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Research Article

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Dosimetric comparison of Volumetric Modulated Arc Therapy and Three-Dimensional Conformal Radiotherapy during Post Mastectomy left chest wall Irradiation

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Abstract

Aims: *To dosimetrically evaluate the Volumetric Modulated Arc Therapy (VMAT) technique and compare it with Three-Dimensional Conformal Radiotherapy (3D-CRT) for postmastectomy breast cancer therapy.*

Methods and Material*: Ten consecutively treated left sided breast cancer patients were selected for this study. VMAT plans were generated from each of the patients planning CT and compared with 3D-CRT plans.*

Statistical analysis used: *Two tailed paired t test*

Results: *The VMAT technique provided statistically significant homogenous and conformal dose distribution with mean HI of (0.1±0.02) and mean CI of (1.1±0.06) when compared mean HI of (0.3±0.02) and mean CI of (1.7±0.2) in the 3D-CRT technique. VMAT plans showed reduced V30 of the heart (10±4.54) when compared to 3D-CRT plans (15.1±8.53). Except V30, VMAT plans resulted in higher doses to heart. The mean doses received by left lung was (17.50±6.27) and was significantly higher than that of 3D-CRT plans (10.20±3.72). VMAT plans also gave higher doses to the contralateral lung and the opposite breast.*

Conclusions: *VMAT plans in post mastectomy breast cancers provide more homogenous and conformal plans as compared to 3DCRT plans but higher doses to normal tissues.*

Keywords: Three-Dimensional Conformal Radiotherapy, Volumetric Modulated Arc Therapy, Post mastectomy chest wall irradiation.

Key Messages: Though VMAT technique results in more homogenous and conformal plans, it should be used in selected patients keeping the normal tissue constraints in mind.

Introduction

Breast cancer is the commonest cancer among females in India and worldwide. Majority of the patients present with locally advanced tumors at diagnosis. Postmastectomy radiotherapy to the chest wall is the standard treatment for all locally advanced breast cancers [1,2]. The target volume i.e. chest wall is convex, thin, irregular and close to lungs and heart. Radiotherapy treatment is associated with morbidity of the heart, lung, subcutaneous tissue, skin and a risk of secondary malignancies [3-10]. Various studies have shown IMRT technique to be superior to the conventional 3D-CRT in target volume dose coverage and sparing of normal tissue [11-13]. However, a disadvantage of IMRT over 3D-CRT is the long treatment duration owing to the higher number of fields and monitor units (MUs) involved. In addition, although IMRT reduces the volume of the heart and ipsilateral lung that receive high doses, it is associated with an increase in overall low-dose radiation. Also, the utilization of IMRT has its share of demerits due to set up and respiratory motion uncertainties. Hence, despite the available clinical data, the wider use and specific indications for IMRT in breast cancer have not been established.

In volumetric modulated arc therapy (VMAT), a technical extension of conventional fixed-field IMRT, an optimized dose distribution is possible with a single gantry rotation. VMAT reduces the number of MUs and treatment delivery time, with similar or better planning target volume (PTV) coverage and sparing of organs at risk (OARs) than IMRT. Reports on VMAT for breast cancer are few [14-19]. The present study was aimed to dosimetrically evaluate the VMAT technique and compare it with 3D-CRT for postmastectomy breast cancer therapy.

Subjects and Methods

Ten consecutively treated left sided breast cancer patients were selected for this study. All patients were previously treated with chest wall radiotherapy using conventional 3D-CRT. Patients were

set up on a breast board with arms raised above head and head turned towards opposite side of the treatment side. Planning images were acquired on a CT simulator with 5mm slice thickness. Images were transferred to the Eclipse Planning System version 11.1 (Varian Medical Systems, Palo Alto, CA).

Target volume

The clinical target volume (CTV) of chest wall was delineated according to Radiation therapy oncology group (RTOG) breast cancer consensus definitions. A margin of 5 mm was added to CTV to generate PTV to account for set up error and intrafraction motion due to respiration. PTV was retracted 3mm from the skin surface. The organs at risk were also defined. The heart contour extended from the inferior aspect of the pulmonary artery trunk through the cardiac apex. The ipsilateral and contralateral lungs were contoured. The contralateral breast was outlined. A dose of 50 Gy in 25 fractions was prescribed to PTV. Beam energy of 6MV was used for all planning.

Tangential Beam 3D-CRT Planning

Tangential beams, physical wedges (usually 15°) and multileaf collimators were used for planning. Gantry angles ranged from 300-310 for medial tangential field and for 120-130 for lateral tangential field for left chest wall treatment. Fields extended 2cm beyond the chest wall surface to account for respiratory motion. Plans were optimized for adequate PTV coverage while minimizing dose to ipsilateral lung and heart.

VMAT planning

1 cm bolus was added to the surface of chest wall to manage the dose to the skin due to megavoltage build up region and displacement of the chest wall due to respiration. The plans were optimized such that 95% of the PTV received the prescription dose. 95% of the prescription dose is received by 99% of PTV. Also, less than 20% of ipsilateral lung should receive 20 Gy, less than 10% of the heart to receive 30 Gy. 2 partial arcs (gantry rotated from 310 to 150 degrees) and 15 degree collimator rotation were utilized to generate the VMAT plans. These angles were chosen to avoid direct irradiation of the contralateral lung and breast, spinal cord. The DVHs of the PTV, lungs, heart and contralateral breast were acquired.

Plan evaluation

For dosimetric analysis, the following indices were extracted from dose-volume histograms (DVHs). For the target, following parameters were calculated. D98% or $D_{near\text{-}min}$ (the dose received by 98% of the target volume, D2% or $D_{near\text{-}max}$ (the dose received by 2% of the target volume), mean dose, dose homogeneity index (HI), V110%, V 107% (percentage of the PTV receiving 110% and 107% of the prescription dose) and conformity index. D98% and D2% were used to evaluate the minimal and maximal dose to the target, respectively.

HI and CI were calculated according to definition proposed by the International Commission on Radiation Units and Measurements (ICRU) and expressed as follows [21]:

$$HI = \frac{D2\% - D98\%,}{D50\%}$$

Where D2%, D98% and D50% are the dose covering 2% , 98% and 50% of the PTV volume.

$$CI = \frac{\text{Volume receiving at least 95\% of the prescribed dose}}{\text{Volume of PTV}}$$

Ipsilateral lung V5, V10, V20 and Dmean, contralateral lung V5 and Dmean, heart V5, V10, V30 and Dmean, contralateral breast V5 and Dmean were calculated and compared.

Statistical Analysis

The results were represented as mean ± standard deviation (SD). Statistical analysis was performed using Microsoft XL version 13. The datasets were compared using two tailed Paired t test. The p value less than 0.05 was considered statistically significant.

Results

Target coverage

The comparative dose coverage of PTV has been shown in **Table 1** and depicted in **(Figure 1)**. The difference in the maximum dose to PTV ($D_{2\%}$) and minimum dose to PTV ($D_{98\%}$) were statistically significant ($p<0.01$). The VMAT technique provided statistically significant homogenous and conformal dose distribution with mean HI of (0.1±0.02) and mean CI of (1.1±0.06) when compared mean HI of (0.3±0.02) and mean CI of (1.7±0.2) in the 3D-CRT technique. The mean dose received by PTV was 50 Gy while that with 3D-CRT was (45.20±2.98) Gy and the difference was statistically significant ($p< 0.05$). The hot spots were also significantly lower in VMAT technique. p values for V107% and V110% were 0.002 and 0.04 respectively favouring VMAT technique. The mean MU delivered by VMAT plans was (642.8±54.6) which statistically higher than that delivered by 3D-CRT plans which was (251.20±11.29) (<0.001) [Table 1].

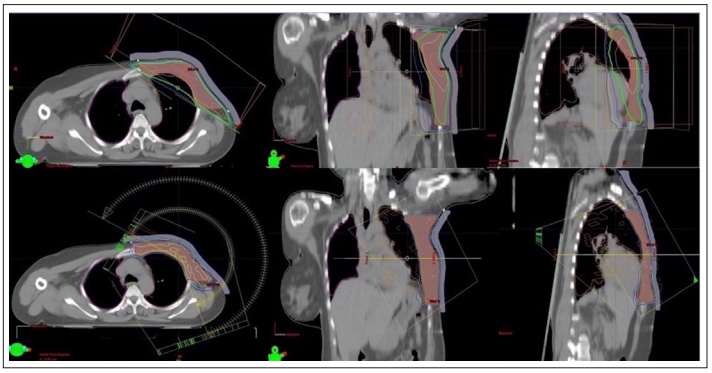

Figure 1: Showing axial, coronal and saggital images comparing 3DCRT and VMAT.

Table 1: PTV coverage based on DVH analysis.

PARAMETER	3DCRT	VMAT	P value
D 2% (Gy)	54.1 ± 0.67	52.2 ± 0.23	<0.01
D 98% (Gy)	40.4 ± 0.85	46.2 ± 0.74	<0.01
HI	0.3 ± 0.02	0.1 ± 0.02	<0.001
CI	1.7 ± 0.22	1.1 ± 0.06	<0.01
Mean (Gy)	45.2 ± 2.98	50	<0.05
V110%	0.8 ± 0.96	0	0.04
V107%	4.5 ± 3.32	0.1 ± 0.13	0.002
MU	251.2 ± 11.29	642.8 ± 54.61	<0.001

Normal tissue sparing

In terms of the doses to the heart for the two treatment techniques, VMAT plans showed reduced V30 of the heart (10±4.54) when compared to 3D-CRT plans (15.1±8.53) which were statistically significant (p=0.02). VMAT plans gave higher mean, V5 and V10

doses to the heart. For the lung, the VMAT plans had higher V20 values as compared to 3D-CRT plans (32.40±7.45 vs 19.70±4.62) and also higher V10, V5 values. The mean doses received by left lung was (17.50±6.27) and was significantly higher than that of 3D-CRT plans (10.20±3.72) (p=0.01).

VMAT plans gave higher mean (8.20±0.97 Gy vs 0.4±0.15 Gy) and V5 doses to the right lung, as compared to 3D-CRT (76.90±11.76 vs 0.04±0.1). The mean dose to the contralateral breast was higher in VMAT plans (3.2±0.43 Gy) when compared to 3D-CRT plans (1.2±0.79 Gy) (<0.001). The mean MU delivered by VMAT plans was (642.8±54.6) which statistically higher than that delivered by 3D-CRT plans which was (251.20±11.29) **[Table 2]**.

Table 2: Comparison parameters of normal tissue with 3DCRT and VMAT.

PARAMETER	3DCRT	VMAT	P value
Heart			
Mean (Gy)	9.3 ± 4.25	14.6 ± 2	0.001
V 30 (%)	15.1 ± 8.53	10 ± 4.54	0.02
V 10 (%)	18.1 ± 9.23	54.3 ± 8.8	<0.01
V 5 (%)	23.9 ± 10.23	98.4 ± 2.48	<0.001
Left lung			
Mean (Gy)	10.2 ± 3.72	17.5 ± 6.27	0.01
V 20 (%)	19.7 ± 4.62	32.4 ± 7.45	0.003
V 10 (%)	23.7 ± 3.05	64.4 ± 10.33	<0.01
V 5 (%)	30.8 ± 3.41	98.3 ± 0.82	<0.001
Right lung			
Mean (Gy)	0.4 ± 0.15	8.2 ± 0.97	<0.001
V 5 (%)	0.04 ± 0.1	76.9 ± 11.76	<0.001
Opposite breast			
Mean (Gy)	1.2 ± 0.79	3.2 ± 0.43	<0.001

Discussion

There have been many studies comparing VMAT technique to IMRT for treating post breast conservation surgery patients [21,22]. They have concluded that IMRT technique is better than VMAT in terms of normal tissue sparing, though VMAT is superior in target coverage. Zhang et al. in their study compared VMAT versus IMRT in post mastectomy patients and concluded that VMAT was similar or superior to IMRT in terms of target coverage.[23] In our study we have dosimetrically compared VMAT and 3D-CRT techniques to know the true benefit. In terms of planning target volume coverage, VMAT plans were definitely better than 3D-CRT plans in our study also as discussed above. VMAT plans were more homogenous and conformal.

In terms of sparing the normal tissues VMAT plans did not have any great advantage over 3D-CRT plans. The high incidence rates and long term survival rate of breast cancer patients makes the toxicity of radiation treatment an important issue during treatment. In our study only heart V30 was reduced when compared to the 3D-CRT plans. But, Heart V5, V10 and mean doses were higher. Several studies have reported incidences of radiation induced cardiac diseases when heart receives more than 35-40Gy and reduction of V40 would reduce heart toxicities [22,23]. Also, ipsilateral lung mean dose, V5, V10 and V20 was higher in VMAT plans. Contralateral lung also received higher doses in VMAT plans when compared to 3D-CRT plans. Hence, in terms of sparing the heart or lung, VMAT plans did not show any great advantage except reducing heart V30.

The delivery of low dose irradiation to healthy tissue, especially to the contralateral breast has been shown to increase the risk of secondary breast cancer [8]. VMAT plans delivered higher doses to the opposite breast also. Our results are comparable to study by Badakhshi et al. in 2013, who evaluated VMAT technique for post breast conservation patients. They concluded that VMAT was inferior to 3D-CRT with regard to dose distribution to organ at risk, especially at low dose level, and therefore VMAT is not recommended for treatment of breast cancers [24].

In our study contours, we have not included the supraclavicular or the internal mammary nodal region and their inclusion in the treatment volumes, which is often required, will further increase the lung and heart doses. When internal mammary nodal region has to be covered, 3D-CRT techniques may also give high lung dose with compromised target coverage. In such a situation VMAT might have an upper hand. In cases where the posterior extent of target volume is extending beyond the mid axillary line, VMAT plans could be better. VMAT will be helpful for cases where 3D-CRT is not giving proper dose distribution due to variation in chest wall shape and also giving high lung or heart doses. Hence, VMAT technique should be used on selected patients keeping the normal tissue constraints in mind.

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