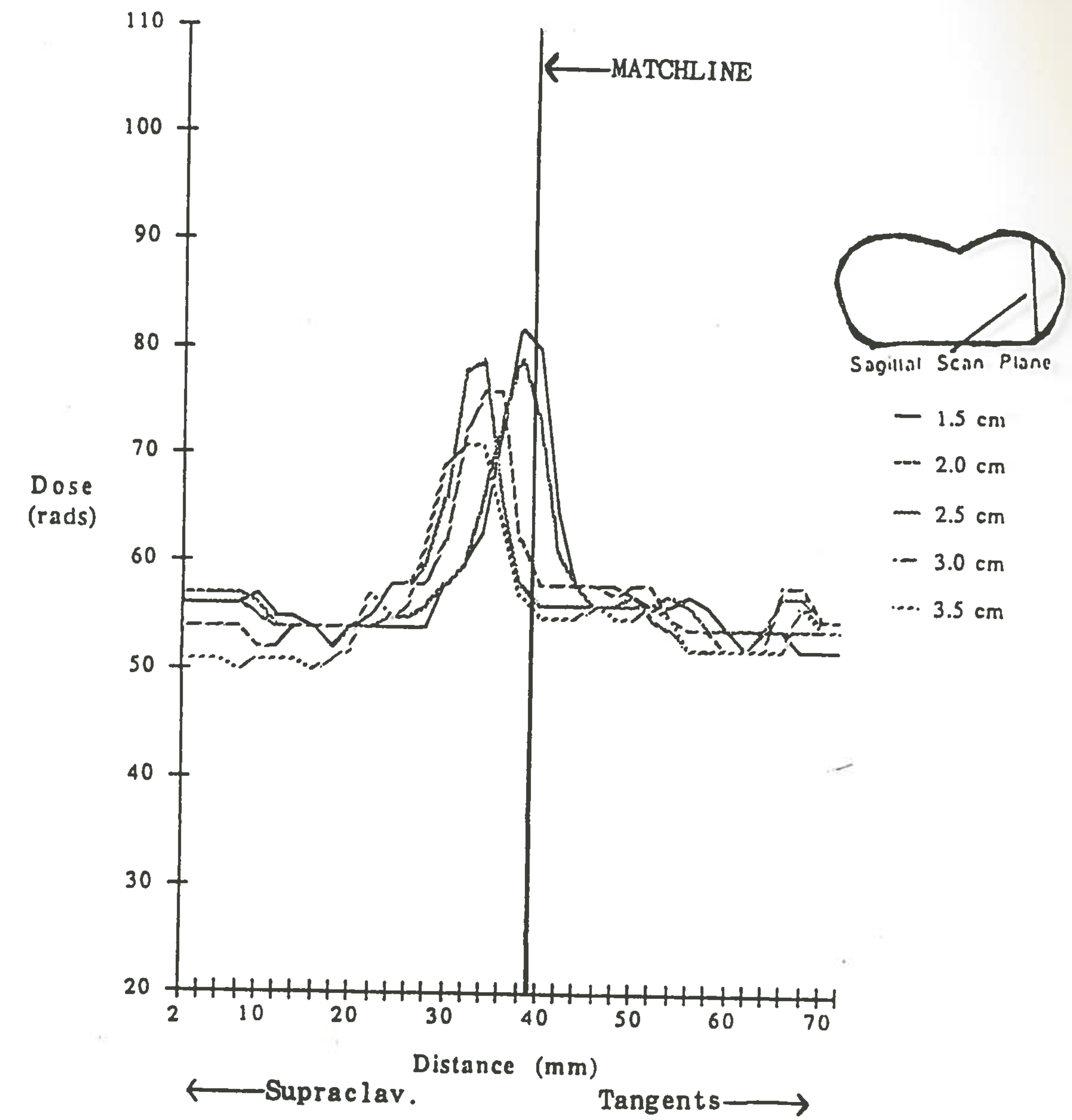


Fig. 20. Matchline dose distributions for the three-field technique used at MBPCC in the sagittal plane 12.0 cm lateral to the supraclavicular medial field border. The distributions are at depths of 1.5 cm, 2.0 cm, 2.5 cm, 3.0 cm and 3.5 cm from the anterior surface measured at the level of the matchline.

No Wedge

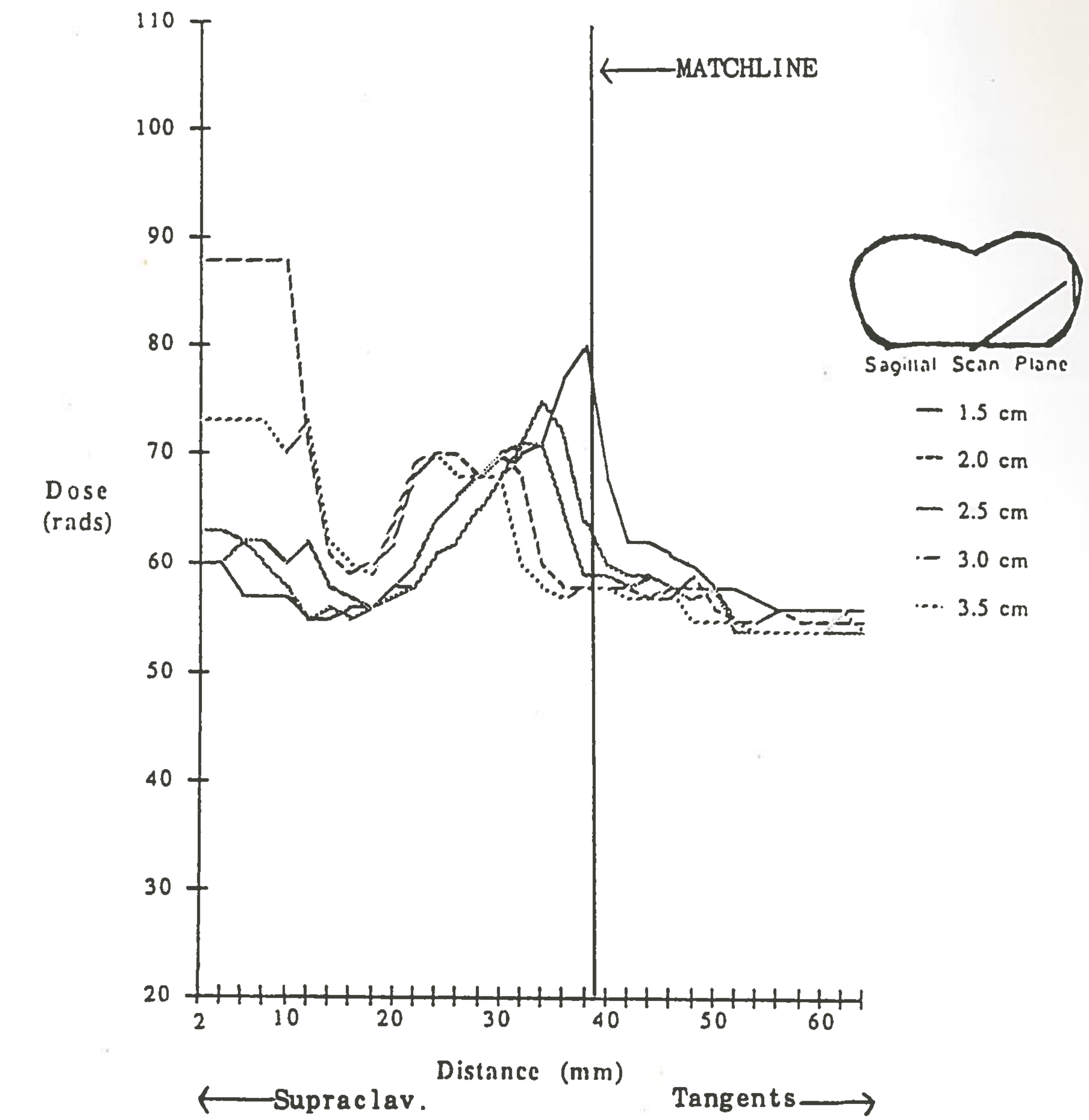
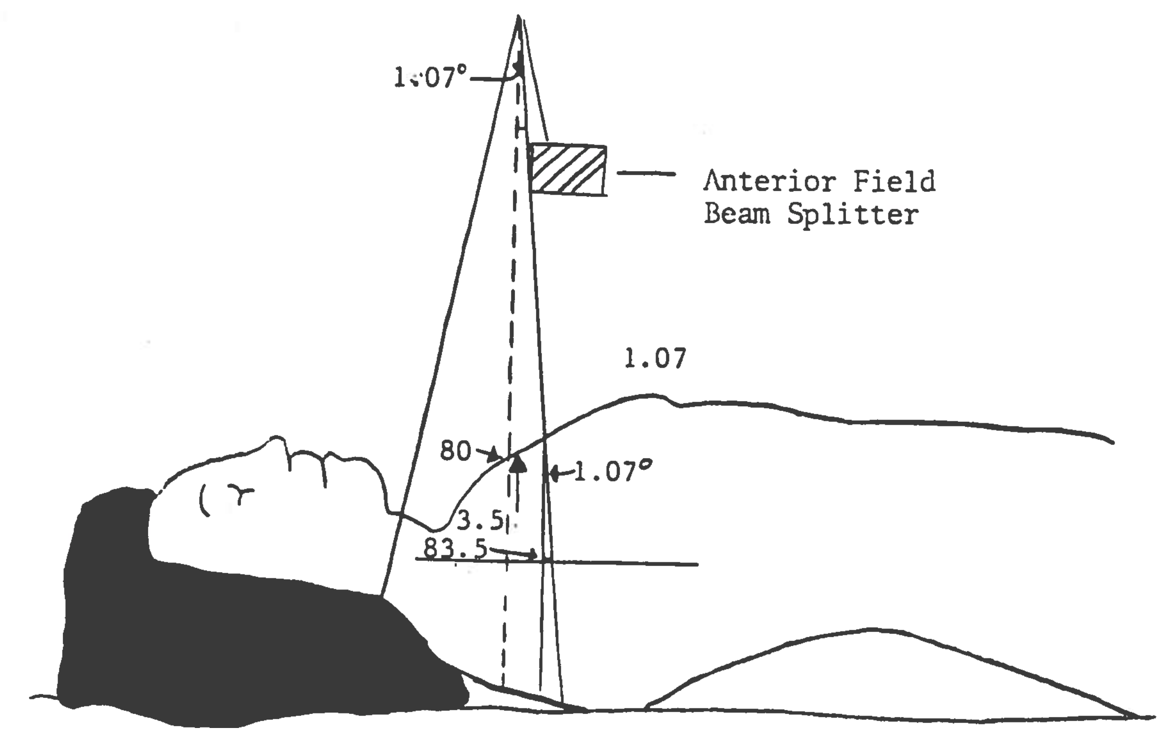


Fig. 21. Matchline dose distributions for the three-field technique used at MBPCC in the sagittal plane 14.0 cm lateral to the supraclavicular medial field border. The distributions are at depths of 1.5 cm, 2.0 cm, 2.5 cm, 3.0 cm and 3.5 cm from the anterior surface measured at the level of the matchline.



$$\tan 1.07 = \frac{\text{opp.}}{3.5}$$

$$\text{opp} = .065 \text{ cm}$$

$$= .65 \text{ mm}$$

Fig. 22. The diagram illustrates the contribution from the divergence of the supraclavicular field with the beam splitter in place. Calculations are used to determine the contribution of the supraclavicular field at 3.5 cm below the matchline.

DISCUSSION

From the results presented in the previous section, it is apparent that the divergence from the supraclavicular field is negligible. The beam splitter causes a sharp beam with less than 1 mm divergence at 3.5 cm below the matchline. Therefore, the largest contribution to the hot spot is from the tangential fields. It should be noted that the technique consists of a built in overlap, because the whole matchline is treated with the supraclavicular field and half the matchline is treated with the tangent fields. Therefore, the technique produces approximately a 1 to 2 mm overlap of fields directly, thereby causing the sharp peak seen in Figs. 8 through 14 and in Figs. 15 through 21.

The curves of Fig. 8 through 14 indicate that with the use of wedges on the tangential fields there is a more uniform dose distribution. More variation in peak doses is seen with the no wedge treatment. Data plotted in Figs. 15 through 21 also indicate this in the variations in the peak dose with depth.

The rotation of the treatment table to align the tangential fields along the matchline is used to rid the beams of horizontal divergence. The superior edges of the beams line up precisely in the middle of the inferior border of the supraclavicular field line. This component is not eliminated in the present technique, therefore this experiment was done to quantify measurements of the actual contribution.

The superior shifts of the beams with increasing depth and the lack of significant decreases in dosages with increasing depth are presently being checked through calculations using off-axis factors. These factors are being investigated more carefully in an attempt to explain the superior shift of the beam with increasing depth and the lack of significant decrease in dosages with increasing depth.

The higher peak doses, analyzed in Table 1, with the 30 wedge plan as opposed to the zero wedge plan are due to the wedge. Higher doses occur under the thin ends of the wedges and their magnitude increases with wedge angle. This is due to the differential attenuation of the beam under the thin end relative to the thick end.

Another factor that may contribute to the hot spot extending into the supraclavicular field has been noted throughout the investigation and should be addressed at this time. The treatment table moves between 1-3 mm after the table has been locked. This variability maybe an added cause of possible hot spot peaks, and warrants further study.

From the data obtained from this study it is apparent there is a prominant hot spot at the junction of the three fields. Theoretically, Fig. 22 illustrates that very little divergence is obtained by using the beamsplitter 1.5 cm off the CAX of the field. This calculation supports the data obtained from the experiment that showed peaks inside the supraclavicular field. From the results of this study, one may conclude that a large contributor to the peak are the tangent fields. Further study in the future could include placing film sagittally in the phantom along the matchline and treating the supraclavicular field. The film would be removed and replaced with fresh film and the two tangents would be treated. The separate films could be analyzed to determine the actual major contributor to the hot spot.

Further investigations based on the present data could be useful. There is a lack of consistancy in aligning the matchline on the simulator and obtaining a table rotation and then transfering this information to the treatment table. The purpose of rotating the table is to align the two tangential fields and this is done on the simulator by fluoroscopy. On the treatment table fluoroscopy is not available or practical therefore it is done empirically on the skin. A continued experiment could be performed using the wax phantom on the treatment table. Port films could be taken until proper alignment is verified. Scan films would be loaded into the patient and then the three-fields would be treated. After the data is analyzed, it could be determined whether the hot spot is reduced by aligning the fields. If so, then it would be possible to use the current technique with improvements in the rotation of the treatment table. A possible improvement could be to convert the table rotation angles on the simulator to correspond to the rotation angles on the treatment table.

If the hot spot still remains after the port film alignment experiment, it would be advantageous to look to amendments or changes in the present technique. Small wedges on the superior edges of the beamsplitter and custom blocks could be useful. The wedges would reduce the sharp edges of the fields and would reduce the need for a precise match of the fields at the matchline.

SUMMARY

The use of the three-field arrangement for the treatment of the intact breast requires a precise technique to avoid either a geometric gap or overlap. The data presented here may be used to analyze further the technique used at MBPCC. It is felt, however, that additional investigation into the off-axis factors would be useful in verifying dosages by hand calculation.

With any matchline technique, the matchline doses will be affected by the local dose distributions in the supraclavicular and tangential fields. These distributions are primarily affected by wedges in the tangential field, a 1.5 cm off the CAX beamsplitter in the supraclavicular field and differeces in the three dimensional shape of the patient. The use of wedges will decrease dose inhomogeneity within the tangents thereby leading to more uniform matchline doses.

REFERENCES

1. American Cancer Society (ACS). 1983. Clinical Oncology For Medical Students and Physicians - A Multidisciplinary Approach. American Cancer Society, New York, NY. pp. 120-140.

2. Baclesse, F., Gricouroff G. and Taillefer, A. 1939. Essai de Roentgentherapie du cancer du sein suivi d operation large. Results histologies. Bull. Cancer. 28: 729-743.

3. Baclesse, F., Ennuyer, A. and Cheguillaume, J. 1960. Eston on Autorise a pratiquerune tumorectomie simple suivie de radiotherapie en cas de tumeur mammaire? J. Radiol. Electrol. 41: 137-139.

4. Bedwinek, J. 1981. Treatment of Stage I and II Adenocarcinoma Of The Breast By Tumor Excision and Irradiation. Journal of Radiation Oncology, Biology, Physics. 7: 1553-1559.

5. Dutriex, J. and Dutriex M. 1969. High Energy Radiation Therapy Dosimetry. Ann., New York. Acad. Science. 161, pp. 33-43.

6. Fletcher, G. 1980. Textbook of Radiotherapy. Lea and Fegiber, Philadelphia. pp. 194-199.

7. Johns, J. E. and Cunningham, J.R. 1983. The Physics of Radiology. Thomas Books. Springfield, Illinois. pp. 320-325.

8. Harris, J.R., Hellman S. and Silen, W. 1983. New Surgical and Radiotherapeutic Techniques. J. B. Lippincott Company, Philadephia. pp. xi-15.

9. Hogstrom, K. 1986. Film Dosimetry (Types, Response, Developing, Phantoms, Techniques).

10. Pierquin, B., Mazeron, J. and Glaubiger, D. 1986. Conservative treatment of breast cancer in Europe: Report of the Groupe Europeen de Curietherapy. Radiotherapy and Oncology. 6: 187-198.

VITA

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