Radiation Therapy Synchronous Bilateral Breast Cancer—a dosimetric comparison of Volumetric Modulated Arc Therapy (VMAT) and 3D conformal radiation therapy

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Abstract:

Background: We aimed to compare the efficiency for various dosimetric parameters and treatment delivery time for volumetric-modulated arc therapy (VMAT) and 3D conformal radiation therapy (3DCRT) treatment plans for bilateral breast cancer (BBC).
Results: The mean volumes of the CTV were (left) 675.1 cc3 ± 220 and (right) 764.0 cc3 ± 197.8. The considered OARs were the lungs, heart, and liver. The VMAT plans provided a better coverage than the 3DCRT ones, the mean values of V95% for breast/chest wall, SCF and axilla were 93.14%, 99.46% and 98.65% with VMAT and 3DCRT, respectively (p = 0.015, 0.016, and 0.015). Similarly, it was also noticed that the VMAT plans achieved lower mean dose to the lungs than the 3DCRT ones, i.e., 12.3 Gy vs. 30.09 for right (p = 0.001), and 12.75 Gy vs. 28.39 for left (p =0.001). The mean treatment time to deliver two arcs was 4.2 minutes (range, 4.1 to 4.3 minutes) compared to 9.0 minutes (range, 8.7 to 13.2 minutes) for 3DCRT
Conclusions: Comparison between VMAT and 3DCRT showed that the VMAT plans were superior in all dose characteristics. However, further studies are warranted to compare VMAT with IMRT for the complex treatment volumes in BBC patients.

Key words: Synchronous bilateral breast cancer, 3D- conformal radiation therapy, Volumetric Modulated Arc Therapy, dosimetry comparison

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Introduction:

Incidence of synchronous bilateral breast cancer (BBC) is infrequent; however, recent upward trend in the numbers of SBBC imposes a great challenge to radiation therapy delivery. [1,2] Data has shown that BBC, compared with unilateral breast cancer, needs relatively larger distribution of dose volume because of its huge C-shaped volume, affecting the organs at risk (OAR) mainly lungs and heart, which are in vicinity. [3,4] Owing to these dosimetric issues, the radiation therapy plan and dose delivery for BBC remains time-consuming and complicated tasks reflecting poor locoregional control as compared to those for Unilateral Breast cancer (UBC). [5]

To overcome, these dosimetric issues in BBC, novel radiation therapy techniques including intensity-modulated radiation therapy (IMRT) and volumetric-modulated arc therapy (VMAT) have been incorporated. [6,7] However, such techniques are related to issues of isocenter, junction matching and breathing affects. [7] There is scanty data available BBC, comparing conformal radiation therapy (3DCRT) and VMAT treatment plans. [8]

Present study aimed to find an optimal Simultaneous bilateral breast cancer (SBBC) treatment method that also involved outstanding dose distribution with ELEKTA VMAT, a type of volumetric modulated arc therapy. This study established IMRT and VMAT treatment plans for SBBC patients and then compared the plans with 3DCRT. Furthermore, we aimed to confirm numerically the differences among treatments regarding dose distribution and treatment efficiency.

Methods:

Total six patients with BBC with confirmed histological diagnosis of ductal or lobular carcinoma, and who underwent breast conserving surgery (BCS) or modified radical mastectomy (MRM).

All patients underwent Computed tomography (CT) with the patients in supine position with both arms elevated, along with 5.0 mm of slice thickness and free breathing. The clinical target volume (CTV) was defined as the volume that enveloped the whole breast or chest wall, regional lymph nodes and the tumor bed, which was contoured according to radiation Therapy Oncology Group (RTOG) contouring atlas. The CTV was expanded by 1 cm in all directions and was also cropped to have the skin trim of 5 mm from the surface (Fig.1).

The prescribed dose for 3DCRT and VMAT was 40 Gy in 15 fractions at 2.66 Gy per fraction to both CTVs, aiming to achieve 95% of the prescribed dose in 95% of CTV and a maximum dose less than 107% of prescribed dose. The irradiated dose to OARs, such as the lungs, heart, spinal cord and liver were according to QUANTEC guidelines. [9] Bolus was applied for both of the treatment plans. The plans were generated using Oncentra Master Plan version 4.1 (OTP, Nucletron, Veenendaal, The Netherlands) for 3DCRT, using a collapsed cone convolution algorithm for dose calculation with a dose grid of 3.0 mm. The VMAT plans were generated on with the Monaco treatment planning system, version 3.0 (Monaco TPS, CMS, St. Louis, MO) Monaco TPS (Fig.2).

The plans were evaluated by a dose-volume histogram (DVH) analysis, the conformity index (CI), and the homogeneity index of the dose distribution (HI). For the OARs, mean doses and VxGy analysis (OAR volume receiving X Gy), depending upon the organ. The V20Gy, V17Gy and V10Gy for the lungs and V40Gy, V25Gy, V20Gy, and V10Gy for the heart were compared. The V30Gy and V5Gy for liver were also compared. Further, the treatment times (including set-up time), and the monitor units (MUs) for each plan were also compared. Independent T test was used to compare the CTV and OAR values of both techniques. Statistical analyses were performed using SPSS software version 22 (IBM Corp, Armonk, NY). Differences were reported to be statistically significant at $p < 0.05$.

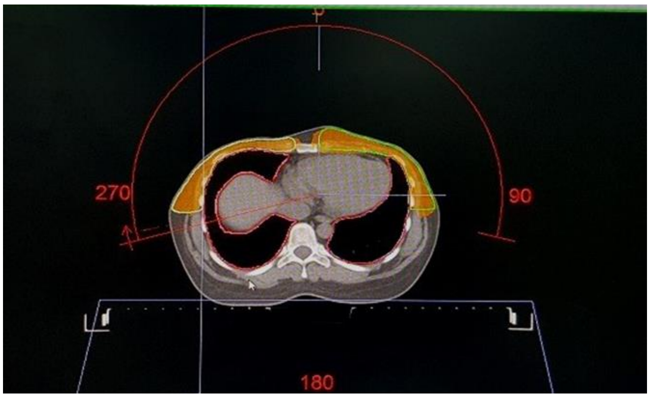

Figure 1: The CTV was expanded by 1 cm in all directions and was also cropped to have the skin trim of 5 mm from the surface

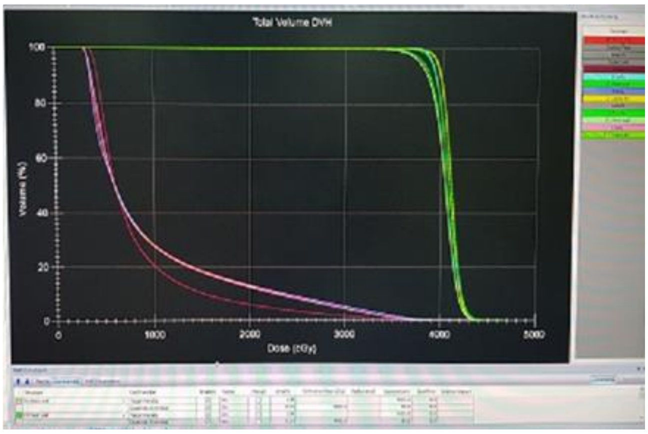

Figure 2: The VMAT plans were generated on with the Monaco treatment planning system, version 3.0 (Monaco TPS, CMS, St. Louis, MO) Monaco TPS

Results:

The mean volumes of the CTV were (left) 675.1 cc3 ± 220 and (right) 764.0 cc3 ± 197.8. The considered OARs were the lungs, heart, and liver. The mean lung volumes were (left) 981.6 cc3 ± 199.3 and (right) 1159.4 cc3 ± 222.0, the mean heart volume was 645.3 cc3 ± 167.6, and the mean liver volume was 2894.1 cc3 ± 210.2.

For the dosimetric comparison data for the smaller PTV (breast/cheat wall, Suprclavicular fossa and axilla)

Internal Mammary nodes (IMN), the VMAT plans provided a better coverage than the 3DCRT ones, the mean values of V95% were 93.14%, 99.46% and 98.65% with VMAT and 3DCRT, respectively (p = 0.015, 0.016, 0.015 respectively). Similarly, the hotspots were observed less in VMAT plans than the 3DCRT plans Table.1 & Fig.3

Similarly, it was also noticed that the VMAT plans achieved lower mean dose to the lungs than the 3DCRT ones, i.e., 12.3 Gy vs. 30.09 for right (p = 0.001), and 12.75 Gy vs. 28.39 for left (p =0.001). Table.2

The mean number of MU for VMAT plans was 473 (range, 402 to 595 MU) compared to 616 (range, 486 to 840 MU) for 3DCRT. The mean treatment time to deliver two arcs was 4.2 minutes (range, 4.1 to 4.3 minutes) compared to 9.0 minutes (range, 8.7 to 13.2 minutes) for 3DCRT.

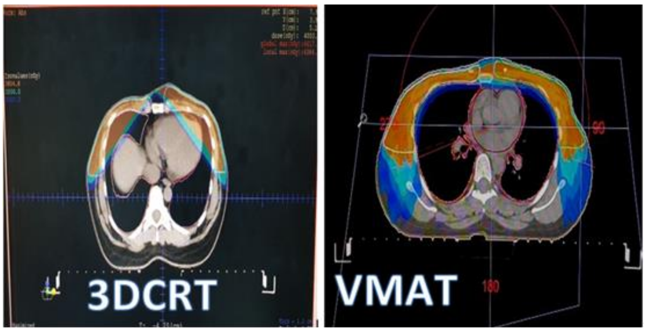

Figure 3: Clour wash of 3DCRT versus VMAT plans

Table.1: Dosimetric results achieved in both the techniques (VMAT & 3CDRT)

Parameter	**VMAT**	**3DCRT**	***P* value**
PTV (breast/chest wall)			
Right			
V95	93.14	88.96	0.015
V90	98.76	93.44	
V108	0.57	8.49	
V110	0.08	0	
Left			
V95	94.76	89.76	0.013
V90	99.06	94.57	
V108	0.66	3.7	
V110	0.08	0	
PTV (SCF)			
Right			
V95	99.46	89.67	0.016
V90	99.89	99.28	
V108	0.78	0	
V110	0.07	0	
Left			
V95	99.46	90.51	
V90	99.94	98.24	0.016
V108	0.82	0	
V110	0.07	0	
PTV (axilla)			
Right			
V95	98.65	89.69	0.015
V90	99.98	100	
V108	1.58	1.28	
V110	0.22	0	
Left			
V95	99.43	93.72	0.014
V90	100	99.55	
V108	0.81	0.62	
V110	0.99	0	
HI	0.12±0.05	0.19 ±0.73	0.033
CI	1.1±0.4	1.73±0.8	0.041

Table.2: Dosimetric results of organs at risk (OAR) for both techniques

Parameter	VMAT	3DCRT	value
Lung			
Right			
Dmean (Gy)	12.3	30.09	0.001
V17Gy (%)	15.48	32.05	
V10Gy (%)	27.84	37.91	
Left			
Dmean (Gy)	12.75	28.39	0.001
V17Gy (%)	15.73	30.09	
V10Gy (%)	27.79	35.44	
Heart			
Dmean (Gy)	4.24	8.73	0.042
V25Gy (%)	3.25	11.42	
V20Gy (%)	5.75	13.06	
V10Gy (%)	20.56	17.06	

Discussion:

Radiation therapy for BBC is challenging owing to its huge C-shaped target volume, and its vicinity to OARs and PTV irregularities. [10] Thus, the 3DCRT planning has shown to be associated with inadequate target coverage, inhomogeneous dose distribution and prolonged treatment time for its delivery. [6,11]

Present study compared the VMAT and 3DCRT treatment plans for six BBC patients, which showed obvious improved dose distribution in VMAT plans using Monaco TPS for the PTV and OARs, which was in agreement with similar studies. [1,5] One study the 3DCRT and IMRT treatment plans for BBC patients. It was reported that both treatment plans showed similar results for PTV coverage, whereas for OAR dose distributions to the lungs and heart, IMRT was superior. [12] In our study, VMAT was not superior in not only PTV coverage but also in OARs doses, conformity and homogeneity indices.

Further, delivery time for VMAT plans were way shorter than for 3DCRT ones, thus reducing setup errors during treatment. There is plenty of data which endorse what shortening of the delivery time could reduce the possibilities of external and internal error and could also affect treatment outcomes. [13]

Main limitations of present study were; (a) small sample size, and (b) not comparing VMAT plans with IMRT ones.

In conclusion, we found that the plan method with the best planning capability for BBC was the VMAT. However, further studies are warranted to compare VMAT with IMRT for the complex treatment volumes in BBC patients.

Conclusion:

Comparison between VMAT and 3DCRT showed that the VMAT plans were superior in all dose characteristics. However, further studies are warranted to compare VMAT with IMRT for the complex treatment volumes in BBC patients.

Abbreviations:

VMAT : volumetric-modulated arc therapy (VMAT).
3DCRT :3D conformal radiation therapy .
BBC :bilateral breast cancer .
DVH :dose-volume histogram
CI :conformity index .
HI: homogeneity index .
OARs: Organs at Risk.
Mus: monitor units
SCF Supraclavicular field
UBC Unilateral breast cancer
SBBC Similtaneous Bilateral breast cancer
BCS breast conserving surgery
MRM Modified Radical Mastectomy.
CT Computed tomography
CTV clinical target volume
RTOG radiation Therapy Oncology Group
VxGy volume receiving X Gy
Mus monitor units
IMN Internal Mammary nodes

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