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Original Research

# Dosimetric Comparison of IMRT Versus 3DCRT for Post-mastectomy Chest Wall Irradiation: An Analytical Observational Study

*Tavseef Ahmad Tali* — 1 Senior Resident Radiation Oncology Sheri Kashmir Institute of Medical Sciences, Srinagar, India.
*Fiza Amin* — Senior Resident Gynaecology & Obstetric SKIMS Medical College Srinagar, India.
*Javaid Ahmad* — Senior Resident Cardiology AIIMS New Delhi, India.
*Aijaz Ahmad Khan* — RSO, Radiological Physics and Engineering, Sheri Kashmir Institute of Medical Sciences, Srinagar, India.

**Purpose:** To compare the dose distribution of three-dimensional conformal radiation therapy (3DCRT) with intensity-modulated radiation therapy (IMRT) for post-mastectomy radiotherapy (PMRT) to left chest wall.
**Materials and Methods:** 30 post-MRM female breast cancer patients with histologically confirmed infiltrating ductal carcinoma of unilateral left breast without evidence of distant metastasis or second malignancy were found eligible during January 2017 to December 2021. All patients received 45 Gy in 20 fractions. Planning target volume (PTV) parameters -$D_2$, $D_{98}$, Dmean, $V_{95}$, and $V_{107}$—homogeneity index (HI), and conformity index (CI) were compared. The mean doses of lung and heart, percentage volume of ipsilateral lung receiving 5 Gy ($V_5$), 20 Gy ($V_{20}$), and 49 Gy ($V_{49}$) and that of heart receiving 5 Gy ($V_5$), 25 Gy ($V_{25}$), and 42 Gy ($V_{42}$) were extracted from dose-volume histograms and compared.
**Results:** PTV parameters were comparable between the two groups. CI was significantly improved with IMRT (1.118 vs. 1.224, $p < 0.04$) but HI was similar (0.0951 vs. 0.0962, $p = 0.125$) compared to 3DCRT. IMRT in comparison to 3DCRT significantly reduced the high-dose volumes of lung ($V_{20}$, 24.52% vs. 29.62%; $V_{49}$, 3.56% vs. 6.42%; $p < 0.001$) and heart ($V_{25}$, 5.89% vs. 8.24%; $V_{42}$, 1.64% vs. 6.12%; $p < 0.001$); mean dose of lung and heart (10.21 vs. 11.96 Gy and 3.86 vs. 7.42 Gy, respectively; $p < 0.001$).
**Conclusions:** For left sided breast cancer, IMRT significantly improves the conformity of plan and reduce the mean dose and high-dose volumes of ipsilateral lung and heart compared to 3DCRT, but 3DCRT is superior in terms of low-dose volume.

## Introduction

Breast cancer is the most common cancer in females, both worldwide and in India [1]. In contrast to Western world, most of the patients here present with advanced stage due to lack of mass screening programmes and awareness; so modified radical mastectomy (MRM) is performed more often than breast conservative surgery (BCS).

Large prospective trials [2] and a meta-analysis [3] have shown that adjuvant radiotherapy of the chest wall improves local control and survival in node positive breast cancer patients after mastectomy. Intensity-modulated radiation therapy (IMRT) has proved to be superior to three-dimensional conformal radiation therapy (3DCRT) in various sites like head and neck, central nervous system, lung, prostate, etc.

In case of chest wall irradiation, lung and heart remain two most important vital organs, irradiation of which always causes concern to radiation oncologists. This becomes even more complicated as most of the chemotherapeutic agents used to treat breast carcinoma like anthracyclines, taxanes and trastuzumab, possess cardiotoxic potential. IMRT directs radiation at the breast tumor and modulates the intensity of the radiation beams with laser accuracy, helping to spare healthy tissue surrounding the breast tumor. IMRT allows each dose of radiation to be custom-tailored according to the exact geometrical shape of the breast tumor [4].

Randomized, retrospective and population based studies have shown that the radiotherapy of the chest wall is associated with a significantly increased risk of cardiac morbidity and mortality [3, 5-16]. Data on the effect of IMRT of the chest wall in post-mastectomy breast cancer patients are scarce in the literature [17-19]. So the present study was carried out at our department to compare the dosimetry in post-MRM patients of left breast with IMRT and 3DCRT.

# Materials and Methods

30 post-MRM female breast cancer patients with histologically confirmed infiltrating ductal carcinoma of unilateral left breast without evidence of distant metastasis or second malignancy were found eligible during January 2017 to December 2021. All patients were immobilized using a thermoplastic mould in supine position over a breast board fixed on the couch with both arms extended above their head onto arm rests, abducted and externally rotated. Scar sites, drain sites and breast borders were marked using lead markers. Patients were simulated using a 16 slice somatom computed tomography (CT) simulator wit 6 MV beam. The 3-mm CT cuts were taken once optimal patient position was confirmed. Supraclavicular fossa (SCF) was irradiated when there was histopathological evidence of 1 or more axillary node metastases, inadequate lymph node dissection (less than 10 nodes examined pathologically) or when neoadjuvant chemotherapy was administered prior to definitive surgery. The clinical target volume (CTV) was contoured according to the Radiation Therapy Oncology Group (RTOG) breast cancer atlas guidelines [20]. The Planning Target Volume (PTV) was then generated by giving 1 cm margin to CTV. Organs at risk (OAR) contoured included heart, lung, spinal cord, esophagus and contralateral breast. 15 patients were treated with 3DCRT and 15 with IMRT with dose of 45 Gy in 20 fractions with 2.25 Gy per fraction, 1 fraction per day for 5 days per week.

## Dosimetric Analysis

Planning target volume (PTV) parameters $D_2$, $D_{98}$, Dmean, $V_{95}$, and $V_{107}$, homogeneity index (HI), and conformity index (CI) were compared. The mean doses of lung and heart, percentage volume of ipsilateral lung receiving 5 Gy ($V_5$), 20 Gy ($V_{20}$), and 49 Gy ($V_{49}$) and that of heart receiving 5 Gy ($V_5$), 25 Gy ($V_{25}$), and 42 Gy ($V_{42}$) were extracted from dose-volume histograms and compared.

HI was defined as the difference between the near-maximum and near-minimum dose normalised to the median dose,

$HI=D_2-D_{98}/D_P$

where $D_2$ and $D_{98}$ are the dose received by 2% and 98% volume of PTV; and Dp is the prescribed dose. The ideal value is zero; an HI value approaching zero indicates a more homogenous dose distribution within the PTV and it increases as homogeneity decreases. CI was defined as the ratio of volume of tissue receiving at least 95% of the prescribed dose divided by the volume of the PTV. The closer the CI to one, the more conformal is the plan.

## Statistical Analysis

For statistical analysis, all data were recorded and analysed on Microsoft Excel 2007 and Statistical Package for Social Sciences (SPSS) version 20.0 (IBM Corp., Armonk, New York, USA). The t-test for two independent means was used for quantitative data. The p-value reports were two tailed and an alpha level of 0.05 was used to assess statistical significance.

# Results

Baseline patient and tumor characteristics were found to be comparable between the two groups. PTV parameters are shown in Table 1.

| Parameter | 3DCRT | | IMRT | | P-value |
|---|---|---|---|---|---|
| | mean | sd | mean | sd | |
| PTV volume (cc) | 815 | 12.2 | 804 | 6.8 | 0.01 |
| D2 (Gy) | 47.82 | 1.09 | 47.64 | 1.01 | 0.18 |
| D98 (Gy) | 43.36 | 0.86 | 43.24 | 0.92 | 0.12 |
| D MEAN | 45.56 | 1.12 | 45.45 | 1.06 | 0.11 |
| V 95 (%) | 97.8 | 1.6 | 98.1 | 1.2 | 0.57 |
| V 107 (%) | 2.24 | 0.98 | 1.86 | 0.94 | 0.29 |
| Homogeneity Index | 0.0962 | 0 | 0.09 | 0 | 0.13 |
| Conformity index | 1.224 | 0 | 1.118 | 0 | 0.04 |

**Table 1. Dosimetric Analysis of Parameters for PTV.**

Values are presented as mean ± 1 standard deviation(sd). PTV, planning target volume; 3DCRT, three-dimensional conformal radiation therapy; IMRT, intensity-modulated radiation therapy; CTV, clinical target volume; $D_2$ and $D_{98}$, the dose delivered to 2% and 98% of PTV; Dmean, mean dose of PTV; $V_{95}$ and $V_{107}$, volume of PTV receiving greater than 95% to 107% of prescribed dose.

It can be seen that although CI was significantly improved with IMRT (1.118 vs. 1.224, $p < 0.04$) compared to 3DCRT, HI was similar (0.0951 vs. 0.0962, $p = 0.125$). No significant difference was noted between $D_2$, $D_{98}$, Dmean, $V_{95}$ and $V_{107}$ with the two techniques. Dosimetric parameters for lung and heart are shown in Table 2.

| Parameter | 3DCRT | | IMRT | | P-value |
|---|---|---|---|---|---|
| | mean | sd | mean | sd | |
| V5 (%) | 52.09 | 6.12 | 58.42 | 4.28 | 0.002 |
| V20 (%) | 29.62 | 2.52 | 24.52 | 1.68 | 0.001 |
| V49 (%) | 6.42 | 1.12 | 3.56 | 1.24 | 0.001 |
| D MEAN (Gy) | 11.96 | 1.86 | 10.21 | 1.94 | 0.017 |
| HEART | | | | | |
| V5 (%) | 21.62 | 1.89 | 26.54 | 4.2 | 0.003 |
| V25 (%) | 8.24 | 0.75 | 5.89 | 0.91 | 0.001 |
| V42 (%) | 6.12 | 0.94 | 1.64 | 0.35 | 0.001 |
| D MEAN(Gy) | 7.42 | 0.98 | 3.86 | 0.89 | 0.001 |

**Table 2. Dosimetric Analysis of Parameters for Lung and Heart.**

Values are presented as mean ± 1 standard deviation. 3DCRT, three-dimensional conformal radiation therapy; IMRT, intensity-modulated radiation therapy; Vx, volume of tissue receiving x Gy; Dmean, mean dose

For lung, IMRT in comparison to 3DCRT significantly reduced the high-dose volumes ($V_{20}$, 24.52% vs. 29.62%; $V_{49}$, 3.56% vs. 6.42%; $p < 0.001$) and the mean dose (10.21 Gy vs. 11.96 Gy, $p < 0.001$).

Similarly for heart also, IMRT in comparison to 3DCRT significantly reduced the high-dose volumes ($V_{25}$, 5.89% vs. 8.24%; $V_{42}$, 1.64% vs. 6.12%; $p < 0.001$) and the mean dose (3.86 Gy vs. 7.42 Gy, $p < 0.001$). However, 3DCRT proved to be superior to IMRT in terms of low-dose volume for both the lung ($V_5$, 52.09% vs. 58.42%; $p < 0.001$) and the heart ($V_5$, 21.62% vs. 26.54%; $p < 0.001$).

# Discussion

Data about the impact of IMRT on the adjuvant radiotherapy of the chest wall in postmastectomy patients are scarce in the literature. This study was undertaken to evaluate the dose distribution of IMRT of the chest wall compared to 3D-CRT in postmastectomy breast cancer patients. Fiorentino et al. [21] compared 3DCRT and 4-fields IMRT treatment plans, in terms of target dose coverage, integral dose and dose to organs at risk (OARs) in early breast cancer and concluded 4-fields IMRT technique significantly reduced the dose to OARs and normal tissue, with a better target coverage compared to 3DCRT.

All our plans had the PTV95% coverage values of >95% of prescription dose. In literature [22,23], various planning studies have shown the PTV95% coverage values ranging from 90% to 97%. Hong et al. have showed that the use of equally spaced gantry angles not only improves HI and CI but also reduces the volume of critical normal tissues [24]. In the present study, statistically significant improvement was noted in CI with IMRT compared to 3DCRT (1.127 vs. 1.254, $p < 0.001$) [25,26]. However, no significant difference was noted in HI (0.094 vs. 0.096, $p = 0.83$). Similar results have been reported by Moorthy et al. [26] (CI,0.14vs.0.18,p=0.01;HI,1.01vs.1.03,p=0.45)andRudat etal.[26](CI, 0.32vs. 0.25,p=0.03; HI, 0.73vs. 0.77,p>0.05).

However, Li et al. [27] concluded that IMRT neither significantly improved CI (1.42 vs. 1.41, $p = 0.13$) nor HI (0.13 for both groups, $p = 1.0$); whereas Beckham et al. [28] concluded that IMRT significantly improved not only CI (0.91 vs. 0.48, $p < 0.05$) but also HI (0.95 vs. 0.74, $p < 0.05$).

Moorthy et al. [25] concluded that IMRT in comparison to 3DCRT had significantly lower V40 heart (2.13% vs. 7.5%) and Dmax left anterior descending artery (29.17 Gy vs. 39.5 Gy, $p < 0.05$). Rudat et al. [26] concluded that tangential beam IMRT statistically significantly reduced the V55 by an average of 43% (5.7% vs. 10.6%) and the mean heart dose by an average of 20% (7.04 Gy vs. 8.77 Gy, $p = 0.03$). Beckham et al. [28] concluded that IMRT significantly reduced volume of the heart receiving more than 30 Gy (V30 heart, 1.7% vs. 12.5%).

In conclusion, IMRT for the irradiation of the chest wall in post-mastectomy left sided breast cancer patients offers the potential to significantly reduce the mean dose and high-dose volumes of the ipsilateral lung and heart compared to 3DCRT ($p < 0.001$). IMRT significantly improves the conformity of the plan ($p < 0.001$) but the homogeneity remains similar with the two techniques ($p = 0.83$).

*Conflict of interest*

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