Protection of the contralateral breast during radiation therapy for breast cancer

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Abstract. Conformal Radiation Therapy (3DCRT) and Intensity Modulated Radiotherapy (IMRT) improve the relationship between tumor control and complications in normal tissue. However, these techniques may cause an increase of the normal tissue volume irradiated with low doses or an increase of the doses outside the beam. The aim of this work was to measure and compare the scatter dose to the contralateral breast using both the conventional two-field technique and the 3DCRT technique with blocks. The contralateral breast dose was measured with thermoluminiscent dosimeters. The present work is divided in three parts: 1) Characterization of the radiation field outside the treatment beam 2) Determination of the dose to the contralateral breast 3) Design and construction of a shield to reduce the scatter dose to the contralateral breast. Treatment using 3DCRT technique was delivered to a phantom. From one to ten 2mm thick lead sheets were placed on the dosimeters to attenuate radiation to the contralateral breast from the head, without blocking the treatment beam. Using the conventional technique the average dose to the contralateral breast was 2.09 Gy, 4.18% (2.9%–19%) of the 50 Gy prescribed dose. The contribution of the medial field was 3.36% (2.3%–21.1%) and of the lateral field 0.86% (0.4%–3.7%). When using 3DCRT technique the average dose to the opposite breast was 5.9 Gy, 11.8% (7.9%–24%) of the prescribed dose. The contribution of the medial field was 10.3% (6.7%–20%) and of the lateral field 1.6% (1.1%–3.8%). A 2mm thick lead shield with a 0.2 g/cm2 thick wax coat was constructed which reduced the dose from 11.8% to less than 2%. The blocks increase the dose to the contralateral breast, the highest dose being attributed to the medial field. Our shield reduced the dose, which allowed the regular use of 3DCRT with blocks. In addition, we found that this shield was comfortable for the patients and easy to position for the therapists.

KEYWORDS: contralateral breast, scattered radiation, breast cancer

1. Introduction

Contralateral breast cancer (CBC) in patients treated for a primary malignancy is the most common of the so-called second primary cancers, whose incidence ranges from 1.2% to 14% depending on the length of follow-up of the population studied. The relationship between radiotherapy and increase in the incidence of CBC has been studied and reported by various authors. One of these studies was undertaken using the SEER database [1] (1973-1996) of 134,501 women with a diagnosis of invasive unilateral breast cancer or DCIS. A total of 1234 (3.3%) of 37,339 irradiated patients developed CBC compared with 4445 (4.6%) of 97,112 patients who did not undergo radiotherapy. The absolute increase in CBC risk associated with radiotherapy was 0.5%, 1.3%, and 1.6% in the 10-15-and 20 year actuarial rate, respectively. Randomized trials designed to compare survival between conservative surgery plus radiotherapy versus mastectomy could not demonstrate greater CBC risk in the group of patients irradiated at 10 and 15 years of follow-up. 3DCRT and IMRT improve the relationship between the likelihood of tumor control and the probability of adjacent normal tissue complications. However, these techniques can result in a larger volume of healthy tissue exposed to low doses as well as in higher radiation doses outside the beam [2]. Besides, the radiation dose delivered to the contralateral breast may vary according to the technique applied and also increase with the use of physical wedges or cerrobend half-beam blocks.

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The purpose of this study was to measure the scatter dose to the contralateral breast using the conventional two-field technique with motorized wedge and the conformal 3D technique with cerrobend blocks.

2. Materials and Methods:

From March 2005 to December 2006 the dose delivered to the contralateral breast during breast cancer irradiation was measured using two different techniques: the conventional two-open tangential field technique with internal motorized wedge, and the conformal two-tangential 3D technique with cerrobend blocks.

The prescribed dose was 50Gy delivered in 25 fractions. Patients were irradiated with a Elekta SL-18 Linear Accelerator with a 6MV photon beam (TPR_{20,10} = 0.681). The results of the dose to the contralateral breast were expressed as percentages in relation to the dose at the ICRU point [3] [4].

The scatter dose to the contralateral breast was measured with thermoluminescent LiF:Mg, Ti TLD 100 Harshaw dosimeters (TLD). Rods (1x1x6 mm3) and cylinders (1mm in diameter and 6mm in length) were used. Annealing was done at 400°C for an hour. The Glow curve was obtained using a Harshaw TLD 4000B automatic Reader, with a heating plate in N atmosphere. The reading ramp adopted was preheated at 90°C for 5 sec. The thermoluminescent signal acquisition stage ranged from 90°C to 290°C in 40 sec without post-reading annealing. The Glow curve analysis was performed with GCA-New v3.0 Ciemat software. The dose was determined using the area below peaks 4 and 5. TLDs were calibrated in PMMA solid phantom under conditions as expressed in the reference [5].

The present work was divided in three parts. 1) characterization of the radiation field that reaches the contralateral breast outside the treatment beam; 2) determination of the typical dose for each beam and each technique, and 3) design and construction of a shield to reduce the scatter dose.

2.1 Characterization of the radiation field to the contralateral breast

Four patients weighing between 60 and 70 Kg and with average size breast were selected for this first stage of the study. They were informed that during the radiation fraction to the treated breast a dosimeter would be placed to measure the dose to the contralateral breast. These measurements were made at a site similar to the point of intersection of the skin with the beam axis, as done on the treated breast. Two dosimeters were placed at this site, one to determine the dose delivered by the lateral field, and the other to estimate the dose from the medial field. The dosimeter was made using a PMMA cylindrical device measuring 5mm in radius and 40 mm in length. A 1mm wide orifice was pierced along the axis of the device, where five aligned cylindrical TLDs were placed. The number of TLDs was chosen in order to reduce uncertainty and to evaluate the homogeneity of the dose along the dosimeter. This cylinder was introduced into PMMA containers which had several external radii and a central perforation measuring 5mm in radius. Cylinders with external radii of 7, 9, 10, 11, 12, 15, and 17 mm were used to determine the radiation penetration. In addition, three dosimeters were placed in a 0.2mm thick polyethylene blister to determine the dose to the surface.

2.2 Determination of the dose to the opposite breast

In order to evaluate the dose range received by the opposite breast, 42 patients presenting the above described characteristics were selected, 29 of whom were treated with conventional technique and 13 with 3D CRT technique.

The scatter dose was measured on the surface of the contralateral breast during irradiation from the medial field using a dosimeter made up of three cylindrical TLDs placed 5cm from the medial line. A similar dosimeter was placed on the same site during irradiation from the lateral field using both irradiation techniques.

2.3 Design of a contralateral breast shield

A 3D standard treatment was reproduced in a phantom, and dose measurements were repeated under the same conditions already described for the beam characterization. A PTW 31003 ionization chamber with a PTW UNIDOS electrometer was placed to anticipate possible dose fluctuations.
A total of 10 lead sheets measuring 200 x 200 x 2mm3 were placed over the dosimeters on a supporting frame 20 mm above the phantom to attenuate the radiation from the accelerator head to the opposite breast without blocking the treatment beam. These 2mm thick sheets were superimposed one by one, until a 20 mm thickness was reached.

3 Results

3.1 Radiation field to the contralateral breast.

The scattered irradiation received by the opposite breast in the first four patients had different characteristics, depending on whether it came from the medial field or from the lateral field. The results obtained under all measurement conditions for the four patients are shown in Fig. 1. Dose percentages are related to the dose at the ICRU point.

Figure 1: a) Percentage of prescribed dose to the opposite breast delivered by the lateral field as a function of dosimeter radius for each patient. b) Percentage of prescribed dose to the opposite breast delivered by the medial field as a function of dosimeter radius for each patient.

The surface dose from the lateral field proved to be of the same order of magnitude as the depth dose (Fig 2a). Concerning radiation from the medial field, the maximum dose, which decreased with depth to 10mm, was measured on the surface (Fig 2b). At greater depth the dose remained practically constant.

Table 1 shows the sum of the doses on the surface and in depth delivered to the opposite breast of each patient from the two fields. Based on these results, a factor \( f_{sp} \) was determined which relates the dose measured on the surface and the dose measured at depths greater than 10mm (weighted average factor of 0.77)

<table>
<thead>
<tr>
<th>Patient N°</th>
<th>Depth Dose %</th>
<th>Surface Dose %</th>
<th>( f_{sp} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.84 ± 0.06</td>
<td>1.04 ± 0.06</td>
<td>0.80 ± 0.10</td>
</tr>
<tr>
<td>2</td>
<td>2.00 ± 0.20</td>
<td>2.70 ± 0.50</td>
<td>0.70 ± 0.20</td>
</tr>
<tr>
<td>3</td>
<td>2.40 ± 0.08</td>
<td>3.10 ± 0.10</td>
<td>0.77 ± 0.05</td>
</tr>
<tr>
<td>4</td>
<td>2.10 ± 0.30</td>
<td>2.80 ± 0.30</td>
<td>0.80 ± 0.20</td>
</tr>
</tbody>
</table>
3.2 Dose measured in the contralateral breast

Using the conventional technique, the mean dose to the contralateral breast was 2.09, that is, 4.18% (2.9%-19%) of the 50Gy prescribed dose. The contribution of the medial field was 3.36% (2.3%-21.1%) and that of the lateral field was 0.86% (0.4%-3.7%). However, with 3DCRT technique the average dose to the contralateral breast was 5.9Gy, that is, 11.8% (7.9%-24%) of the prescribed dose, the medial field contributing 10.3% (6.7%-20%) and the lateral field 1.6% (1.1%-3.8%).

3.3 Construction of a contralateral breast shield

Figure 2 shows that a mass thickness of 2.3 g/cm of Pb may attenuate 80% of the dose received by the opposite breast. A tiny reduction of the dose with larger mass thickness was observed.

In view of these results, a 2.3 g/cm2 thick, 200mm long, 150mm wide lead shield with a 0.2 g/cm2 thick wax coat shield was constructed with the intent of protecting the opposite breast.

**Figure 2:** Percentage of attenuation as a function of thickness shield

![Attenuation graph](image)

Figure 3 shows the results of measurements with a shield for the contralateral breast in 7 patients treated with 3D-CRT.

**Figure 3:** Dose percentage received by the contralateral breast with and without shield

![Dose graph](image)
4 Discussion

In agreement with Starrkchall, [6] we observed that in the characterization of the radiation field outside the treatment beam measured at 10 cm from the median line on the opposite breast, for 6MV the dose reaches its maximum value on the surface and then decreases with depth. These results do not agree with Frass’s findings [7] who observed that the dose decreases with depth, drops to a minimum and then increases again.

In the present study the dose received by the contralateral breast is higher from the medial field in comparison with that from the lateral field. These results are in accordance with those reported by Tercilla [8], who found that the dose received by the contralateral breast was 3 to 5 times higher from the medial field of a cobalt beam than from the lateral field. Conversely, Yaparpalvi [9] stated that during phantom measurements for an open beam, the contribution of both medial and lateral fields to the opposite breast was almost identical.

In this work we observed that the contribution of the scatter dose to the contralateral breast from the lateral field was 0.86% (0.4%-3.7%) with conventional technique, and 1.6% (1.1%-3.8%) with 3DCRT, regardless of which treatment technique had been used. On the contrary, the contribution of the medial field was a dose lower than 5% using the conventional technique, and of 6% to 20% with 3DCRT.

Boice [10] undertook a retrospective study between 1935 and 1982 on irradiated breast cancer patients. He estimated that the median radiation dose to the uninvolved breast was 2.82 Gy (max 7.10 Gy). Similarly, we observed that the mean dose to the opposite breast was 2.09 with conventional technique and 5.9 Gy with 3DCRT. Yaparpalvi measured the scatter dose to the contralateral breast in 11 patients at a distance of 5cm from the medial tangential field edge. He found that this dose varied between 4.9 and 10.5% of the therapeutic daily dose from the tangential fields plus 1% of the prescribed daily dose from the supraclavicular or axillary fields, if included.

On measuring the radiation to the contralateral breast delivered by the medial field, we found differences between the two techniques. We observed that this field contributed 80% of the total scatter dose with the conventional technique and 87% when using 3DCRT with cerrobend blocks.

With reference to the effect of the scattered beam produced by a modifying agent, Sohn [11] performed measurements on 10 patients and on an anthropomorphic phantom. He observed that the scattered dose received by the uninvolved breast from a field without wedge is 2/3 lower than the radiation from a field with wedge, and that the main contribution is from the medial field (70-75%). With a prescribed dose of 50 Gy and medial wedge, the mean scattered dose to the opposite breast was 5.3 Gy compared to 3.8 Gy without medial wedge. In the studies Chang [12] conducted to compare standard irradiation techniques to the breast with the IMRT technique, he observed that the conventional technique with two tangential fields and physical wedge as well as IMRT with compensator (4.3% and 4% of the prescribed dose respectively) contributed to the highest scatter dose as compared to the other techniques without compensators. His studies also revealed that the lowest dose to the contralateral breast was delivered when using the IMRT technique with MLC (2.1%) and the technique with virtual wedge (2.3%) respectively.

When we used the conventional technique with motorized wedge, the scatter dose to the contralateral breast was 4.18% of the prescribed dose, in agreement with the scatter dose detected by Chang with techniques using wedge filters or compensators. But the amount of scattered dose delivered with 3DCRT plus cerrobend blocks was remarkably higher when compared to the above described wedge filters and compensators, 11.8% of the prescribed dose. Our results are similar to those obtained by Kelly [13] who used a RANDO phantom to measure the dose received by the opposite breast at various locations, and to compare several radiation techniques. This author found that the use of half beam cerrobend blocks with a physical wedge, and of a half beam cerrobend block alone, delivered 8% and 7% respectively of the prescribed dose to the contralateral breast, while the asymmetric collimation technique only contributed 3% of therapeutic dose. This is mainly due to the difference between the cerrobend block transmission and the collimator transmission.

At this point, we might suggest that, unlike an open field, the use of physical wedges, cerrobend blocks or compensators increases the scatter dose to the opposite breast; therefore, protection to the contralateral breast is necessary when 3DCRT plus cerrobend is used.

Macklis [14] developed a lead shield of 2.5 cm thickness for the uninvolved breast. This polystyrene coated shield filters high and low energy photons and reduces 60% of the dose to the contralateral
Sohn proposed a similar design but mounted on a base. This latter protection reduces the dose received by the contralateral breast to 2% of the prescribed dose (1Gy throughout the treatment). With the use of varying lead thickness we noticed that 2mm of lead coated with 2mm of wax reduced 80% of the dose, while by increasing the lead thickness to 20 mm, the dose was reduced by 90%, that is, only 10% more with lead 10 times thicker, which would make it impossible to lay this heavy shield on the breast surface. These results are compatible with Goffman [15] who showed that 1-2mm of Pb dramatically increased the protection effect, in contrast to a slight increase with thickness above 2mm. By using the shield we propose it would be easier to block the low energy electrons and photons, the major contributors to the contralateral breast dose, resulting in a reduction of 2.4%, that is, 1.2 Gy for the 50Gy prescribed dose. This dose can be compared to the lowest contralateral breast dose produced using the IMRT with MLC and virtual techniques, as reported by Chang et al. In conclusion, the use of cerrobend blocks increased the dose to the contralateral breast, the highest dose being delivered by the medial field. On the other hand, the 2mm thick lead shield reduced the dose and therefore the risk of radiation-induced cancer, thus allowing the regular use of 3DCRT with cerrobend blocks. The use of this contralateral breast shield in our institution proved comfortable for the patients and easy to position for the therapists.

REFERENCES