Radiation Doses to Contralateral Breast During Irradiation of Breast Cancer

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Abstract

Aims: External beam radiotherapy is being used regularly to treat the breast malignancy postoperatively. The contribution of collimator leakage and scatter radiation dose, as well as the dose of the treatment fields, to contralateral breast is of concern because of high radio sensitivity of breast tissue for carcinogenesis. This becomes more important when the treated cancer breast patient is younger than 45 years and therefore the contralateral breast must be treated as organ at risk. Quantification of contralateral dose during primary breast irradiation is helpful to estimate the risk and reduce scatter dose to the contralateral breast.

Materials and Methods: In present study contralateral breast dose was measured in 30 cancer breast patients undergoing external beam therapy. Postoperative radiotherapy was delivered by medial and lateral tangential fields daily, in addition to supraclavicle field with 200cGy/F to a total dose of 5000cGy in 25 fractions. A themoluminescence dosimeter chips were employed for these measurements. TLD chips were put on the surface of skin of contralateral breast, on the level of nipple, with and without shield, TLD chips were removed and measured for dose after 2h on Harshaw reader 5500.

Results: The dose at the contralateral breast nipple measured by TLD chips and it was between 4.5 and 17% of the total primary breast dose which is 5000cGy in 25 fractions. Further it was observed that the maximum contribution of contralateral breast dose was due to medial tangential half blocked field (in Kds2). Dose was reduced to one third of the scatter dose to the contralateral breast using 2mm of lead shield and some modifications in the treatment technique.

Conclusion: Thermoluminescence dosimetry is quite easy, accurate and convenient method to measure the contralateral breast dose. Reduction in unwanted scatter dose to the contralateral breast is in accord with the philosophy of keeping radiation exposure as low as reasonably achievable and might be of most benefit for young patients.

Key Words: Breast cancer – Radiotherapy – Breast dose – TLD.

Introduction

DURING external beam therapy of malignant breast, the contralateral breast receives radiation due to leakage from collimator and scatter from primary. Breast is highly radiosensitive tissue for radiation induced second malignancy and is of more concern for female younger than 45 years of age receiving radiotherapy for breast malignancy. Boice et al. [1] have reported that incidence of radiation induced breast cancer is a linear function of dose received by the contralateral breast and the latent period is over 10 years. Several investigators [2,3,4] have measured the contralateral breast dose either on Alderson female phantom/Rando phantom and on actual patients and observed that the scatter dose to contralateral breast during medial tangential and supra clavicle field is quite high and some times of the order of 500cGy for 5000cGy primary breast dose. The quantification of the contralateral breast especially during treatment of diseased breast by external beam is very important, as the scatter contribution will be more. In present study measurement of contralateral breast dose is done using thermoluminescence chips because of small size, very high sensitivity ability to record very small doses and energy independent response for energy in the range of our study (4, 6 and 10MeV), its many other advantages were reported by author elsewhere [4,6].

Scatter dose can be reduced by choosing a proper treatment technique. Kelly et al. [4] compared four commonly used techniques and showed that a half-field technique implemented with independent jaws yielded the lowest contralateral doses. Frass et al. [2] argued that use of thick layers of lead is necessary for effective protection of the contralateral breast: Use of a 2.5-cm layer of lead reduces the dose to the deep contralateral breast tissue by a factor of three, which, of course, poses practical problems. At breast radiation therapy, tangential fields and, if used, the anterior supraclavicular field contribute to contralateral scatter...
dose. Little can be done to reduce the dose from the lateral tangential field because the dose is caused by internal body scatter. On the other hand, dose from the medial beam is about three to five times higher than that from the lateral beam [3]. The dose contributions from the medial tangential and supraclavicular fields originate in the collimator and its accessories. In this study we describe a method with which to measure and reduce the low-energy component of this unwanted dose with relatively simple means.

The scatter dose to the contralateral breast varies with treatment technique. It has been shown [6,7] that the dose to the medial part of the contralateral breast can be reduced considerably when the deep edges of the tangential fields are aligned. We conducted measurements with thermoluminescent dosimeters (TLDs) in 30 patients who received tangential breast or chest-wall irradiation with this technique on either Primus accelerator (Siemens Medical Systems, Iselin, NJ) or a Kds2 accelerator (Siemens Medical Systems, Iselin, NJ).

Patients and Methods

Patient measurements:

A target dose of 5000cGy was delivered in 25 fractions, in an isocentric technique, followed by a boost dose of 1000 up to 2000cGy (2cGy per fraction), delivered with electrons of suitable energy, to the tumor bed. Among the thirty patients in this study, twenty four patients were treated with opposing tangential fields only, six were treated with a matching supraclavicular field and a required an additional internal mammary field with electrons to avoid excessive lung irradiation. Patients were treated with 6-MV photons from Kds2 accelerator, or with 4MV and 10MV from Primus accelerator. The major achievement of our technique is the reduction of exposure of the contralateral breast to scatter radiation by alignment of the deep edges of the tangential beams. The supraclavicular field is a half-field to optimize matching with the aligned cephalic borders of the tangential ports. On the Primus accelerator, the multileaves defined the half-field; on the Kds2, a half-field block was used. A lead sheet, which are 2mm thick is used to reduce the scatter dose.

The precalibrated thermoluminescent dosimeters (TLDs) were used to measure scatter radiation to the uninvolved breast in the 30 patients who received tangential breast or chest-wall radiation with a technique in which the deep edges of the tangential fields were aligned. In most patients, measurements were made during the 1st week of radiation therapy. For each dose measurement, two TLD chips (LiF, 3.0 X 3.0 X 0.9mm) were wrapped in thin plastic foil and placed on the patient’s skin on the contralateral breast, at the nipple (measured along the skin surface).

For each measurement, TLD chips were selected with a relative sensitivity variation of less than ±3%. TLDs were read two hours after exposure on a 5500 TLD system (Harshaw/Filtrol Partnership, Cleveland). The readings from the two chips were averaged.

Phantom measurements:

To investigate in a systematic manner how the scatter dose is influenced by the kinds of accelerator, wedge and beam energy that are used, we performed the following in-phantom measurements:

1. Scatter dose outside open and wedged field:
   Surface doses at various distances from the geometric field edge of a 15 X 15-cm field for different energies and wedge angles, were measured with a thin-window parallel-plate chamber (Markus; Physikalisch-Technische Werkstätten, Freihurg, Germany) in a solid water phantom (RMI 457; Radiation Measurements, Middleton, Wis). For this purpose, the surface of the chamber was placed at the appropriate distance from the source and all readings were normalized to a reading obtained with the chamber at the center of the respective field at the depth of maximum dose buildup (1.5cm for 6-MV X-rays and 1cm for 4-MV X-rays and 2.5cm for 10MV).

2. Influence of source to skin distance: In our study group of patients, the steepest medial gantry angle was 42 degrees, measured from the vertical; the shallowest angle was 69. A field arrangement was used throughout [ 15 x 15-cm ² field size, 55 degrees gantry angle (measured from the vertical)], with use of wedges of varying angles and other parameters to measure the scatter dose with source to skin distance (Table 2).

Results

Measurements made during treatment:

Table (1) summarizes the results of our TLD measurements. For most patients the scatter dose to the medial aspect of the contralateral breast was 4.5%-17% of the therapeutic dose delivered. The medial gantry angle seems to have had an influence. As will be shown below, the higher energy is responsible to some degree for such a high scatter.
dose. More significant are the protruding shape and large volume of these patients’ breasts, which placed the surface of the contralateral breast relatively close to the edge of the medial tangential field. Fraass et al. [6] showed that scatter dose decreases with increasing perpendicular distance from the geometric field edge. For a large, protruding breast and shallow medial gantry angle, this distance is shorter than for a shallow, small breast and steep medial gantry angle.

Table (1): Measurement of surface dose to contralateral breast at the nipple with and without shield to the contralateral breast.

<table>
<thead>
<tr>
<th>Patient no.</th>
<th>Field arrangement</th>
<th>Accelerator</th>
<th>Energy (MV)</th>
<th>Wedge angle</th>
<th>Dose to contralateral breast/fraction in cGy</th>
<th>Dose with shield (2mm Pb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mastectomy</td>
<td>4</td>
<td>T</td>
<td>Primus</td>
<td>4</td>
<td>15</td>
<td>9.1</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>T</td>
<td>Primus</td>
<td>4</td>
<td>30</td>
<td>12.9</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>T</td>
<td>Primus</td>
<td>4+10</td>
<td>30</td>
<td>17.1</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>T+S</td>
<td>Primus</td>
<td>10</td>
<td>30+15</td>
<td>19.1</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>T</td>
<td>Primus</td>
<td>10</td>
<td>45+30</td>
<td>29.1</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>T</td>
<td>Primus</td>
<td>10</td>
<td>30</td>
<td>15.4</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>T</td>
<td>Kds2</td>
<td>6</td>
<td>15+30</td>
<td>21.2</td>
</tr>
<tr>
<td></td>
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<td>T+S</td>
<td>Kds2</td>
<td>6</td>
<td>30</td>
<td>15.6</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>T+S+I</td>
<td>Kds2</td>
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<td>30</td>
<td>33.8</td>
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<tr>
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<td>T</td>
<td>Primus</td>
<td>4</td>
<td>30</td>
<td>7.8</td>
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<tr>
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<td>Kds2</td>
<td>6</td>
<td>30</td>
<td>17.1</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>T+S</td>
<td>Primus</td>
<td>10</td>
<td>15</td>
<td>9.8</td>
</tr>
</tbody>
</table>


The observed difference between machines in doses outside the treated area was due mainly to difference in design. The scatter doses outside the treated area were generally twice as high on the Kds2 as on the Primus (except for 10MV). Table (2) lists scatter doses at 10cm outside the geometric field edge for open and wedged fields with and without a block tray (in Kds2).

The scatter dose increases with wedge angle (Table 2) and is higher for the Kds2 than for the Primus accelerator (except for 10MV).

Table (2): Scatter surface dose at 10cm outside field for open and wedged field 15x15cm at 100cm SSD.

<table>
<thead>
<tr>
<th>Accelerator/energy</th>
<th>Open field</th>
<th>15 degree</th>
<th>30 degree</th>
<th>60 degree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kds2 (6MV)</td>
<td>5.2</td>
<td>5.4</td>
<td>5.7</td>
<td>6.7</td>
</tr>
<tr>
<td>Primus (4MV)</td>
<td>4.1</td>
<td>4.3</td>
<td>4.7</td>
<td>5.8</td>
</tr>
<tr>
<td>Primus (10MV)</td>
<td>8.3</td>
<td>8.8</td>
<td>9.2</td>
<td>11</td>
</tr>
</tbody>
</table>

Fig. (1) shows the scatter doses in the phantom at a distance of 10cm, measured horizontally from the beam edge for gantry angles of 55 degrees and a 15 X 15-cm field at different source skin distance and for open and different wedged fields, which indicates the gantry angle, also the patient size. The recorded doses increased with gantry angle, because the perpendicular distance of the measurement point from the geometric beam edge decreases with increasing gantry angle. The recorded doses increased also with wedge angle, this was due to scatter radiation generated in the wedge material. These measurements demonstrate that a patient treated with a shallow medial gantry angle and a thick wedge will receive a considerably higher dose to the contralateral breast than a patient treated with a steep medial gantry angle and no wedge. This effect is enhanced for a large, protruding breast.

The medial gantry angle is influenced to some extent by the separation between the medial and lateral entry points of the opposing tangential fields. A large separation may not only imply a shallow medial gantry angle, it also means a reduced distance between source and skin for an isocentric technique.

Large field separations are found in obese patients, who often have large breasts that may require higher energies for adequate treatment. One can therefore expect higher contralateral breast doses for these patients.

Fig. (1): Scatter dose for open field ($y_1$) and 30 degree wedge field ($y_2$) for 4MV and 30 degrees wedge field with half beam blocs ($y_3$) for 6 MV at 10cm outside the field as a function of source to skin distance.
Among the 30 patients in our study, the surface doses recorded at the nipple of the contralateral breast ranged from 4.5% to 17% of the prescribed dose. An attempt was made to explain this wide range of doses by performing in-phantom measurements. We found that the following factors are likely to increase the dose to the contralateral breast:

- A short perpendicular distance from the contralateral breast surface to the geometric beam edge increases the dose at the surface. A short perpendicular distance can be caused by a shallow medial gantry angle or a large, protruding breast. A combination of both is the least favorable. Almost all tangential fields are wedged to achieve optimal dose uniformity throughout the breast tissue.

- A large, thick wedge will generate more-and harder-scatter radiation than a small, thin wedge. To minimize the dose to the contralateral breast, it is therefore desirable to use the smallest wedge angle possible.

- It is observed that the contribution to contralateral breast dose due to all the fields. The contribution due to the medial tangential field is almost twice as that due to lateral tangential field. The lateral tangential fields enters laterally and may be contributing to internal scatter, which is very difficult whereas the medical tangential field is close to the contralateral breast and hence the scatter and the collimator contribution is more.

Only thin layers (2mm) of lead are needed to shield against such low-energy radiation. Use of additional lead has little effect on further dose reduction at the surface or at depth. With reasonable means, therefore, scatter dose can be reduced to the superficial layers of breast tissue, which is worthwhile because scatter dose decreases rapidly with depth [4].

Some authors [6,11] propose to use wedging for the lateral tangential field only. The obtained dose distributions, however, may be less homogeneous. Finally, scatter dose is dependent on accelerator design and beam energy selected for treatment. The choice here, however, will usually be dictated by accelerator availability and adequacy of beam penetration. Fraass et al. [6] suggested protecting the contralateral breast with a lead shield 2.5cm thick. This may be cumbersome and not always feasible. A simpler way to shield the contralateral breast might be to tape it down once the setup is complete.

Many researchers have reported the contralateral breast dose; some reported results of direct measurement on patient, some reports measurement on phantom and some gave the figures from calculation. Boice et al. [8] have conducted case control study in cohort of 41,109 women diagnosed with breast cancer and analyzed the records. They found mean contralateral breast dose to be 282cGy with maximum of 710cGy and relative overall increase in risk of contralateral breast malignancy due to treatment of primary by radiation to be 1.19. However the risk of second malignancy in contralateral breast was 1.59, significantly high, in patients who underwent radiotherapy at younger age than 45 years for primary breast malignancy. This indicates high risk for younger patients.

Kelly et al. [4] reported a study of evaluation of four different breast treatment techniques with 6MV linac beam to compare the radiation dose to the contralateral breast. They have done the dose measurement on Rando phantom using TLD and used four different techniques of half beam with custom blocks, half beam using asymmetric collimator jaw, half beam using asymmetric collimator jaws with custom blocks and isocentric technique with non divergent posterior border. They observed higher contra lateral breast dose during medial field with wedge and lowest dose with asymmetric jaws and no medial wedge or block. Bhatnagar et al. [9] reported comparison of contralateral breast dose during primary breast irradiation using intensity modulated radiotherapy (IMRT) and conventional tangential field technique. They have treated 36 patients of breast malignancy with IMRT and 8 with 3-D technique using tangential fields with wedge and measured contralateral breast dose during treatment using TLD. They observed the contralateral breast dose of 7.74±2.35% of primary breast dose (5000cGy) in IMRT treatment planning and 9.74±2.04% of primary breast dose during conventional tangential field technique i.e., about 20% reduction in contralateral breast dose with IMRT as compared to conventional tangential treatment with wedge.

Muller-Runkel et al. [12] have advocated covering of contralateral breast with thin lead sheet to reduce the scattered contribution to contralateral breast skin though little can be done to reduce the dose from the lateral tangential field as the dose is caused by internal body scatter. They used 4mm thick commercially available vinyl coated flexible lead shield containing lead powder of 1mm equivalent lead density to cover the contralateral breast and found that the contralateral dose is reduced by 3-fold from 15% to 5% [13,14].

Discussion

Among the 30 patients in our study, the surface doses recorded at the nipple of the contralateral breast ranged from 4.5% to 17% of the prescribed dose. An attempt was made to explain this wide range of doses by performing in-phantom measurements. We found that the following factors are likely to increase the dose to the contralateral breast:
Conclusions:

Scatter dose from the medial tangential field to the contralateral breast originates in the accelerator head and its accessories. This radiation is composed mainly of low-energy X rays and electrons. Therefore, only thin absorbers are needed to achieve an effective reduction in unwanted dose. By shielding the contralateral breast with one layer of lead of 2-mm during breast radiation therapy, we achieve a considerable reduction in dose to an approximately one third, which is in accord with the philosophy of keeping mediastion exposure as low as reasonably achievable.

Dose to the contra lateral breast as a result of radiotherapy of breast should not be ignored in radiotherapy and more so in patients younger than 45 years. The breast tissue is highly sensitive and therefore the contralateral breast must be regarded as organ at risk (sensitive organ) while planning for radiotherapy.

Themoluminescence dosimetry is very easy, most convenient and reasonably accurate method to measure the dose to contralateral breast.

References