3D-CRT Techniques for Simultaneously Integrated Boost in Breast Conserving Radiation Therapy

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Abstract

Aim: To evaluate the dosimetric outcomes of two different three dimensional conformal radiation therapy (3D-CRT) of concomitant boost delivery to the intact breast.

Methods: Ten patients were evaluated using two standard opposed tangents conformal to the whole breast PTV, plus a pair of wedged fields conformal to the boost PTV; all fields have the same isocenter, placed in the whole breast planning target volume (PTV) (WBI) or located in the boost (BI) PTV. Dose Volume Histograms were calculated and analysed for the difference in maximum and minimum doses; also mean doses and volumes receiving 90% and 107% of the prescribed dose. Lung irradiation was analysed in terms of maximum and mean doses.

Results: For breast PTV coverage, significant differences were observed only in the maximum doses (62.3Gy Vs. 61Gy, \(p=0.003\)) and higher Dose Homogeneity Index DHI (0.66 Vs. 0.64, \(p=0.003\)) in favour WBI. For boost PTV coverage, a significant difference between the two techniques with maximum dose (62.6 versus 60.87, \(p=0.003\)) as well the DHI (0.97 Vs. 0.94, \(p=0.002\)) in favour of WBI. The Conformity Index CI was significantly better in WBI (0.87 Vs. 0.64, \(p=0.001\)). Dose to lung or healthy tissue was not statistically significant difference between the two methods.

Conclusion: This study shows a dosimetrical superiority of using the whole breast isocenter technique over boost isocenter technique in whole breast PTV coverage, dose homogeneity index and boost PTV coverage. The clinical significance of this difference needs further clinical studies.

Key Words: Breast cancer – Breast boost – 3D-CRT planning.

Introduction

BREAST conserving surgery followed by external beam radiation therapy has become the standard of care in management of early carcinoma breast. A boost to the tumor bed after whole breast radiation therapy is employed in view of the pattern of tumor bed recurrences in the index quadrant and was particularly considered in patients with some adverse histo-pathological characteristics such as positive margins, extensive intraductal carcinoma, lymphovascular invasion, etc. There is however, now, a conclusive evidence of improvement in local control rates after a boost radiation therapy dose in patients even without such factors and for all age groups. The maximum absolute reduction of local recurrences by the addition of boost is especially seen in young premenopausal patients [1-4].

Traditionally, delivery of this boost dose has been performed sequentially [after completion of the whole breast radiation therapy (RT)]. However, with the implementation of intensity-modulated RT in breast cancer, the simultaneously integrated boost (SIB) technique has also been introduced for breast conserving RT. With this method, the initial planning target volume encompassing the whole breast and the boost PTV are integrated in a single treatment plan. With the SIB technique, patients are treated with the same treatment plan for each fraction throughout the treatment course. In general, a greater dose per fraction is delivered to the boost PTV and the number of treatment fractions is reduced. To date, the SIB technique has only been presented in combination with intensity modulated radiotherapy (IMRT). It seems that with SIB-IMRT, a high level of dose to target conformity can be
obtained. Because the use of a SIB technique has practical advantages (a reduced number of fractions) and, theoretically, a radiobiologic advantage with respect to tumor control (greater dose per fraction and a reduction of the overall treatment time), we decided to perform a planning study in order to establish a 3D-CRT technique [5-7].

The standard method of breast radiation therapy has typically used two opposed tangential photon fields for the whole breast irradiation, followed by a boost to the tumor bed, delivered with different techniques, within a 6-8 week period of treatment. Decreasing the overall treatment time and therefore, the cost/inconvenience to the patient and radiation oncology department is particularly attractive.

The shorter fractionation schedule decreases the use of limited physical and financial resources and increases access for those patients with logistical difficulties. Also, it allows an easier integration with chemotherapy.

The purpose of our study was to retrospectively evaluate the dosimetric outcomes of two different 3D-CRT methods of concomitant boost delivery, using one isocenter in the setting of a concomitant boost technique.

**Material and Methods**

The archived CT scans of 10 patients treated for breast cancer after breast conservative surgery and referred to the Radiotherapy Unit of King Abdul Aziz University Hospital during March and April 2008, five right sided and five left sided, were selected at random for this analytical, dosimetric study.

Both whole breast PTV and boost PTV were drawn by radiation oncologist on the CT dataset. The whole breast PTV included the breast tissue and a margin of 2cm, except on the skin surface. Boost PTV included tumour bed seen in CT cut with 1cm margin all around, except the skin surface if the tumour is superficial (below the skin). The same PTVs were used to design treatment plans for both investigated techniques. Also, anatomic information from the CT scan was used to define the volumes at risk and normal structures [8].

An additional contour was created consisting of the breast PTV less the boost PTV. This eliminated the tissue targeted to receive the concomitant boost and allowed a separate analysis of the effective dose received by the tissue surrounding the tumor bed.

**Two concomitant boost delivery methods were designed:**

1- Two standard opposed tangents conformal to the whole breast PTV, plus a pair of wedged fields conformal to the boost PTV; all fields have the same isocenter, placed in the whole breast PTV.

2- Two standard opposed tangents conformal to the whole breast PTV, plus a pair of wedged fields conformal to the boost PTV; all fields have the same isocenter, placed in the boost PTV.

Dose normalisation and prescription was set to 50Gy (2Gy/fraction, 5 fractions/week) (conventional fractionation schedule) to the whole breast PTV, simultaneously with 10Gy (0.4Gy/fraction, 5 fractions/week) to the boost PTV for all plans. The dose and dose fractionation used for concomitant boost irradiation are beyond the purpose of this study, as it will be investigated further. A PTVs dose homogeneity of −5%, +7%, as recommended by International Commission on Radiation Units and Measurements (ICRU )Report No. 62 (9), was considered for PTVs coverage for both techniques, in addition to the requirement that both PTVs receive 90% or more of the prescribed dose. The techniques investigated were set to avoid the undue irradiation of contralateral breast. The principal organs at risk (OAR) considered for treatment optimisation are the ipsilateral lung and the healthy tissue, defined as the result of subtraction of whole breast PTV and ipsilateral lung volumes from the body volume. Because we considered in this study patients presenting breast carcinoma right and left sided, the heart involvement is different, so the heart was not included in analysis as an organ at risk.

**Planning techniques:**

Dose plans for all patients and techniques were designed on the Varian Eclipse 3D treatment planning system, using Photon Pencil Beam Convolution algorithm version 8.1.17 with a heterogeneity correction by modified Batho method and a size of the calculation grid of 0.5cm. The multi leaf collimator (MLC) shielding was applied to fit the whole breast PTV with an outside surrounding margin of 1cm and the boost PTV with 0.7cm margins, in order to obtain adequate coverage.

Two dose plans were produced and analysed for each patient. Fig. (1) illustrates the main characteristics of the beam arrangements with respect to whole breast PTV and boost PTV.
Fig. (1): Beam arrangements for 3D-CRT concomitant boost techniques showing the corresponding digital reconstructed radiographs (DRRs) and field locations.

A- Whole breast isocenter technique:


Field arrangement for whole breast PTV.


Field arrangement for boost PTV.

B- Boost isocenter technique:


Field arrangement for whole breast PTV.


Field arrangement for boost PTV.
**Whole breast isocenter technique (WBI):**

This technique is an isocentric beam arrangement, with the isocenter positioned approximately in the center of the whole breast PTV and it is characterised by:

- Two standard opposed tangents conformal to the whole breast PTV.
- A pair of wedged fields conformal to the boost PTV.

With the use of beam’s-eye-view projections, the gantry angles were determined to achieve a homogeneous dose distribution and maximal avoidance of the heart, ipsilateral lung and contralateral breast. The beams have been weighted and wedges were used, when necessary. Shielding was adapted with use of a MLC. The dose normalization point was the isocenter for the whole breast PTV and a calculation point in the geometrical center of the boost PTV for the pair of wedged fields.

**Boost isocenter technique (BI):**

This technique is an isocentric beam arrangement, with the isocenter positioned approximately in the center of the boost PTV and it is characterised by:

- Two standard opposed tangents conformal to the whole breast PTV.
- A pair of wedged fields conformal to the boost PTV.

With the use of beam’s-eye-view projections, the gantry angles were determined to achieve a homogeneous dose distribution and maximal avoidance of the heart, ipsilateral lung, and contralateral breast. The beams have been weighted and wedges were used, when necessary. Shielding was adapted with use of a MLC. The dose normalization point was the common isocenter.

**Evaluation tools:**

Dose plans were assessed through visual inspection of the dose distributions for all CT slices and through calculation of Dose Volume Histograms (DVH) for PTVs and OARs.

Maximum and minimum significant doses to both PTVs were reported together with mean doses, as were defined in the ICRU Report No. 50 (9). Also, the volumes receiving at least 90% and 95% of the prescribed dose (V_90% and V_95%), were reported. The Conformity Index CI (ratio between the volume receiving the prescribed dose V_100% and PTV) as specified by ICRU Report No. 62 (5) was calculated. The dose homogeneity was assessed in terms of a Dose Homogeneity Index DHI, defined as DHI = (D_{max} + D_{min})/2 D, where D is the prescribed dose [9].

Lung irradiation was analysed in terms of maximum and mean doses. Also, the volumes receiving 5Gy (V_{5Gy}) and 20 Gy (V_{20Gy}) were reported.

The healthy tissue was defined as the volume included in the CT dataset excluding the target and ipsilateral lung volumes. The maximum and mean doses were reported, as well as the volume receiving 5Gy (V_{5Gy}).

To appraise the difference among the two studied techniques, the Wilcoxon pair test was applied. Data were considered statistically significant for \( p < 0.05 \).

**Results**

We included ten patients in this study. Five malignancies were on the left breast and five on the right.

In Fig. (2), the dose distributions at the level of the whole breast PTV and of the boost PTV are shown for a representative patient for both techniques. Also, the dose volume histograms are shown for both PTVs, ipsilateral lung and healthy tissue. From DVH and isodoses, it is possible to appraise the equivalence of the different solutions on target coverage and in normal tissues sparing.

**PTVs coverage and conformity:**

In Table (1) a summary of the DVH analysis is reported for whole breast PTV, boost PTV and OARs, by the mean value and standard deviation of each dosimetric parameter considered. For each pair of techniques, it is indicated also the statistical significance of the differences (computed by Wilcoxon pairs test); \( p < 0.05 \) means statistical significance. Minor differences are observed among the two techniques concerning the target coverage.

**Breast PTV coverage and conformity:**

In evaluating the results of the DVHs, no significant difference was observed with respect to the volume fraction covered by the lower (V_90%) and V_95% dose levels. Significant differences are observed only in the maximum doses (62.3Gy Vs. 61Gy, \( p = 0.003 \)) and higher (V_107%) dose levels (21.2% Vs. 17.9%, \( p = 0.048 \)), but the absolute difference is hardly significant from the clinical point of view.
However, a subtle improvement in dose homogeneity using WBI compared with BI was revealed (Dose Homogeneity Index of 0.661 Vs. 0.648, \( p=0.003 \)).

In synthesis, results on breast PTV show a global equivalence between both techniques, WBI technique appearing slightly better.

Boost PTV coverage and conformity:

Evaluation of the boost PTV coverage Comparison of the concomitant boost techniques revealed small improvements in the dose homogeneity with the WBI technique compared with the BI technique (Dose Homogeneity Index of 0.97 Vs. 0.94, \( p=0.002 \)).

In the setting of a concomitant boost, excellent boost PTV coverage was obtained for both techniques and with a significant improvement of WBI technique vs. BI technique (Conformity Index of 0.87 Vs. 0.64, \( p=0.001 \)).

However, despite the statistical significance, the absolute differences were quite small and the clinical benefit of such small improvements is uncertain.

Organs at risk and healthy tissue:

The organs at risk analysed were the ipsilateral lung and healthy tissue.

The ipsilateral lung irradiation, as well as the healthy tissue, shows a similar pattern among both techniques and well within the accepted standard of care. The average percentage of lung volume receiving 20Gy was 10% for both techniques.

![Fig. (2): Dose distribution for 3D-CRT concomitant boost techniques.](image)

A- Whole breast isocenter technique:

A 1- Dose distribution whole breast.  
A 2- Dose distribution boost.  
A 3- Dose volume histogram (DVH).

B- Boost isocenter technique:

B 1- Dose distribution whole breast.  
B 2- Dose distribution boost.  
B 3- Dose volume histogram (DVH).
Lung: particularly important Boost PTV: techniques in delivering a concomitant boost is nature of IMRT, we believe that the use of IMRT to department resources and the cost intensive tangential RT only. We tried to achieve this using normal structures. Because increasing the dose per volume while maintaining acceptable doses to technique in terms of dose delivery to the target can be obtained with conventional wedges, excel-

Table (1): Comparison of two 3D-CRT techniques for con-

<table>
<thead>
<tr>
<th>Whole breast PTV:</th>
<th>WBI</th>
<th>BI</th>
<th>p</th>
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<tbody>
<tr>
<td>Dmax (Gy)</td>
<td>62.30±1.62</td>
<td>61.04±2.20</td>
<td>0.003</td>
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<tr>
<td>Dmean (Gy)</td>
<td>49.82±2.50</td>
<td>49.74±2.15</td>
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<td>DHI</td>
<td>0.66±±0.06</td>
<td>0.64±±0.07</td>
<td>0.003</td>
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<td>V90% (%)</td>
<td>86.98±5.22</td>
<td>85.90±6.00</td>
<td>0.160</td>
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<td>V95% (%)</td>
<td>81.98±7.92</td>
<td>81.91±7.79</td>
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<td>V107% (%)</td>
<td>21.28±19.2</td>
<td>17.97±18.9</td>
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<tr>
<td>CI</td>
<td>0.807±0.16</td>
<td>0.796±0.14</td>
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<th>Boost PTV:</th>
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<tr>
<td>Dmax (Gy)</td>
<td>62.60±1.25</td>
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<td>Dmean (Gy)</td>
<td>60.26±1.54</td>
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<td>DHI</td>
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<td>V90% (%)</td>
<td>97.33±2.67</td>
<td>96.52±3.48</td>
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<tr>
<td>V95% (%)</td>
<td>96.53±3.47</td>
<td>94.42±5.58</td>
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<tr>
<td>V107% (%)</td>
<td>0</td>
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<tr>
<td>CI</td>
<td>0.874±0.20</td>
<td>0.645±0.44</td>
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<tr>
<td>Dmax (Gy)</td>
<td>54.81±3.80</td>
<td>53.93±3.79</td>
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<td>Dmean (Gy)</td>
<td>6.31±±3.98</td>
<td>6.17±±4.05</td>
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<td>VSGy (%)</td>
<td>18.67±10.83</td>
<td>18.50±11.3</td>
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<td>V20Gy (%)</td>
<td>10.58±8.02</td>
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<tr>
<td>Dmax (Gy)</td>
<td>59.44±2.42</td>
<td>58.44±1.50</td>
<td>0.695</td>
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<tr>
<td>Dmean (Gy)</td>
<td>2.17±0.86</td>
<td>2.54±4.16</td>
<td>0.830</td>
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<td>V5Gy (%)</td>
<td>5.51±2.19</td>
<td>7.18±14.02</td>
<td>0.312</td>
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Discussion

This study aimed to evaluate the dosimetric outcomes of two different concomitant boost deliv-

ery techniques. Our goal was to identify the best technique in terms of dose delivery to the target volume while maintaining acceptable doses to normal structures. Because increasing the dose per fraction could potentially affect cosmesis negative-

ly, choosing the optimal delivery method was particularly important [10-15].

One potential way to minimize a negative effect on the cosmetic outcome would be to maximize dose homogeneity in the part of the breast receiving tangential RT only. We tried to achieve this using simple 3D-CRT techniques. With the heavy burden to department resources and the cost intensive nature of IMRT, we believe that the use of IMRT techniques in delivering a concomitant boost is often not necessary. When dose homogeneity ≤7% can be obtained with conventional wedges, excel-

lent coverage of the whole breast and tumor bed with a minimal dose to normal tissue is possible with technology that is already widely available and less costly.

The techniques proposed by this study are noninvasive and employ technology used daily by radiation therapy departments. Furthermore, these techniques are attractive to patients because they eliminate the need for further procedural trauma to the breast.

These techniques require little experience to employ effectively and professionals who commonly perform CT-guided treatment planning learn this approach quickly. The minimum experience required to generate dosimetrically appealing plans coupled with the use of simple beam arrangements suggests this technique could be widely adopted.

An unique feature of these techniques is the use of the same isocenter for all fields; this will simplify the treatment delivery set-up and will reduce the errors related to patient positioning as well as reduce the overall treatment time; so lessens the burden on the patient and radiation therapy staff.

Thus, the 3D-CRT techniques described herein provides a technically feasible and dosimetrically appealing strategy for breast conserving radiation therapy.

However, a note of caution must be added. Setup error has not previously been considered a concerning factor in breast RT. This is because the target volume has always included the whole breast. The conventional method of patient setup for breast RT is to use skin-marks (usually tattoos), which are aligned to the treatment room lasers. A simple visual verification to confirm that the entire breast is covered by the light field immediately before treatment delivery is commonly performed. The chances of "missing" the target are therefore small.

With an SIB technique the target volume is significantly smaller. The probability of a geographical miss is consequently higher. As volumes be-

come more conformal, it is believed that measures to lessen setup errors should be taken.

In this regard, a rigorous verification of treat-
ment set-up must be performed, leading to more frequent imaging procedures than in the case of conventional two tangential fields technique.

Intrafraction motion was not assessed by this study; this is another factor to be considered when designing appropriate PTV margins [16].
To the best of our knowledge, this technique had not been tried before after thorough review of the current literature.

**Conclusion:**

The techniques described in this study are simple, easily replicated, conformal approaches that employ traditional supine positioning.

The 3D-CRT simultaneously integrated boost techniques are proposed for standard use in breast conserving radiation therapy, because they can be easily implemented to reduce excess volumes of normal tissue irradiated and shorten the treatment course.

The clinical interest for these techniques is also due to their simplicity. No compensators, no IMRT tools, or sophisticated major technologies are needed. They can be adopted easily by radiation oncologists and physicists.

**References**


