Dosimetry study for Post-Mastectomy Breast Cancer in Intensity Modulated Radiotherapy plans and Field in Field (FiF) forward plans

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ABSTRACT

Aim: The aim of this study, to correlate the planning and delivery efficiency between three dimensional conformal radiotherapy, field in field forward planned intensity modulated radiotherapy (FIF-FP-IMRT) and inverse planned intensity modulated radiotherapy (IP-IMRT).

Materials and Methods: Treatment plans of 20 post mastectomy patients with left and right side breast cancer, treated to a prescribed dose of 50 Gy to the chest wall and to the supra clavicle fossa in 25 fractions. Treatment plans of 3DCRT, FIF-FP-IMRT plans were created by combining two open fields with three to four segments in two tangential beam directions and one anterior field, posterior oblique. Six to seven different beam directions were chosen to create IP-IMRT plans and were inversely optimized. The homogeneity of dose to planning target volume (PTV) and the conformity index were similar for 3DCRT and FP-FP-IMRT, whereas the IP-IMRT plans had better conformity index at the cost of less homogeneity. The 3DCRT and FIF-FP-IMRT plans gives the similar saving the critical organs. In IP-IMRT gives heart and ipsilateral lung dose was higher than 3DCRT and FIF-FP-IMRT. Also contra lateral Breast receive low dose (0.1-3 Gy) in 3DCRT and FIF-FP-IMRT. Also in IP-IMRT opposite breast getting more than 5 Gy.

Results and Conclusion: Compared with 3DCRT and IP-IMRT, FIF-FP-IMRT gave a simple and good planning technique for breast irradiation. It gives dosimetric advantages of the minimal hotspot and good coverage to PTV. It felt that FIF-FP-IMRT needed less planning time and easy field placements.

Key word: Post-mastectomy breast cancer, contra lateral breast, 3DCRT, field in field breast plans, intensity modulated radiation therapy, organ at risks
acceptably, on the way minimizing the critical organ dose (i.e., ipsilateral lung, contra lateral lung, contra lateral breast, heart, liver and spine). In that two opposing field gave maximum dose (hot spot) to the breast because of the ununiform surface of the breast.

For that physical or dynamic wedges reduced that hot spot and it compensate for changes in the external contours and improves the dose distribution to the chest wall (CW) and supraclavicle region (SCF). The risk of contra lateral breast cancer has been discussed in recent studies, it gave special need for reduction of radiation to the contra lateral breast using with dose modifiers (wedges and blocks).

Many number of studies addressed the three dimensionally computerizes tomography (3D-CT) based treatment planning And field shaping as well better dose conformity by applying the multi leaf collimator (MLC). In field in field technique two opposite tangential field covered the chest wall and one anterior (AP) and posterior oblique field to cover the SCF.

In FiF technique which allows acceptable coverage of mastectomy breast tissue while minimizing dose to the critical structures, MLC optimized tangential beams using FiF techniques, in achieving better conformity and homogeneity.

Dose related morbidity in irradiation of heart tissue has been reported recent studies. Inversely planned intensity modulated radiotherapy (IMRT) has proved the adequacy in various sites, where there are constraints in the dose delivery in general, restricting dose to the critical structures in particular. Many number of publication shows the necessity of IMRT in radiotherapy treatment for example one head and neck region tongue cancer treatment plans shows the IP-IMRT plan achieving significant reduction in the dose to organ at risk (OARs), such as spine and parotid.

Several studies show the improvement of dose conformity and dose homogeneity in IP-IMRT plans. The present works aims to compare the dose delivery and dose distribution in IP-IMRT plan vis-à-vis other simple plans with parallel opposed tangential fields and FiF in the treatment of breast (mastectomy breast) cancer.

MATERIALS AND METHODS

The data of radiotherapy treatment collected from 20 left side breast cancer and 20 right side breast cancer patients, where they underwent mastectomy breast surgery. These patients were treated from January 2015 to December 2015 in CAIMS cancer hospital and research center at Karimnagar, Telangana, India. Each patient received 50 Gy to chest wall and supraclavicle region in 25 fractions.

These patients were treated with 3DCRT and IMRT plans in Varian CLINAC iX machine which is installed in CAIMS cancer hospital and research institute.

In the first step of patient molding was done with the thermoplastic mask and other suitable accessories (i.e., breast board, AIO board, head rest and leg extensions). After the mold preparation a 3D CT image (which was in 2.5 mm slice thickness) were taken from the computed tomography and sent to the treatment planning system (Figure1).

The radiation oncologist did contours on that CT images, such as clinical treatment volume (CTV), planning target volume (PTV), and the critical structures (i.e., heart, contra lateral breast, contra lateral lung, liver, ipsilateral lung and spinal cord). Additional 3 mm margin added for PTV because to include the setup errors while set the patients on the treatment couch.

The treatment planning was done by computerized radiation treatment planning system (RTPS) Eclipse (version 11.0 Varian). On the basis of 3DCRT plans created by two open fields, in that patients received 6 MV photons from CLINAC iX machine. In FiF-FP-IMRT, plans were created by two tangential beams one anterior field and one posterior oblique field in single isocenter with same machine with 120 MLCs as tertiary collimators at 100 cm source to skin distance (SSD). This FiF-FP-IMRT planned with one isocenters with the junction separation, chest wall covered by two tangential fields and SCF covered by AP and posterior oblique field.

Inversely planned IMRT plans created on CT images of already treated patients as ‘studyplan ‘with sliding window dynamic IMRT employing segmental multifields’ delivery using Eclipse software. Seven different field directions selected to create IMRT isocentric plans and were inversely optimized. Target dose and
OARs dose was calculated with heterogeneous corrections, using Analytical Anisotropic Algorithm (AAA). The target doses and critical organ doses listed in Table 1.

**Comparison of treatment techniques**

The plan comparison and the dose distribution of the three dimensionally conformal radiotherapy and intensity modulated radiation therapy plans compared and analyzed. The details of beam arrangement and objectives of plans are explained below.

**3D- Conformal Plan**

It is the basic plan technique offered in basic model linear accelerator, in this conventional treatment plan beam arrangement had two parallel opposing tangential fields with a single isocenter. This conventional plan ensuring the adequate coverage to the planning target volume and minimizing dose to the critical structures (i.e., heart, contralateral breast, contralateral lung, liver, ipsilateral lung and spine). The figure 2 shows the dose distribution for the 3DCRT treatment plan. The physical and dynamic wedges were used to increase the dose uniformity and to reduce the maximum dose present in the plan.

**Field-in-field-forward – IMRT**

In field in field forward plan IMRT planning technique, beam arrangement consisted two parallel apposing tangential fields and anterior, posterior oblique fields with the finite margin around the PTV. These treatment fields of MLC and the jaws set the geometry to achieve the uniform dose to the PTV. In that plan limiting the volume of ipsilateral lung receiving >20 Gy not to exceed 37%, minimize hot spot region in ipsilateral lung, heart, contra lateral breast and liver and limit dose to these OARs.

In that plan had two photon energies such as 6MV and 15 MV, all the beams were consisted on one treatment isocenter with the junction field i.e., chest wall plan consisted parallel opposed tangential field and SCF had one anterior and one posterior oblique fields. Figure 4: Field separation and half jaw closed dose distribution. Sub fields and boost fields were created to reduce the maximum dose in the planning and to increase the uniform dose to the PTV respectively. Figure 3: Dose distribution for two tangential fields with sub fields and boost fields.

This plan had 95% of dose coverage in PTV and average of maximum dose to PTV is 108% received in our hospital plans. In all the plans had maximum treatment fields are 9 fields which are including in subfield and boost field.

<table>
<thead>
<tr>
<th>Target or Organ of interest</th>
<th>Aim or dose constraints (%)</th>
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</thead>
<tbody>
<tr>
<td>Planning target volume</td>
<td>45 or 50 Gy</td>
</tr>
<tr>
<td>Heart</td>
<td>67 ≤45 Gy</td>
</tr>
<tr>
<td></td>
<td>100 ≤40 Gy</td>
</tr>
<tr>
<td>Ipsilateral lung</td>
<td>37 ≤20 Gy</td>
</tr>
<tr>
<td></td>
<td>100 ≤20 Gy</td>
</tr>
<tr>
<td>Contra lateral lung</td>
<td>100 ≤10 Gy</td>
</tr>
<tr>
<td>Contra lateral breast</td>
<td>100 ≤2 Gy</td>
</tr>
<tr>
<td>Liver</td>
<td>100 ≤35 Gy</td>
</tr>
<tr>
<td>Spine</td>
<td>Max dose &lt;44 Gy</td>
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</tbody>
</table>

Table 1: target doses and dose limit to OARs.
Inversely planned isocentric IMRT (IP-IMRT)

In inversely optimized IP-IMRT plans consisted seven different angles according to the site and side of the post-mastectomy breast. For left side breast plan had these angle of the beam directions are 340°, 0°, 40°, 80°, 120°, 160°, and 200°. The right side breast IMRT plan consisted seven treatment fields in different beam directions such as 340°, 0°, 40°, 80°, 120°, 160°, and 200°. In this plan prescribed by 25 fraction and 50 Gy. The isocenter of the treatment machine is positioned at the same point as in the FiF-FP-IMRT. Figure 5: IP-IMRT plans with seven photon fields in breast treatments.

Assessment of plans

The treatment plans were created and compared objectively using the dose volume histogram (DVHs) for planning target volume and different critical structure such as contralateral lung, ipsilateral lung, contralateral breast, heart and liver. V95, V90, Dmean, Dmax, Homogeneity index, conformity index were compared for all the three techniques. For ipsilateral lung OARs, the values of V37, and Vmean, and heart, liver dose values are Vmean, and also dose value for spinal cord seen that max dose Dmax.

The following criterions were used to assess the plans equitably:

1. Corresponding volume of breast PTV getting 108 of the prescription dose (V108%) (mean the extension of hot-spot regions within the breast).
2. Mean (Dmean) and maximum dose (Dmax) delivered to the PTV.
3. Target volume receiving 90%, 95% and 99% of the dose, (V90%, V95% and V99%).
4. Homogeneity index (HI) in PTV defined by the relation

\[ HI = \frac{(D_{\text{max}} - D_{\text{min}})}{D_{\text{mean}}} \]  

5. Conformity index (CI) defined as per relation

\[ CI = \frac{(PTVRI/PTV)}{(PTVRI/PTVRI)} \]  

(PTVRI is the 95% of the planning target volume, which should be covered by 95% of the prescribed dose)

6. The corresponding volume of the lung receiving 20 Gy of V37% and mean dose 20 Gy.

7. Relative volume of heart and contralateral lung receiving less than 18 Gy and less than 2 Gy respectively.

8. Relative volume of contra lateral breast receiving less than 3 Gy to 5 Gy.

<table>
<thead>
<tr>
<th>Measure values from DVH</th>
<th>Volumes and doses for three breast treatment techniques</th>
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<tbody>
<tr>
<td></td>
<td>3DCRT</td>
</tr>
<tr>
<td>V47.5Gy</td>
<td>94.5-95.2</td>
</tr>
<tr>
<td>V45Gy</td>
<td>96.3-98.6</td>
</tr>
<tr>
<td>V52.5Gy</td>
<td>2-8.2</td>
</tr>
<tr>
<td>V54.Gy</td>
<td>1.2-5.7</td>
</tr>
<tr>
<td>Dmean</td>
<td>99.2-100.2</td>
</tr>
<tr>
<td>Dmax</td>
<td>105-108</td>
</tr>
<tr>
<td>HI</td>
<td>0.13-0.42</td>
</tr>
<tr>
<td>CI</td>
<td>0.36-0.6.7</td>
</tr>
</tbody>
</table>

V47.5Gy= relative volume of PTV receiving 47.5 Gy, Dmax= maximum dose to PTV, (HI=Homogeneity index; CI=Conformity index)
Figure 5: (a) DVH shows opposite breast for 3DCRT and FiF-FP-IMRT plans

Figure 5: (b) DVH shows opposite breast for IP-IMRT plans

Figure 5: (c) DVH shows contra lateral lung and heart for 3DCRT and FiF-FP-IMRT plans

Figure 5: (d) DVH shows contra lateral lung and heart for IP-IMRT plans

Figure 6: (a) DVH shows ipsi-lateral lung for 3DCRT and FiF-FP-IMRT plans

Figure 6: (a) DVH shows ipsi-lateral lung for IP-IMRT plans
RESULTS

All the three plans, 3DCRT, FiF-FP-IMRT, and IP-IMRT, attain comparable good dose coverage, delivering prescribed dose more than 95% to 95% of the breast PTV. In all these techniques, 108% of dose (hot region) was noticed in less than 5% of the target volume. Mean Planning target volume getting 108% was 1.4% for IP-IMRT, 1.7% for FP-IMRT, and 3.7% for 3DCRT. The results and predicted dosimetric parameters shown in table 2.

From Table 2 it can be seen that the 3DCRT and FiF-FP-IMRT plans consisted Dmax 105-108%. For the IP-IMRT plan, Dmax range from 103-112%. The 3DCRT and FiF-FP-IMRT plans consisted a good conformity and same with homogeneity index.

Figure 5 a-d shows the average dose volume histograms (DVHs) for heart, liver, ipsilateral lung, contra lateral lung, contra lateral breast, and spine for the three treatment irradiation. It can be revealed that the minimum and mean dose to the heart, lung, liver, and opposite breast are much higher in IP-IMRT than in 3DCRT and FiF-FP-IMRT. It is observed that the volumes getting low dose are much in the IP-IMRT techniques.

The resemblance of the average dosimetric parameters for OARs for the three treatment techniques are shown in Table 3. The 3DCRT and FiF-FP-IMRT were commensurate in sparing critical organs. For the IP-IMRT planning technique, the average V20Gy and Vmean for the heart were observed to be higher than in the 3DCRT and FiF-FP-IMRT plans.

The value of mean dose to the ipsilateral lung was higher in IP-IMRT than the values for the FiF-FP-IMRT and 3DCRT. The relative dose was significantly lower for the FiF-FP-IMRT and 3DCRT plans than for the IP-IMRT.

Even if the contrast between 3DCRT and FiF-FP-IMRT planning techniques were not statistically significant, a small dose increase in OARs is present in 3DCRT plan technique.

DISCUSSION

The current effort was aimed to correlate the planning dose distribution efficiency among three techniques of radiotherapy to the chest wall and to the supra clavicle region, namely 3DCRT, field-in-field forward plan IMRT and inversely planned IMRT. Table 1 show that the result of 3DCRT and FiF-FP-IMRT comparatively equal the breast coverage, delivering 95% of the prescribed dose to >95% of the planning target volume. However in the IP-IMRT plans, mean maximum doses were more than 100% of the prescribed dose.

The results of our study match with other similar studies.[1,14-15] the authors of this study [14] guess that the treatment plan with IMRT photons is lesser to 3DCRT For contra lateral breast and contra lateral lung mean For dosimetry of the OARs, excluding contra lateral beast, the FiF plan technique remarkably reduce the dose than the prescribed dose for PTV. dose significantly reduce than the conventional plan technique and IP-IMRT. The volume getting <1 Gy of the prescribed dose to the contra lateral breast was significantly minimized using the field in field technique. In additive, dose distribution using in the FiF technique was less sensitive to the normal structures and to the effect of breast motion Suring normal breathing. In the clinical outcome, the FiF technique remarkably decreased the Radiation Therapy Oncology Group (RTOG) grade II acute skin toxicity compared with conventional plan technique.

<table>
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<tr>
<th>Critical structures</th>
<th>Volume and doses for three breast irradiation techniques</th>
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<tr>
<td></td>
<td>3DCRT</td>
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<tr>
<td>Ipsi-lateral lung</td>
<td>V100%</td>
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<tr>
<td></td>
<td>V37%</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Heart</td>
<td>V67%</td>
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<tr>
<td>Contra lateral lung</td>
<td>V100%</td>
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<td></td>
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<tr>
<td>Contra lateral breast</td>
<td>V100%</td>
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<tr>
<td>Liver</td>
<td>V100%</td>
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<td>Spine</td>
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<td>Maxdose</td>
<td>V100%</td>
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Figure 7: Islands of hot spot with the IP-IMRT plans near the surface of the skin
The 3DCRT and FiF-FP-IMRT plan techniques are needed only few monitor units to delivery prescribed radiation dose compared with IP-IMRT. In the IP-IMRT the number monitor units (MU) are higher than the 3DCRT and FiF-FP-IMRT. The more MU increase the treatment time which means for three dimension plan and forward plan IMRT have 250-350 MU approximately but in the same way IP-IMRT having 1000-1200 MU. The 3DCRT and FiF-FP-IMRT required 10-30 minutes to deliver these monitor units, in IP-IMRT required 25-45 minutes to deliver the monitor units (for a dose rate of 400MU/min) as well as higher machine leakage and total body stray radiation dose.

These treatment delivery times depending on the person who had good planning skill. The main point of view the IP-IMRT plan needs verification of pretreatment patient specific QA measurements. The addition of QA time must be add in to the account when considering the total workload per plan. Comparatively the 3DCRT and FiF-FP-IMRT required less time to create a plan, in inversely planned IMRT required more time than others, because it need separate time for dose optimization for each OARs and PTV and for calculation.

The 3DCRT and FiF-FP-IMRT plan gives the good homogeneity index and conformity index, where as the IP-IMRT had less HI, but good conformity index. The 3DCRT and FP-IMRT plans were equal to spare the critical organs, it can be seen that the DVHs for the critical structures.

However the mean volume of ipsilateral lung receiving 20 Gy and the mean volume of heart receiving < 25 Gy were lower for the 3DCRT and FiF-FP-IMRT. In IP-IMRT results more dose to lung and heart. In FiF-FP-IMRT had anterior field and posterior oblique field, this gives the max dose to the spine 35 Gy, where as liver receiving less than 18 Gy from 3DCRT and FiF-FP-IMRT plans.

Many reports proposed a series of contra lateral breast dose-volume thresholds (V0.05Gy, V0.6Gy, V2.0Gy, and the mean dose) which could help as the maximum dose. The treatment times 10-30 minutes and 25-45 minutes could increase considerably for someone with less experience. Hot spots in the IP-IMRT plans have some entailment in cosmetic outcomes.[10]

The ahead specified facts objectively bring out the fact that the IP-IMRT is not suitable for breast irradiation because of increases planning time, required for more MU, advanced planning skills, increased max dose (Dmax) in PTV, over dose to contra lateral breast, contra lateral lung, ipsi lateral lung, heart and liver dose and island of hot spots. Hence, it is summarized that, compared with the 3DCRT and IP-IMRT, the FiF-FP-IMRT is a simple and effective planning techniques for post mastectomy breast irradiation. It gave dosimetric advantages and minimally increasing mean dose to the planning target volume. In addition less experience is enough plan the FiF-FP-IMRT no dependent on planner’s skills.

**CONCLUSION**

The FiF-FP-IMRT plan technique is very simple and easy to plan for a post mastectomy breast irradiation. The correlation with the 3DCR and IP-IMRT, the FiF-FP-IMRT is effective to reduce the hot spot and increase radiation dose to the planning target volume, for critical organ reduced dose optimally. This plan technique is user friendly and reducing the treatment time.

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**CONFLICT OF INTEREST**

The authors declared no conflict of interest.

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**REFERENCES**


8. Murthy KK, Sivakumar SS, Davis CA, Ravichandran R, El...


