RESEARCH ARTICLE

Treatment Planning With Unflattened as Compared to Flattened Beams for Bilateral Carcinoma of the Breast

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Abstract

Aim: To evaluate the plan quality of 6MV unflattened (UFB) and flattened beam (FB) photon energy using AAA dose calculation algorithms for volumetric arc therapy. Materials and Methods: Plans were generated for bilateral carcinoma of breast and breast dose prescribed was 50.4Gy in 28 fractions. Two different plans were made for each patient using 6MV FB and 6MV UFB. Dose calculations were performed on an AAA dose calculation algorithm. Plans were generated on Eclipse TPS and were capable of being delivered with a true beam STx linear accelerator. The homogeneity index (HI), conformity index (CI), normal tissue integral dose (NTID), and effect of low dose volume on normal tissue and monitor units (MU) were noted. Results: All the plans were clinically acceptable. The HI and CI of 6MV UF rapid arc (RA) plans were higher than with the 6MV FB plan (1.16±0.05 and 0.12±0.00 respectively). There was no appreciable difference observed in Organ at risk (OAR) doses. The mean NTID and low dose volume were significantly low with 6MV RA UFB as compared to FB. 6MV RA UFB required a 35% higher MU than with the 6MV RA plan (p<0.05). Conclusion: RA plans generated with UFB on Eclipse TPS achieved target volume coverage and preserved OAR’s essentially similar to 6MV RA FB plans. However RA plans generated in Varian Eclipse of UFB were superior with respect to mean NTID and low dose volumes in normal tissue.

Keywords: Flattened beam- unflattened beam- rapid arc and volumetric arc therapy

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Introduction

Bilateral breast carcinoma (BiB) is a rare clinical entity. However, with increasing awareness and better diagnostic tools, the incidence of synchronous BiB cancer is on a rise. It is well known that conventional tangential technique with or without wedges fail to give a homogenous dose distribution throughout the target volume. The drawback of these techniques included hot spots and high maximum dose (>107%), especially in large-breasted patients, which leads to worse/poor cosmetic outcomes after irradiation and under dosage may result in increased chance of local recurrence. In the past decade (Moorthy et al., 2013), 3-Dimensional Conformal Radiotherapy (3DCRT) became a standard treatment technique, which reduced the doses to lung, heart, and other critical structures in the breast cancer treatment. However, using 3DCRT, it is not always possible to achieve adequate normal tissue constraints, especially when treating left sided tumor. This is mainly due to the overlying concave shape of the target, which can result in more doses to adjacent structures such as heart and lung. By modulating photon beam (Hong L et al., 1999), it is possible to obtain concave and convex shape dose distributions with IMRT and has the ability to conform radiation dose to irregular target volumes, thereby sparing the underlying critical structures with better tumor control probability (TCP).

In most of the radiotherapy plans, the photon beam energy is selected depending up on tumor depth and location. The chosen optimal energy in a busy department depends upon the beam energy to target volume (TV) achieve the coverage and OAR sparing. Recently, so many modification / innovation like VMAT, UFB have been proposed and implemented clinically. At high energy greater than 10MV, the neutron contamination and exit dose is prominent. The advantage of treatment with high energies is more skin sparing as compared to lower energies (less than 6MV). The exit dose is low at lower energies which will help in OAR sparing. The advances in technique will improve target coverage, homogeneity, conformity and reduce toxicity that will help reduce chronic breast edema. Many authors compared 3DCRT, IMRT and VMAT techniques for different anatomical sites. Already, VMAT plays an important role in reducing delivery time compared to IMRT (Rana S et al., 2013). However limited as numbers of publication are available for bilateral breast cancer cases. In this present study we will discuss the advantage of UFB or Flattening filter free
beam in VMAT technique for bilateral breast carcinoma
cases.

Materials and Methods

In VMAT or Rapid arc planning, a single isocentre
was placed at the middle of sternum for easy setup and
to further reduce the treatment duration. There were
two partial arcs placed around each breast, the arc angle
being 200°. The collimator jaws were fixed for the both
breast and angulated to take are the tongue and groove.
Similarly, treatment planning of photon beam for 6MV
FB and 6MV UFB Rapid Arc was performed on Eclipse
Treatment Planning system using Anisotropic analytical
algorithm (AAA) with 0.25 cm grid size was used. Plans
were capable of delivering treatment on Varian True Beam
Linear Accelerator equipped with HD 120 MLC (MLC of
60 pair, inner 32 leaf pair of 0.25 cm, and outer 28 leaf pair
of 0.50 cm projection width at isocenter and a maximum
leaf speed of 2.5 cm/s). The VMAT and Rapid Arc
delivery mode were same, however the vendor’s trades
name their products diffently. The Varian arch technique
is called Rapid Arc and Elekta was VMAT.

All the photon beams were calibrated at 1 cGy/MU
at dmax on the central axis for a 10 cm x 10 cm field
with SSD of 100 cm, for both flattened and UF beams as
per Technical Reports Series No. 398 (TRS-398, 2000)
of International Atomic Energy Agency. Plans were
optimized selecting a maximum dose rate of 600MU/min
in 6MV FB and 1400 MU/min for 6MV UFB in Varian.

Patients Characteristics

Five patients who had undergone bilateral mastectomy
with axillary lymph node clearance were identified. These
five patients’ detailed post-operative histopathology report
warranted radiotherapy to the chest wall on both sides.

Imaging and contouring

Patients were taken up in the CT simulator room and
made to lie in the supine position on AIO (All In One)
base plate with head rest below the head and both arms
abducted above the head. Room lasers were used to
align the patient. A topograph was obtained for ensuring
correct alignment of the patient. Radio-opaque markers
and wires were placed to mark the area of interest. Then
a 4 clip thermoplastic orfit cast (Orfit industries, Belgium)
was made to immobilize the thorax and upper abdomen
of the patient for simulation and daily treatment. Three
reference fiducials (one in midline and two lateral) were
placed on the cast on a bony landmark preferably in the
area of interest with the help of room lasers which guide
the isocentre shift during first day of treatment delivery.

A CT scan was obtained on the CT Simulator
(Sensation Open Duo Wide Bore version Syngo CT 2007
by Siemens Medical Solutions, Germany) for treatment
planning with 5 mm slices from the angle of the mandible
to 5 cm below the inferior border of the breasts. DICOM
(Digital Imaging and Communication System) images
from the CT simulator were transferred to the contouring
station. The TV and OAR’s were contoured. Target
volumes were defined by radiation oncologists: PTV
included the entire breast (combination left and right
breast). PTV was restricted to the skin by cropping at
least 5 mm from the skin surface and to exclude the ribs.

PTV is defined medially at the lateral edge of the
sternum, inferiorly at the infra-mammary fold, superiorly
at the inferior edge of the medial head of the clavicle, and
laterally to include all apparent breast tissue. OAR’s such
as heart, and common lung were also delineated. PTV,
Common lung, and heart volumes were 878.6 ± 389.5cc,
2791.5 ± 811.2cc, and 410.5 ± 76.5cc respectively.

Dose Prescription and Optimization objective used for
Inverse Treatment planning

Dose prescribed to PTV was 50.4Gy (1.8Gy/fraction)
in 28 fraction. Planning objective was to deliver 100%
prescription dose (PD) to 95% of PTV as recommended
in International Commission on Radiation Units and
Measurements (ICRU-50, 1999) Report 50 & 83 (ICRU
Report 83, 2010). The normal dose constraint used were
heart V25Gy ≤ 10%, Common lung V20Gy ≤ 30%, as per
institutional protocol.

Plan Evaluation and statistical Methods

Homogeneity index (HI): A ratio evaluating the dose
homogeneity (D2%-D98%)/D50%, in TV, where D2%,
D98%, and D50% are the minimum dose delivered to
2%, 98%, and 50% volume of the TV, respectively. HI of
zero indicates the dose distribution to be homogeneous.

Conformity index (CI): A ratio evaluating the coverage
of the prescription dose in treatment Plans. CI = Volume
within 98% isodose line / TV. CI of one indicates good
dose conformity.

Parameters selected for comparison of heart V25Gy
and common lung V20Gy were chosen because there was
evidence that dose beyond these values could cause acute
or late clinical symptoms. To assist in further analysis,
V10Gy, and V35Gy for heart, as well as V45Gy and
V5Gy for common lung, were noted. Healthy tissues,
common lung dosimetric parameters (mean doses and
V5Gy) were compared as they may represent doses that
might be associated with a carcinogenic risk.

Normal tissue integral dose (NTID) ( D’Souza WD et
al., 2003) was defined as the integral of the absorbed dose
extending to overall voxels excluding those within the TV.
It was calculated to assess the plan quality based on the
following formula. Normal tissue integral dose (NTID) =
Mean dose × Volume of normal tissue outside TV.

In addition, the treatment parameters including the
monitor units (MU) and beam on time (BOT) for each
treatment plan were recorded for evaluation. BOT was
defined as the radiation delivery time and did not include
the patient positioning and imaging procedures.

In order to quantify the differences between plans
a test of significance was required. All statistical tests
were done using paired sample t-test for comparisons of
data, performed using the IBM Statistical Package for
Social Sciences (SPSS) software (release 20.0, SPSS Inc.,
Chicago, IL, USA). Statistical significance was defined as
p < 0.05.
Results

**Target volume Coverage**

The target volume coverage of 6MV RA UFB was clinically acceptable. However there was significant $p$ value $<0.05$ were observed in homogeneity and conformity index in both plans. The V110% was greater than 3% in 6MV RA UFB plan in comparison to 6MV RA FB plan. The CI, HI, and target coverage (D98%, D95%, D50%, and D2%), values were mentioned in table 1 and isodose color wash of one patient in all three views is shown in Figure 1.

**Organ at risk**

Dose to common lung and heart are mentioned in table 1. The common lung V20Gy, V45Gy and mean dose found to be less in 6MV RA FB plan and similarly for heart V45Gy, V25Gy, and V10Gy.

**Normal Tissue Integral Dose**

The NTID and body minus PTV volume receiving low dose of 1Gy, 2Gy, 3Gy, 4Gy and 5Gy were comparatively less in 6MV UFB RA plans. The $p$ value of less than 0.05 is observed and mentioned in the Table 1.

**Monitor units and beam on time**

In this study, 6MV UFB RA plans generate higher MU’s compared to 6MV RA FB plan. The significant $p$ value ($<0.05$) observed in both the plans. However the BOT was less in 6MV RA UFB and a significant $p$ value was observed.

Table 1. PTV Coverage and OAR’s Doses for 6MV FB and UFB. SD, Standard Deviation

| Target and OARS          | Parameters | 6MV_FB RA Mean ± SD | 6MV_UFB_RA Mean ± SD | 6MV_RA FB Vs UFB (p value) |
|--------------------------|------------|----------------------|-----------------------|-----------------------------|
|                          |            | D98% (Gy)            | D98% (Gy)             |                             |
|                          |            | 49.45 ± 0.2          | 50.31 ± 0.3           | NS                          |
|                          |            | D95% (Gy)            | D95% (Gy)             |                             |
|                          |            | 50.34 ± 0.1          | 50.26 ± 0.74          | NS                          |
|                          |            | D50% (Gy)            | D50% (Gy)             |                             |
|                          |            | 53.00 ± 0.3          | 53.20 ± 0.3           | $p<0.05$                    |
|                          |            | D2% (Gy)             | D2% (Gy)              |                             |
|                          |            | 55.31 ± 0.3          | 45.74 ± 1.5           | $p<0.05$                    |
| PTV                      | HI         | 0.11 ± 0.01          | 0.12 ± 0.00           | $p<0.05$                    |
|                          | CI         | 1.12 ± 0.04          | 1.16 ± 0.05           | $p<0.05$                    |
|                          | V110%      | 1.8 ± 1.4            | 3.4 ± 1.04            | NS                          |
|                          | V26Gy (%)  | 26.6 ± 4.5           | 26.9 ± 3.9            | $p<0.05$                    |
|                          | V45Gy (%)  | 3.1 ± 1.5            | 3.7 ± 1.5             | $p<0.05$                    |
| Common Lung              | V5Gy (%)   | 84.0 ± 14.7          | 84.2 ± 14.9           | $p<0.05$                    |
|                          | Mean dose (Gy) | 15.47 ± 1.3      | 15.82 ± 1.4           | $p<0.05$                    |
|                          | V10Gy (%)  | 34.3 ± 6.7           | 37.8 ± 9.6            | $p<0.05$                    |
|                          | V25Gy (%)  | 9.5 ± 4.2            | 10.6 ± 4.4            | $p<0.05$                    |
| Heart                    | V35Gy (%)  | 3.0 ± 2.1            | 3.6 ± 2.3             | $p<0.05$                    |
|                          | Mean dose (Gy) | 10.17 ± 2.6      | 10.84 ± 3.1           | $p<0.05$                    |
| NTID (105Gy cm3)         | V5Gy (%)   | 142.44 ± 45         | 141.44 ± 45           | $p<0.05$                    |
|                          | V10Gy (%)  | 62.33 ± 11.05       | 61.50 ± 10.8          | $p<0.05$                    |
|                          | V25Gy (%)  | 51.16 ± 9.20        | 56.41 ± 9.03          | $p<0.05$                    |
|                          | V35Gy (%)  | 47.19 ± 8.33        | 46.76 ± 8.21          | $p<0.05$                    |
| Low Dose Volume          | V4Gy (%)   | 44.81 ± 7.89        | 43.45 ± 7.74          | $p<0.05$                    |
|                          | V8Gy (%)   | 42.37 ± 7.56        | 41.89 ± 8.13          | $p<0.05$                    |
|                          | V10Gy (%)  | 28.55 ± 6.19        | 27.12 ± 5.89          | $p<0.05$                    |
| MU                       | Monitor Unit | 1214 ± 66           | 1638.4 ± 78           | $p<0.05$                    |
| BOT                      | minutes    | 3.01 ± 0.13         | 2.50 ± 0.12           | $p<0.05$                    |
Discussion

Treatment planning of bilateral breast is a challenge case due to involvement of the bilateral lungs, heart and a large treatment volume in comparison to other sites. Many authors (Jobsen J et al., 2002; Yamauchi C et al., 2005; Graham M Purdy et al., 1999) suggested that radiation therapy is the best choice in bilateral breast cancer. The present study was the first study, to compare the arc planning of 6MV RA plans using flatten and unflattened beam in bilateral breast case. Johannes Maier et al., (2016) noted that rapid arc (RA) conformity is better than VMAT. Elekta VMAT plans generate lesser NTID and low dose volume (V2Gy, V5Gy, and V10Gy) due to jaw tracking. However in low and high dose regions no significant difference in dose calculation accuracy was noted in FB and UFB or FFFFB (Flattening filter free beam) in both IMRT and VMAT modality. More MU’s were generated in FFFFB generated IMRT and VMAT plans due to the shape of the FFF beam profile, particularly at off axis region to achieve the dose constraint. FFF beam quality was superior in tVMAT and VMAT technology. The dose to contralateral OARS was found to be less in FFFB. For right side breast cases, the FFFB VMAT MU were 1.2 time was higher, due to higher dose rate, the treatment times reduced by 7%. The present study also noted that UFB needs 35% more MU’s in RA plan as compared to FB. (1214±66 for FB and 1638±78 for UFB). The MU ratio of FB/UFB factor was 1.35, hence the UFB drop the BOT by 17%.

Wiant et al., (2014) observed the intra-fractional movement in breast cases, the result were significant as treatment time increased. Koivumaki et al., (2015) found that tangential VMAT plan showed time advantage in FFF beam as compared to tangential IMRT in breast cases. Spruijt et al., (2013) noted that treatment times reduced in IMRT with use of FFF beam plans.

Giorgia Nicolini et al., (2009) found that there was no significant difference (p>0.14) in the beam on time (BOT) observed, by comparing IMRT versus VMAT in bilateral breast planning. The Beam on time was 2.3min for IMRT and 2.23 min for VMAT. However p value was significant (p<0.01) for total treatment delivery. The rapid arc delivery time (3min) was 74% lesser in comparison to IMRT(11.45min), which will reduce the intrafractional movement of the patient. By comparing the mean and integral dose to non-tumor tissue volume the was more in RA plan due to higher low dose volume contribution, however the high dose volume contribution was less, therefore reducing the cosmetic effects. In our study, there is significant p value significant were observed in BOT between 6MV RA FB versus UFB plans. (2.5±0.12 min for UFB and 3.01±0.13 min for FB). But the mean NTID and low dose volume of V1Gy, V2Gy, V3Gy, V4Gy, V5Gy, and V10Gy, in non-tumor tissue for 6MV RA UFB plans was lesser in comparison to 6MV RA plan, due to UFB physical properties. (Like lesser head scatter, leakage etc.)

ICRU Report 50 recommends a dose variation to the PTV to be within−5% to 7% of the prescription dose. Mundt et al., (2002) reported that the high dose volume V110 (%) and V115 (%) in the PTV was 9.8% and 0.2% respectively. In our study, V110 (%) was less than 3.0% (except 6MV UFB RA plan) and V110 (%) is zero. Many authors (Pirzkall A et al., 2000; Verhey LJ et al., 1999) noted longer delivery time in IMRT due to more MU’s and multiple beam angles. Faster treatment delivery time is needed to take care of patient comfort during delivery. The UF beam VMAT and IMRT plans dose distribution was clinically acceptable and added benefit of reduction in treatment time helped in imaging and gating.

In Conclusion, this study compared the UFB with FB in VMAT plans for bilateral breast cancer patients. All the plan achieved the better target coverage and OAR sparing. We conclude in this study that UFB also produces better plans. Ours is a dosimetric study where only one of the generated plans was implemented on the patient. Hence, no comparison could be made between the long term clinical outcomes on the heart, the ipsilateral lung, opposite breast or the loco-regional control. A randomization of patients with similar clinical characteristics between the various planning algorithms would provide more robust information about the clinical implication of these dosimetric techniques. Though the rarity of the scenario of bilateral breast carcinoma make it difficult due to small sample size in each sub group. Further investigations were required to study the performance of TPS for different energies and different anatomical sites.

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