THE USEFULNESS OF A NEW CARBON FIBER COUCH AS A COUNTERMEASURE FOR THE ATTENUATION BY METAL SUPPORTS OF A COUCH ATTACHED TO A LINEAR ACCELERATOR IN ROTATION THERAPY

Mitsuharu IJJIMA*1*3, Tetsuo NISHIMURA*1, Michikatsu TAKAI*2, Masao KANEKO*1

(Received 19 October 1998, accepted 28 May 1999)

Abstract: A treatment couch attached to a linear accelerator (attached couch or A. couch) has metal supports. In full rotation therapy, attenuation of absorbed dose by these supports can not be ignored. Therefore, our institution has devised a new couch of carbon fiber (C.F. couch) for brain tumors or head and neck lesions. We evaluated the influence of both couches in rotation therapy with 4 MV or 10 MV photon beam.

For the A. couch, the maximum dose attenuation at full rotation was 4-5% at 4 MV and 4% at 10 MV. On the other hand, the influence of the C.F. couch was negligible.

Consequently, the influence of the A. couch in full rotation should not be ignored. Our results suggested the need to correct the metal support-induced attenuation.

Our C.F. couch was useful as a countermeasure for the attenuation by metal supports of the attached couch in rotation therapy.

Key Words: Dose attenuation, Dose distribution, Treatment couch, Rotational technique, Conformal therapy

INTRODUCTION

We use rotation therapy, including conformation radiotherapy1)-3) in our routine treatment. However, the treatment couch (A. couch) of the linear accelerator unit now in use is equipped with metal supports. The attenuation induced by these supports might not be tolerable in full rotation therapy. On this assumption, we devised a new carbon fiber treatment couch (C.F. couch) for our institution's use in the treatment of brain tumors or head and neck cancer.

In this study, the attenuation of the A. couch's metal supports in rotation therapy was estimated, and the usefulness of the C.F. couch was evaluated.

MATERIALS AND METHODS

1. Instruments

In our institution, a Clinac 2100C (Varian Oncology System, Palo Alto, USA) was installed in 1994. The A. couch has metal supports that are placed parallel to the axis of rotation (Fig. 1). These metal supports consist of low-carbon steel. This A. couch has two side supports (side support) and one center support (center support). The side supports are located along each side of the couch, running approximately 2/3 of the way down the couch. The center support runs lengthwise through the center of the remaining 1/3 of the couch. The sizes of a cross-section of the side and center supports in the plane of rotation are 1.0...
cm×2.7 cm and 4.0 cm×8.0 cm, respectively. We use both types of couch depending on the treatment site. The size of the carbon fiber couch, which we devised, is 45 cm×40 cm×1 cm (Fig. 2). This couch consists of acrylic foam covered with a 0.6-mm-wide surface of carbon fiber. The density of the carbon fiber is 0.3 g/cm³. According to the measurements of the C.F. couch, the air dose was attenuated by a reduction of 0.5% at 4 MV and 0.3% at 10 MV. A new cylindrical phantom (Tough-water®, Kyoto Kagaku Co, Kyoto, Japan) of 25 cm in diameter was specially prepared for this investigation (Fig. 3). Dose distributions were evaluated by film dosimetry using X-OmatV (Eastman Kodak, Rochester, USA), Dyna Scan and a densitometer with an aperture diameter of 3 mm (Computerized Medical Systems, St Louis, USA). An absorbed dose was measured using the same shaped phantom, Ionex Dosemaster 2590 (Bicron/Ne Technology Ltd, Reading, England) and JARP (Japanese Association of Radiological Physicists) level dosimeter (PTW2333, Physikalisch-Technische Werkstaetten, Freiburg, Germany).

2. Methods of dosimetry
2.1 Film dosimetry
2.1.1 Analysis with isodose curves
   The axis of the cylindrical phantom was set parallel to the axis of rotation, and the film was placed in a cross-sectional plane perpendicular to the axis of rotation (Fig. 3). Full rotational irradiation of 4 MV or 10 MV photon in the field size of 10 cm×10 cm was performed with the A. couch and the C.F. couch.
The film was scanned in an area of 12 cm square around the isocenter and converted to an isodose curve using Dyna scan with a scanning pitch of 2 mm. These isodose charts were checked for distortion of the concentric circle in the isodose curve.

2.1.2 Comparison of dose profiles

We defined a gantry angle at the twelve o'clock position as 0 degrees. Each film was scanned in a cross-sectional plane parallel to the axis of rotation and converted to dose profile using Dyna scan with a scanning pitch of 1 mm. In each series of full rotation, ten dose profiles were represented from 90 degrees to 180 degrees, every 10 degree around the isocenter. These dose profiles of full rotation with the A. couch were compared with those of the C.F. couch as a standard in the same cross-section.

2.2 Measurement of absorbed dose using ionization chamber

The radiation dose was measured with an ionization chamber in the gantry angle where the influence of the couch was most prominent. The measurement points consisted of the isocenter and points 2 cm and 4 cm outside the isocenter (Fig. 4).

---

Fig. 3 A new cylindrical phantom (25 cm in diameter) developed for this investigation.
(A) A setting for film dosimetry.
(B) A setting for dosimetry by the ionization chamber.

Fig. 4 Schematic diagrams of phantom and treatment couch.
(A)-(1), (2): Full rotational irradiation using C.F. couch.
(B)-(1), (2): Full rotational irradiation using A. couch with side supports.
(C)-(1), (2): Full rotational irradiation using A. couch with center support.
3. Comparison between calculated dose and measured dose

We also evaluated the attenuation at the isocenter induced by the metal supports. An absorbed dose at the isocenter as measured with the ionization chamber was compared to the calculated dose.

RESULTS

1. Film dosimetry

1.1 Analysis with isodose curves (Fig. 5)

(a) Full rotation with C.F. couch

In full rotation therapy with the C.F. couch, desirable concentric isodose curves without distortion were recognized at 4 MV and 10 MV.

(b) Full rotation with A. couch

Concentric circles of isodose curves were distorted along the line between the isocenter and the support. The influence of supports was observed most remarkably in the side support at 150 degrees and in the center support 180 degrees. These results led to the determination of measurement points.

1.2 Analysis with dose profiles (Fig. 6)

(a) Full rotation with C.F. couch

Symmetrical dose profiles, along with the axis of rotation, were obtained for both photon energies.

(b) Full rotation with A. couch

Dose profiles of the A. couch were asymmetrical, and the left shoulder of profile with the A. couch was downward compared to the C.F. couch. Distortion of dose profile appeared near supports.

2. Measurement of absorbed dose using ionization chamber (Table 1)

The maximum dose attenuations using the center support were 5% with 4 MV and 4% with 10 MV. In case of side support, the maximum dose attenuations were 4% with 4 MV and 4% with 10 MV.

3. Comparison between calculated dose and measured dose

The absorbed dose at the isocenter is estimated from the prescribed dose monitor unit as follows:

<table>
<thead>
<tr>
<th>Energy</th>
<th>Calculated Dose (cGy)</th>
<th>Measured Dose (cGy)</th>
<th>Attenuation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 MV</td>
<td>118</td>
<td>114</td>
<td>3.4-4.2%</td>
</tr>
<tr>
<td>10 MV</td>
<td>141</td>
<td>138</td>
<td>2.3-2.8%</td>
</tr>
</tbody>
</table>

On the other hand, with the C.F. couch, the absorbed doses that we measured were 117 cGy (4 MV) and 142 cGy (10 MV). These results corresponded to calculated dose within the error of the dosimetry instruments.

DISCUSSION

More than thirty years ago, Takahashi\textsuperscript{1, 2}) devised several radiation methods, such as the rotational body technique, column-focus technique, and hollow-out technique, designed to converge the radiation dose on the lesion. He systematized those techniques for conformation radiotherapy. Later, conformation radiotherapy by telecobalt shifted to that by linear accelerator because of the superiority of dose distribution\textsuperscript{4}). Conformation radiotherapy has technically been developed since then, with the development of computer-controlled equipment\textsuperscript{5) and the use of a 1-cm-wide multileaf collimators.

Now, conformation radiotherapy is applied to the treatment of various sites on the human body. Takahashi \textit{et al}\textsuperscript{6) pointed out the significance of the influence of the treatment couch on dose distribution in rotation therapy in their early investigations using telecobalt. They refined the treatment couch for preferable dose distribution and reported correction factors for that couch. Okumura \textit{et al}\textsuperscript{7) measured attenuation of the...
Influence of couch in rotational technique

Fig. 5 Dose distributions are in a cross-sectional plane of rotation. 

(A), (B): Full rotation therapy with C.F. couch using 4 MV and 10 MV photon energies. A concentric circle of isodose curve was obtained. 

(C), (D): Full rotation therapy with A. couch with side supports using 4 MV and 10 MV photon energies. Concentric circles of isodose curves were distorted along the line between the isocenter and the side support. 

(E), (F): Full rotation therapy with A. couch with center support using 4 MV and 10 MV photon. Distortion of the concentric circle were exhibited in isodose curves along the line between the isocenter and center support.
Fig. 6 Dose profiles in the cross-section parallel to the axis of rotation. Relative dose in the irradiation of 180 dose monitor units is shown among the vertical axis. Relative dose was normalized to the dose at the isocenter with each couch. Each profile was compared with profiles of the C.F. couch in full rotation as a reference. In (A), (B), 4 MV photons were used. In (C), (D), 10 MV photons were used. Dose profiles of the A. couch were asymmetrical in comparison with the C.F. couch. Distortion of dose profile appeared near supports.

(A) Full rotation, C.F. couch vs. A. couch with center support (the line a-a vs. e-e in Fig. 5).
(B) Full rotation, C.F. couch vs. A. couch with side supports (the line a'-a' vs. c'-c' in Fig. 5).
(C) Full rotation, C.F. couch vs. A. couch with center support (the line b-b vs. f-f in Fig. 5).
(D) Full rotation, C.F. couch vs. A. couch with side supports (the line b'-b' vs. d'-d' in Fig. 5).
Influence of couch in rotational technique

Table 1 The absorbed dose of the new couch of carbon fiber (C.F. couch) and the attached couch (A. couch).

<table>
<thead>
<tr>
<th>Energy</th>
<th>MP</th>
<th>Absorbed dose (cGy)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C.F. couch</td>
<td>A. couch (side)</td>
</tr>
<tr>
<td></td>
<td>Dose(1)</td>
<td>Dose(2)</td>
</tr>
<tr>
<td>IC</td>
<td>117</td>
<td>113</td>
</tr>
<tr>
<td>4 MV</td>
<td>2 cm</td>
<td>118</td>
</tr>
<tr>
<td></td>
<td>4 cm</td>
<td>118</td>
</tr>
<tr>
<td>IC</td>
<td>142</td>
<td>137</td>
</tr>
<tr>
<td>10 MV</td>
<td>2 cm</td>
<td>142</td>
</tr>
<tr>
<td></td>
<td>4 cm</td>
<td>142</td>
</tr>
</tbody>
</table>

MP = Measurement point, IC = Isocenter

Treatment couch and pointed out the need for correction of the tissue/air ratio in the clinical use of conformation radiotherapy. He also emphasized the significance of knowing the influence of the treatment couch before actual treatment. However, to our knowledge, there have been no reports of the influence of the treatment couch in conformation radiotherapy by a recent linear accelerator.

The attenuation of supports might not be tolerable in full rotation therapy, including conformation radiotherapy, in a modern linear accelerator. On this assumption, we devised a new treatment couch of carbon fiber (C.F. couch) for application in treatments of brain tumors or head and neck cancer.

We also developed a new cylindrical phantom in order to conduct this study more accurately. The shape of the cylindrical phantom is different from the ordinary type of phantom or the human body. However, the isodose curve in the ellipsoid phantom is known not to be concentric in full rotation therapy. In our study, we used a cylindrical phantom for the sole purpose of assessing the influence of a treatment couch in rotation therapy.

From our results, the attenuation of the absorbed dose induced by metal supports was more significant than the distortion of the dose distribution.

In the measurement of absorbed dose using an ionization chamber, in comparison with the C.F. couch, the maximum dose attenuations with center support were 5% at 4 MV and 4% at 10 MV. In the case of side support, they were 4% at 4 MV and 4% at 10 MV. In the comparison between calculated dose and measured dose at the isocenter, the attenuation of the absorbed dose by metal support were 3.4-4.2% in 4 MV and 2.3-2.8% in 10 MV. These results suggested the need to correct the attenuation induced by the metal supports.

On the other hand, with the C.F. couch, the absorbed dose corresponded to calculated dose within the error of the dosimetry instruments. Accordingly, there is no need for correction in treatment using the C.F. couch. Furthermore, dose distribution of the C.F. couch was almost concentric; the C.F. couch provides more suitable dose distribution in rotation therapy. This new device is required on a treatment couch for precise radiotherapy. A C.F. couch such as we made for brain tumors or head and neck lesions should be employed as a solution to the influence of the treatment couch on rotation therapy.

Although slight sag of the C.F. couch was
observed in loading a patient, there was no need to correct the position of the couch in clinical use. In addition, there is a probability that the radiation dose on the skin surface is increased with scattered radiation by carbon fiber. In our institution, we use an immobilization device on the C.F. couch for brain tumors or head and neck lesions. There is some distance from the skin surface to the C.F. couch. We have never experienced an increased skin reaction of patients in this situation. Therefore, these devices are thought to be acceptable in clinical use.

For lesions of the trunk, the use of couch is also required to improve dose distribution. However, we need to solve problems of stability and increase of surface dose.

CONCLUSION

We confirmed that the attenuation induced by the supports of the treatment couch in rotation therapy could not be ignored. Therefore, a technical improvement in treatment devices is required to achieve radiotherapy that is more accurate. The carbon fiber treatment couch we developed was useful as a countermeasure for the attenuation by metal supports of the attached couch in rotation therapy.

Acknowledgments: The authors sincerely appreciate N. Shibata, R.T. and S. Suzuki, R.T. for their support of this study. The content of this article was presented at the 10th JASTRO meeting, Takamatsu, from the 30th of October to the 1st of November, 1997.

REFERENCES