Volume 9, Issue 7, July – 2024
International Journal of Innovative Science and Research Technology
ISSN No:-2456-2165
https://doi.org/10.38124/ijisrt/IJISRT24JUL1127

Dosimetric Comparison of Synchronous Bilateral Breast Cancer Treatments: Volumetric Modulated Arc Therapy vs. Three-Dimensional Conformal Radiotherapy

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Abstract:- This study compares the dosimetric parameters of Volumetric Modulated Arc Therapy (VMAT) and Three-Dimensional Conformal Radiotherapy (3DCRT) in patients with synchronous bilateral breast cancer (SBBC). Five patients who underwent modified radical mastectomy and axillary lymph node dissection were included in the study. The plans for VMAT and 3DCRT were evaluated based on dose distribution and protection of critical organs at risk (OARs). The results indicate that VMAT provides superior target volume coverage and better protection of OARs compared to 3DCRT.

I. INTRODUCTION

Breast cancer ranks as the foremost cancer among women, with 2,261,419 new cases diagnosed worldwide annually (1).

Synchronous bilateral breast cancer (SBBC) remains rare, yet the number of SBBC diagnoses has shown an increasing trend alongside rising breast cancer cases (2).

The radiotherapy planning and dose administration for SBBC are deemed lengthier and more complex processes compared to unilateral breast cancer (UBC), as it necessitates a broader distribution of the treatment volume. The treatment volume is closer to the skin than other treatment sites and significantly nearer to the lungs and heart (3,4,5).

Various techniques have been employed for SBBC radiotherapy, including two-dimensional radiotherapy (2DRT) or three-dimensional conformal radiotherapy (3DCRT) with tangential beam irradiation (3, 4, 6, 7). Recent trends indicate the application of intensity-modulated radiotherapy (IMRT) and volumetric modulated arc therapy (VMAT)(7, 8, 9). However, there is a limited amount of data comparing 3DCRT and VMAT treatment plans for SBBC (10 ,11,12).

This study developed 3D and VMAT treatment plans for the same SBBC patients with the aim of comparing these two treatment techniques in terms of dose distribution and organ-at-risk (OAR) protection.

II. METHODS

A. Patients, Delineation, and Prescription

In total, five patients diagnosed with SBBC confirmed histologically with ductal or lobular carcinoma, and who underwent modified radical mastectomy (MRM) with positive axillary lymph node dissection, were included in the study.

All patients underwent a dosimetric CT scan in the supine position with both arms raised, with a slice thickness of 3.0 mm and free breathing. The target volumes were defined according to the criteria of the European Society for Radiotherapy and Oncology (ESTRO) (13)

The planning target volumes (PTVs) were derived by expanding 5 mm in all directions from the clinical target volumes (CTVs) and were constrained to maintain a skin gap (trim) of 3-5 mm from the surface.

The prescribed dose for both 3DCRT and VMAT was 42 Gy delivered in 15 fractions at 2.8 Gy per fraction for the PTV T (chest wall) and PTV N (supraclavicular region and axilla).

Given the absence of a distinct treatment protocol for bilateral breast cancer, we adhered to the strictest dose constraints outlined by the Danish Breast Cancer Group (14). These constraints aimed to achieve 95% of the prescribed dose covering 95% of the PTV ($V95\% \geq 95\%$) while ensuring a maximum dose not exceeding 110% of the prescribed dose ($D_{max} \leq 110\%$, $V107\% \leq 2\%$).

Regarding organ-at-risk constraints, for the lungs, dose constraints were set as $V17Gy \leq 25\%$, $V26Gy < 20\%$, and for the heart, $V17Gy \leq 10\%$, with a mean dose <4Gy.

No bolus was utilized in any of the treatment plans.

B. Planning Technique

3D and VMAT treatment plans were generated for each patient using the Monaco Treatment Planning System (TPS).

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24JUL1127

The plans were calculated by applying the beam data from an Elekta Synergy linear accelerator.

All of the treatment plans were delivered using a 6-MV photon beam.

C. Evaluation Tools

The plans were evaluated using dose-volume histogram (DVH) analysis. (Fig 1,2)

For the PTV, maximum doses and values of V95% and V107% (the volumes receiving at least 95% and 107% of the prescribed dose, respectively) were reported.

Regarding the organs at risk, mean doses and VxGy analysis (volume of the OAR receiving X Gy) were compared based on the organ. Specifically, V26Gy and V17Gy for the lungs, and V17Gy along with the mean dose for the heart, were analyzed and compared.

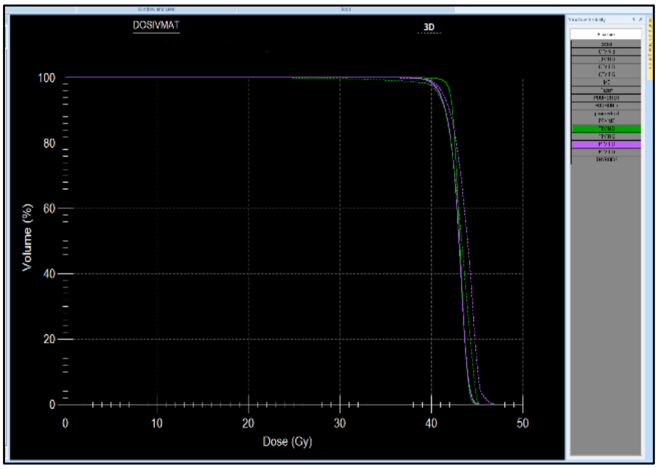

Fig 1: Dose-Volume Histograms of the PTV in VMAT and 3DCRT

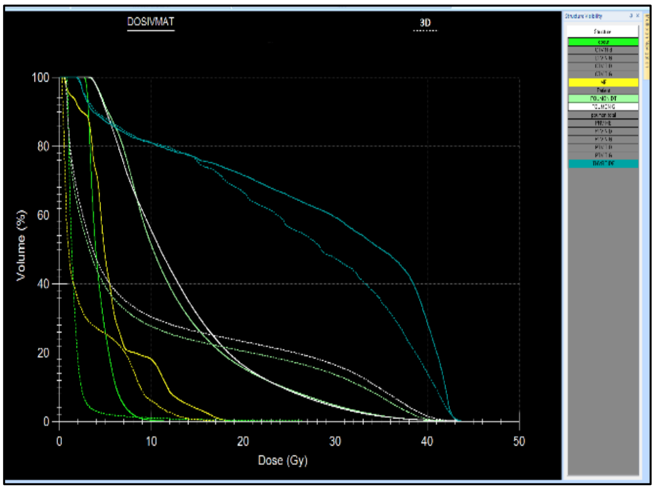

Fig 2: Dose-Volume Histograms of the OARs in VMAT and 3DCRT

III. RESULTS

The mean volumes of the left PTV were 680.1 cm³ ± 269.45, and for the right PTV, it was 732.05 cm³ ± 297.8.

The mean lung volumes were 986.9 cm³ ± 202.3 for the left lung and 1238.4 cm³ ± 211.7 for the right lung. The mean heart volume was 520.6 cm³ ± 101.6.

A. PTV Dose Distribution

The data for the dose distribution to PTV T (breast/chest wall) and PTV N (supraclavicular region and axilla) of the 3DCRT and VMAT plans are summarized in Table 1.

Both VMAT and 3DCRT plans provided similar coverage, with mean values of V95% >97% for both techniques. Hotspots were observed less frequently in VMAT plans compared to 3DCRT plans, where D2% exceeded 107%. (Table.1)

Table 1: Dosimetric Results Achieved in Both the Techniques (VMAT & 3DCRT)

Dose Constraint	**3D CRT**		**VMAT**	
	Right	**Left**	**Right**	**Left**
$V_{95\%} \geq 95\%$ PTV T (chest wall) PTV N (supraclavicular region and axilla)	 99,1% 97,7%	 98,81% 98,56%	 98,61% 99,88%	 98,41% 99,81%
$V_{107\%} \leq 2\%$ PTV T (chest wall) PTV N (supraclavicular region and axilla)	 109,1% 107%	 109,2% 107,2%	 105,8% 105,5%	 106,2% 105,9%
$D_{max} \leq 110\%$ PTV T (chest wall) PTV N (supraclavicular region and axilla)	 112% 107,9%	 113,5% 108,04%	 109,7% 107,8%	 110,6% 108,6%

B. OARs Dose Distribution

It was observed that the VMAT plans achieved lower doses to the lungs compared to the 3DCRT plans, with V26 = 8.22 Gy vs. 16.85 Gy for the right lung, and 7.85 Gy vs. 19.69 Gy for the left lung (Table.2).

However, it was also noted that the 3DCRT plans achieved a lower mean dose to the heart compared to the VMAT plans, 1.72 Gy vs. 4.39 Gy, respectively (Table.2).

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24JUL1127

Table 2: Dosimetric Results of Organs at Risk (OAR) for Both Techniques

Dose Constraint	3D CRT		VMAT	
	Right	Left	Right	Left
Lung $V_{17Gy} \leq 25\%$ $V_{26Gy} \leq 20\%$	 22,06% 16,85%	 24,84% 19,69%	 21,43% 8,22%	 24,04% 7,85%
Heart Mean dose <4Gy $V_{17Gy} \leq 10\%$	 1,72Gy 0,40%		 4,39Gy 0%	

IV. DISCUSSION

SBBC has a huge C-shaped target volume, and the shape and volume of the target can vary greatly. Additionally, the target is closer to the skin and to OARs with large volumes, such as the lungs.

In this study, 3DCRT and VMAT treatment plans for SBBC were developed and then compared regarding dosimetry distribution.

Our study found that VMAT, compared to 3DCRT, showed a similar value for V95% of the PTV, as demonstrated in a similar published study.(10)

However, in terms of OAR doses, it was noticed that the VMAT plans achieved lower doses to the OARs than the 3DCRT plans, except for the heart, as shown in the study by Alsaeed et al. (11), which compared 3DCRT and VMAT treatment plans for SBBC patients and reported that VMAT was superior in all dose characteristics.

The treatment of SBBC using VMAT achieves more effective dose distribution by adjusting the range of arc rotation, which showed improved dose distribution in VMAT plans for the PTV and OARs, in agreement with similar studies (8, 11, 15).

Kim et al. (10) established treatment plans for IMRT and VMAT and compared these plans with 3DCRT. In terms of target and OAR dose distribution, IMRT was superior, whereas VMAT had advantages in terms of treatment efficiency.

Yusoff et al. (7) compared 3DCRT and IMRT treatment plans for SBBC patients and found that both treatment plans showed similar results for PTV coverage, whereas IMRT was superior in OAR dose distributions to the lungs and heart.

The main limitations of the present study were the small sample size, not comparing VMAT plans with IMRT ones, and the limited number of studies comparing 3DCRT and VMAT. Further studies are warranted to compare VMAT with IMRT for the complex treatment volumes in SBBC patients.

V. CONCLUSION

In conclusion, this study illustrates that the VMAT technique can be performed conveniently in SBBC. It improves target volume dose homogeneity, spares normal tissue, and prevents field overlapping issues.

Additional research on the ideal radiotherapy planning techniques should be conducted with a larger participant pool in order to determine common guidelines for SBBC radiotherapy.

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