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Comparison of Chest Wall and Lymphatic Radiotherapy Techniques in Patients with Left Breast Carcinoma

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ABSTRACT

Objective: The aim of this study was to find the most appropriate technique for postmastectomy chest wall (CW) and lymphatic irradiation.

Materials and Methods: Partially wide tangent, 30/70 photon/electron mix, 20/80 photon/electron mix and CW and internal mammary en face electron field, were studied on computerized tomography (CT) scans of 10 left breast carcinoma patients and dosimetric calculations have been studied. Dose volume histograms (DVH) obtained from treatment planning system (TPS) were used for minimal, maximal and mean doses received by the clinical target volumes and critical structures.

Results: Partially wide tangent field resulted in the most homogeneous dose distribution for the CW and a significantly lower lung and heart doses compared with all other techniques. However, right breast dose was significantly higher for partially wide tangent technique than that each of the other techniques. Approximately 0.6-7.9% differences were found between thermoluminescent dosimeter (TLD) and treatment planning system (TPS). The daily surface doses calculating using Gafchromic® external beam therapy (EBT) dosimetry films were 161.8±2.7 cGy for the naked, 241.0±1.5 cGy when 0.5 cm bolus was used and 255.3±2.7 cGy when 1 cm bolus was used.

Conclusion: As a result of this study, partially wide tangent field was found to be the most appropriate technique in terms of the dose distribution, treatment planning and set-up procedure. The main disadvantage of this technique was the higher dose to the contralateral breast comparing the other techniques.

Key words: Breast cancer, treatment, techniques, dosimetry, radiation

Introduction

Chest wall (CW) and lymphatic irradiation in postmastectomy radiotherapy constitute one of the most challenging treatments in radiation oncology. Different target volumes in different planes and the close proximity of the critical structures, such as lung, heart, and spinal cord, make the treatment highly complicated in terms of planning and administration. Several studies with various treatment planning techniques showed the importance of conformal therapy planning (1-6). Three-dimensional (3D) treatment planning allows estimation of the dose distribution of target tissues and normal structures. To evaluate the actual doses of target volumes and critical structures, a thermoluminescent dosimeter (TLD) and Gafchromic™ external beam treatment (EBT) dosimetry films (international specialty products manufacturer) are used.

In this study, 3D planning is used to compare four different techniques for CW and lymphatic irradiation with respect to target volumes and doses in critical structures in patients with left-sided breast carcinoma. All techniques were also simulated on Alderson rando® phantom using the computed tomography (CT) scans of the phantom. In addition, a certain number of TLDs and Gafchromic™ EBT dosimetry films were placed to the points defined by the treatment planning system (TPS) on Alderson rando® phantom. The primary goal of this study was to define the ideal treatment plan according to the TPS and the dosimetric analysis.

Materials and Methods

The CT scans of 10 patients with left-sided breast carcinoma treated by postmastectomy radiotherapy were used for this study. The target volume [CW, supraclavicular fossa (SCF), level I-II-III axilla, and internal mammary lymphatics] and the normal structures (heart, lung, brachial plexus, spinal cord, right breast, and esophagus) were contoured on the CT scans by a single radiation oncologist (F.Y.), and 3D conformal treatment planning for four treatment techniques (partially wide tangent, 30/70 photon/electron mix, 20/80 photon/electron mix, and CW and internal mammary en face electron field) was planned for each patient (3-6). The partially wide tangential technique uses unique tangential fields that cover both CW and internal mammary lymphatics. In the mixed 30/70 photon and electron beam

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technique, CW is irradiated with photons by separate tangential fields, and internal mammary lymphatics are irradiated with parallel photon beams in 30% of the treatment and electron beams with the appropriate energy in 70% of the treatment. The mixed 20/80 photon and electron beam technique is the same as the 30/70 photon/electron mix technique, apart from their different percentages of combination (20% photon and 80% electron). In the en face CW and internal mammary electron field technique, the CW and internal mammary chain are irradiated with only electron fields. All dose-volume histograms (DVHs) obtained from different treatment techniques were evaluated for target volumes (CW, internal mammary, SCF, level I, level II, and level III) and critical structures (heart, lung, right breast) separately. When electrons were used for treatment, the appropriate energy was chosen as the 90% isodose surface that reached the anterior pleural surface.

Pursuant to the treatment planning used in the TPS, an individual simulation was done in Alderson rando[R] phantom for each technique. Field borders were defined, and CT markers were placed to delineate margins. The CT scans of Alderson rando[R] phantom were transferred to the TPS, and treatments were planned with 4 different techniques. After the determination of treatment fields in rando phantom, TLDs thought to represent the SCF, axilla, and internal mammary were put on certain depths. Additionally, the TLDs were several points that were thought to represent the right breast, CW, lung, and heart. In order to determine surface doses, Gafchromic™ EBT dosimetry films were placed on the CW and right breast with either 0.5 or 1 cm tissue equivalent bolus material or as naked. In this way, three different measurements were taken for each plan. Precise, version 2.15 was used for this study (Elekta Oncology Systems Ltd, Crawley, UK). TLD and Gafchromic™ EBT dosimetry films were calibrated before treatment.

Statistical Analysis

All statistical analysis was performed using SPSS, version 15.0 (SPSS, Chicago, Illinois). Plan evaluation parameters were chosen for each structure, and the same parameters were used to evaluate all plans. Forty different DVHs were calculated for all target volumes, including the CW, SCF, axilla, and internal mammary chain and normal structures. For evaluating the homogeneity of dose distribution, DVHs were calculated for each target volume and critical structures in all plans. The minimal dose, maximal dose, and mean doses were obtained, and standard deviations were defined. Friedman test was used for comparison. P-value <0.05 was considered significant. The mean values obtained from the TLD and Gafchromic™ EBT dosimetry films and standard deviations were compared to the doses of the same points in the TPS.

Results

The minimal, maximal, and mean doses ± standard deviations in target volume obtained from different treatment plans were specified and are presented in Table 1. No differences could be observed among the four techniques for mean and maximal doses of CW. However, the CW and internal mammary en face electron field technique resulted in a significantly lower minimal dose compared to other techniques (p=0.002). Again, this technique was inadequate for delivering effective doses to the internal mammary and axillary lymphatics (Table 1). Partially wide tangent fields provided significantly lower maximal dose to the internal mammary chain compared to the other three techniques (p=0.001). Similarly, dose homogeneity for the partially wide tangential technique was significantly better than all the other techniques (p=0.005). Again, no differences could be observed in dose distribution of SCF lymph nodes among the different techniques.

Table 1. The minimal, maximal, and mean doses ± standard deviations in target volume obtained from different treatment plans

Techniques	CW min. dose	CW max. dose	CW mean dose	IM min. dose	IM max. dose	IM mean dose	Level 1 min. dose	Level 1 max. dose	Level 1 mean dose	Level 2 min. dose	Level 2 max. dose	Level 2 mean dose	Level 3 min. dose	Level 3 max. dose	Level 3 mean dose
	cGy± SD	cGy± SD	cGy± SD	cGy± SD	cGy± SD	cGy± SD	cGy± SD	cGy± SD	cGy± SD	cGy± SD	cGy± SD	cGy± SD	cGy± SD	cGy± SD	cGy± SD
Partially wide tangent	4557.8± 107.3	5881.9± 241.4	5124.7± 132.7	4653.1± 193.6	5427.9± 192.9	5093.7± 141.1	4553.6± 58.8	5736.0± 299.9	5077.7± 161.6	4587.8± 58.4	5464.7± 322.3	5007.2± 167.8	4652.0± 110.0	5507.4± 231.4	5039.0± 139.5
30/70 photon/electron mix	4502.6± 83.1	6214.2± 347.4	5189.6± 104.5	4520.0± 45.7	6159.3± 186.2	5502.6± 129.2	4628.1± 71.8	5814.3± 154.0	5103.9± 101.1	4723.1± 104.2	5562.9± 107.2	5054.6± 87.4	4745.8± 132.2	5552.8± 240.7	5065.0± 90.2
20/80 photon/electron mix	4429.6± 128.9	6094.2± 120.0	5138.6± 121.9	4536.0± 21.7	6217.3± 383.5	5516.7± 246.5	4664.0± 114.1	5837.7± 214.5	5120.0± 115.6	4754. 3±88.4	5574.4± 132.9	5092.0± 90.2	4767.8± 85.3	5514.1± 208.9	5099.0± 89.4
CW-IM only electron	4085.3± 491.0	6026.6± 783.7	5340.0± 403.4	3809.3± 733.7	6199.9± 401.2	5364.2± 386.4	3118.8± 1367.9	6437.8± 393.1	5033.0± 316.8	3400.1± 1470.7	6151.2± 413.0	4943.3± 395.4	4047.0± 946.9	6092.0± 354.0	5100.7± 206.2
p value	0.002	0.163	0.62	0.01	0.001	0.002	0.003	0.017	1	0.006	0.001	0.782	0.056	0.003	0.696

CW: Chest wall; IM: internal mammary; min.: minimum; max.: maximum; SD: standard deviation

When comparing techniques for heart doses, it was observed that the heart dose in partially wide tangent fields was significantly lower than in the other techniques (Table 2). This difference was highly significant when compared with the 20/80 photon/electron mix and CW and internal mammary en face electron field.

The partially wide tangent field technique resulted in lower mean lung dose, the percentage lung volume receiving more than 20 Gy (V20), and mean left lung dose compared with the other techniques (Table 3). Partially wide tangent fields resulted in the lowest mean dose (919.8±84.6 cGy), and CW and internal mammary en face electron field resulted in the highest (1209±128 cGy) mean dose for whole lungs. Similarly, partially wide tangent fields resulted in the lowest mean dose (1831±176 cGy), and the en face CW and internal mammary electron field technique resulted in the highest (2374±298 cGy) mean dose for left lung.

As shown in Table 4, partially wide tangent fields produced significantly higher right breast doses than all other techniques ($p<0.001$).

Thermoluminescent dosimeter dose calculations in certain points representing the SCF, axilla, internal mammaria, CW, and critical normal structures were compared with the dose calculations obtained from TPS. In the partially wide tangential technique, the difference between TLD and TPS was 0.1%-6.4%. The corresponding comparisons for the 30/70, 20/80, and en face CW and internal mammaria electron field techniques were 0.5%-5.9%, 0.4%-7.9%, and 0.1%-6.1, respectively. The surface doses in the partially wide tangential technique found by EBT films were 161.8±2.7, 241.0±1.5, and 255.3±2.7 cGy with no bolus, with 0.5 cm bolus, and with 1 cm bolus, respectively.

When we compared the treatment planning and set-up periods for each technique, the partially wide tangent field and CW and internal mammary en face electron fields techniques took 30-45 minutes for planning and approximately 15 minutes for set-up procedures. The treatment planning time of the 30/70 and 20/80 photon/electron mix technique took 4-5 hours, and the set-up time took 30-45 minutes.

Discussion and Conclusions

The aim of this study was to evaluate the best treatment technique in patients with left breast carcinoma in the 3D conformal radiotherapy era. For left CW and lymphatic irradiation, 4 different techniques were chosen and compared according to DVH analysis obtained by TPS and dosimetric analysis using Gafchoromic™ EBT dosimetry films and TLDs.

The description of homogenous dose distribution was announced within the limits of between -5% and +7% according to the International Commission on Radiation Units and Measurements (ICRU) 50 report (7). However, in breast cancer radiotherapy, contour irregularity of CW and clinical target volumes on different depths and planes can frequently cause difficulties in reaching homogeneous dose distribution, as indicated in the ICRU 50 report. Generally, a minimum dose of 4,500 cGy to target volumes is believed to be acceptable. The maximum dose, on the other hand, is observed to be in the range of ≤120%. In our study, all the techniques except en face electron field to CW and internal mammaria achieved the goal of delivering a minimum of 4,500 cGy to the CW and internal mammaria, and the best homogenous dose distribution of CW was achieved by the partially wide tangent field technique. Similar to our study, Pierce et al. (8) confirmed that the partially wide tangent field was the most suitable technique, providing better coverage of the target volume and sparing the critical structures for CW and internal mammary radiotherapy.

Table 2. V_{10}, V_{30}, and mean doses for heart ± standard deviations and p values

Techniques	Heart V_{10}(%)± SD	Heart V_{30}(%)± SD	Heart Mean Dose (cGy)±SD
Partially wide tangent	11.0±6.3	6.7±5.5	534.7±250.7
30/70 photon/electron mix	20.9±10.2	9.6±4.4	853.7±304.3
20/80 photon/electron mix	31.4±9.3	8.4±4.3	972.8±256.6
CW-IM only electron	30.9±10.2	12.3±7.1	1054.7±369.5
p value	<0.001	0.088	<0.001

CW: Chest wall; IM: internal mammary; SD: standard deviation

Table 4. V_5 and mean doses for right breast ± standard deviations and p values

Techniques	Right Breast Mean Dose cGy±SD	Right Breast V_5 (%) ±SD
Partially wide tangent	126.2±44.4	1.2±1.8
30/70 photon/electron mix	78.6±23.0	0.1±0.3
20/80 photon/electron mix	68.5±24.6	0.1±0.4
CW-IM only electron	27.4±18.5	0.2±0.7
p value	<0.001	0.019

CW: Chest wall; IM: internal mammary; SD: standard deviation

Table 3. V_{20} and mean doses for whole, left, and right lung ± standard deviations and p values

Techniques	Lung V_{20}(%) ±SD	Mean Lung Dose cGy±SD	Mean Left Lung Dose cGy±SD	Mean Right Lung Dose cGy±SD
Partially wide tangent	16.7±1.5	919.8±84.6	1830.9±175.8	101.7±18.7
30/70 photon/electron mix	21.2±2.8	1113.6±138.6	2202.7±291.5	86.8±24.4
20/80 photon/electron mix	18.2±2.4	1019.3±110.3	1991.4±220.5	85.9±28.7
CW-IM only electron	23.4±1.9	1209.6±128.1	2374.2±298.4	128.0±70.3
p value	<0.001	<0.001	<0.001	0.026

CW: Chest wall; IM: internal mammary; SD: standard deviation

Chest wall and internal mammary en face electron field uses electron beams with appropriate energy for CW, internal mammary, and axillary region irradiation. Homogenous dose distribution and optimum coverage of the CW could not be obtained with this technique, since the depth of each volume showed considerable variations with respect to human anatomy. When the energy is selected according to the maximum depth, heart and lung doses become critical. In the literature, it was shown that the differences of beam obliquity and skin-source distance (SSD) resulted in low CW and internal mammary doses (6). The missing dose on the lateral CW is caused by this distance effect. Although a boost dose is suggested by some authors, no recurrence was observed in some reports when the boost dose was not applied to this region (6). In addition, hot dose spots are frequently defined with this technique. It was reported that homogenous and sufficient dose distribution could be obtained for internal mammary and CW because of the absence of axillary lymph nodes in the target volume (6). However, our data showed that both high-dose regions and unacceptable low-dose regions were observed in the CW, axilla, and internal mammary, and the dose distribution was very heterogeneous when en face electron beam fields were used for the CW and internal mammaria. This technique was assumed to be useful when axillary lymph nodes were not irradiated, and the literature showed that it could be as effective as photon beams for CW radiotherapy (9, 10).

The minimal dose of the internal mammary was less than 45 Gy with the CW and internal mammary en face electron field technique, despite the other 3 techniques. On the contrary, it was equal or greater than 45 Gy for the other three techniques. The reason for this difference can be attributed to the deeper localization of the internal mammary chain in some patients. Increasing the electron energy to reach an adequate dose on internal mammary lymph nodes, on the other hand, raised the doses of other target volumes and critical structures, which constituted a disadvantage of this technique. Kirova et al. (6) reported that a more homogenous dose distribution was observed with one unique electron field that included both the CW and the internal mammary chain compared to the standard technique; however, in that special manuscript, the internal mammary lymphatics were irradiated separately with different energies. In this particular study, only 5 CT slices were used, and minimal doses were not given. In our study, on the other hand, CT slices with 0.5-cm intervals covering the whole neck and thorax were used, and axillary lymphatics were also included in the treatment field. The most homogenous dose distribution in our study was provided with the partially wide tangent field for internal mammary chain.

In patients with breast carcinoma, one of the most important points for radiotherapy is minimizing the irradiated heart volume. It is observed that the risk of cardiac morbidity is severely increased when the median heart dose is greater than 35 Gy (11). It is indicated that if the percentage heart volume receiving more than 25 Gy (V25) is less than 10%, cardiac mortality ~15 years after radiotherapy would be seen as less than 1% (12). When the percentage heart volume receiving more than 10 Gy (V10), 30 Gy (V30), and mean heart dose was evaluated, our data demonstrated that the use of the partially wide tangent field resulted in the lowest cardiac exposure. The mean heart dose was found to be 534.7±250.7 cGy, which is significantly lower than the other three techniques. The heart V10 was significantly higher for the 20/80 photon/electron mix and CW and en face electron field technique. On the other hand, another important point for radiotherapy is the decreasing the risk of pneumonia. Pneumonia was rarely seen when lung V20 was less than 30% of the ipsilateral lung (13, 14). In our study, calculated lung V20, mean left lung dose, mean right lung dose, and mean total lung dose were obtained for each technique. The lung V20 and mean left lung dose were lower for the 20/80 photon/electron mix and partially wide tangent field when compared to the other techniques. The highest doses on lung were observed with the CW and internal mammary en face electron field. All our results are consistent with similar studies in the literature (8, 15, 16).

The probability of contralateral breast cancer is higher in patients with breast cancer after breast-conserving surgery than normal counterparts (17). It is important to minimize the contralateral breast dose in order not to increase the secondary carcinoma risk and not to cause side effects, like fibrosis, in healthy breast tissue. The CW and internal mammary en face electron field resulted in the lowest mean dose for the right breast in our study. The percentage of right breast volume receiving more than 5 Gy (V5) was significantly higher for the partially wide tangent field technique and lower for the 30/70 photon/electron mix technique. The main disadvantage of the partially wide tangent field is the higher right breast doses than all other methods. If the right breast is closer to the midline, other techniques rather than the partially wide tangent field are recommended or the right breast should be taken away from the treatment field by some daily immobilization method.

There is a significant correlation between tumor recurrence risk and tumor size, invasion at surrounding tissues, and positive axillary lymph nodes in breast carcinoma (18, 19). Recurrence after modified radical mastectomy is mostly observed at the CW with a frequency of 50% and then at the SCF region after postmastectomy radiotherapy (20, 21). The aim of CW irradiation is to minimize the risk of CW recurrence due to microscopically residual disease and to treat subcutaneous, interpectoral, and intercostal lymphatics sufficiently. In modern radiotherapy, recurrence is generally observed at the superficial part of the CW due to the skin-sparing effect of megavoltage radiotherapy (11, 22, 23). According to a study using photon energy of 6 MV, the surface dose is 15%-40% lower than the prescription dose (24). The surface doses of CW need to be known during the treatment planning process. However, none of the TPSs can estimate the surface dose correctly. Due to the high spatial resolution and low spectral sensitivity, Gafchromic™ EBT dosimetry films are used as an ideal detector for surface dose measurements (24). In our study, surface doses without bolus after the partially wide tangent field were 84%±2.7% by using Gafchromic™ EBT dosimetry films for 6 MV photon beams. It resulted in 120% ± 1.5% and 128%±2.7% with the use of 0.5 and 1 cm tissue equivalent bolus, respectively. In our department, the 7, 11, and 7 technique is used for CW irradiation with 6 MV photon beams: open field for the first 7 days, all CW with 1 cm bolus for the following 11 days, and around the incision scar with 1 cm bolus for the last 7 days. With this technique, the CW skin and scar surroundings receive 50 and 57 Gy, respectively. Thus, dose escalation could be done at the regions with high recurrence risk.

In all techniques, the planned and applied treatments were attempted to be validated after comparing the dose from the TPS and the measurements from the TLD-100H put on the phantom. With the partially wide tangent field for the CW and internal mammary irradiation, the difference between TPS and dosimetric measurements was a maximum of 6.4%. It was determined to be 7.9% with the techniques using a photon/electron mix.

The applicability of the treatment plan becomes as important as providing the best dose homogeneity and sparing critical structures. Set-up errors may cause terrible results, even if the treatment plan is perfectly prepared in the TPS. Additionally, treatment planning time is also important for busy departments. In our study, planning and set-up procedures were significantly shorter for the partially wide tangent field and en face CW and internal mammary electron field techniques. Considering the dose distribution and time required for the planning and set-up procedure, the partially wide tangent field technique is proven to be the best method, especially for the department with high patient load.

In our study, the partially wide tangent field was the most suitable technique for CW and lymphatic irradiation in view of providing homogenous dose distribution for clinical target volume and decreasing lung and heart doses. Compared to the other techniques, easier and quicker planning and set-up were other advantages of this technique. However, the main disadvantage of the partially wide tangent field is higher doses to the contralateral breast, especially when it is located closer to the midline. In these cases, other techniques, rather than the partially wide tangent field, are recommended, or the contralateral breast should be taken away from the treatment field by immobilization in order to prevent secondary carcinomas.

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