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Evaluation of 3D-CRT and VMAT Radiotherapy Plans for Left Breast Cancer with Regional Lymph Nodes Irradiation

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Abstract

Introduction: Radiation therapy after breast surgery is an integral part of the treatment of early breast cancer. The goal of radiation therapy is to achieve the best possible coverage of the planning target volume (PTV), while reducing the dose to organs at risk (OARs) which are normal tissues whose sensitivity to irradiation could cause damage that can lead to modification of the treatment plan. In the last decade, radiation oncologist started to use the Intensity Modulated Radiotherapy (IMRT) and Volumetric Modulated Arc Therapy (VMAT) for irradiating the breast, in order to achieve better dose distribution and target dose to the PTV and OAR. The aim of this study is to compare 2 external radiotherapy techniques (VMAT vs 3D) for patients with node-positive left breast cancer. **Patients and Methods:** We randomly selected 10 cases of postoperative radiotherapy for breast cancer in our hospital. The patients are all female, the average age was 45.4 years old, and the primary lesions are left breast. The ANOVA test was used to compare the mean difference between subgroups, and the p value < 0.05 was considered significant. **Results:** Dose volume histogram (DVH) was used to analyze each evaluation dose of clinical target volume (CTV) and organs at risk (OARs). Compared to 3DCRT plans, VMAT provided more uniform coverage to the breast and regional lymph nodes. The max point dose for tVMAT was lower on average (106.4% for VMAT versus 109% for 3DCRT). OAR sparing was improved with tVMAT, with a lower average V17Gy for the left lung (27.91% for VMAT versus 30.04% for 3DCRT, $p < 0.3$), and lower for V28Gy (13.75% for VMAT versus 22.34% for 3DCRT, $p = 0.01$). We also found a lower V35Gy for the heart on VMAT plan ($p = 0.02$). On the contrary, dose of contralateral breast was lower in 3DCRT than VMAT (0.59 Gy vs 3.65 Gy, $p = 0.00$). **Conclusion:** The both types of plans can meet the clinical dosimetry demands of postoperative radiotherapy for left breast cancer. The VMAT plan has a better conformity, but 3CDRT can provide a lower dose to the contralateral organs (breast and lung) to avoid the risk of secondary cancers.

Keywords

Volumetric-Modulated arc Therapy, 3D-Conformal Radiation Therapy, Left Breast Cancer, Target Volumes, Treatment Plan

1. Introduction

Radiation therapy after breast surgery is an integral part of the treatment of early breast cancer. This radiotherapy proved to reduce the local recurrence and the risk of death from breast cancer. But it can also augment the risk of heart disease through the incidental irradiation of the heart, especially in the left sided breast cancer [1].

Conventionally, the 3D-CRT has been one of the typical technique for breast cancer, with tangentials fields and anterior one for those lymph nodes irradiation.

But, ideal plans are not always achievable with the conformal three dimensions plans (3DCRT), so others techniques were developed, using the Intensity Modulated Radiotherapy (IMRT) and Volumetric Modulated Arc Therapy (VMAT) for irradiating the breast, in order to achieve better dose distribution and target dose of both the PTV and OAR [2].

The aim of this study is to compare 3DCRT and VMAT for left breast cancer patients in terms of PTV coverage, OAR constrains by comparing dosimetric parameters.

2. Patients and Methods

1) Case selection: We randomly selected 10 cases of postoperative radiotherapy for breast cancer in our hospital during March 2021 and August 2021. The patients are all females, the average age was 45.4 years old, and the primary lesions are left breast.

2) CT simulation location and target area delineation: patients raised both arms above their heads, and were fixed by the vacuum negative pressure bag. Simulation was performed using the CT simulator (SOMATOM Sensation Open; Siemens, Erlangen, Germany). An intravenous iodine contrast enhanced planning CT with 3-mm slice thick reconstruction was obtained. CT scans ranges from the mandible to the thorax.

The CT DICOM images were transferred to the Monaco treatment planning system version 5.11 (Elekta, Stockholm, Sweden) for target delineation.

CTV included the left breast only or, with lymph node region, and/or boost to the tumor bed. OAR included: ipsilateral and controlateral lung, heart, the spinal cord, contralateral breast.

All delineated by the radiation oncologist, using ELEKTA MONACO treatment planning system (TPS). Planning Target Volume (PTV) were created using 5 mm margin around the CTV.

3) Plan design:

The prescription dose given was 42 Gy, which was irradiated for 15 times, for fractionated dose of 2.8 Gy, 95% of PTV is supposed to receive at least 95% of prescription dose (39.9 Gy). Clinical constraints for hypofractionned breast cancer are as follows:

PTV ≤ 107%, the minimum dose ≥95%, V17Gy < 30% and the V28Gy < 20% for the ipsilateral lung, the maximum dose of the spinal cord Dmax < 40 Gy, V35Gy < 5% for heart and Dmean < 5 Gy, and the contralateral breast should be less as far as possible (Dmean < 2 Gy).

The two radiotherapy plans are as follows (Figure 1):

1) 3D-CRT: using 6 MV X-ray, the plan was created using a mono-isocentric technique. The chest wall was irradiated using two opposing tangential beams, a single anterior field with an angle of 10˚ away from the spinal cord was used to treat the SCF. To ensure adequate PTV coverage and reduce hotspot to less than 107%, the Field-in-Field technique with MLCs was used.

2) VMAT: using 6 MV X-ray, The VMAT plans comprised of two optimized coplanar partial arcs (2P-VMAT), with beam-on gantries rotating clockwise from 180˚ to 292.8˚ through 90˚ and 0˚. All plans were collimated at a 0˚ angle. The chest wall and supraclavicular fossa were treated using the same arc plans.

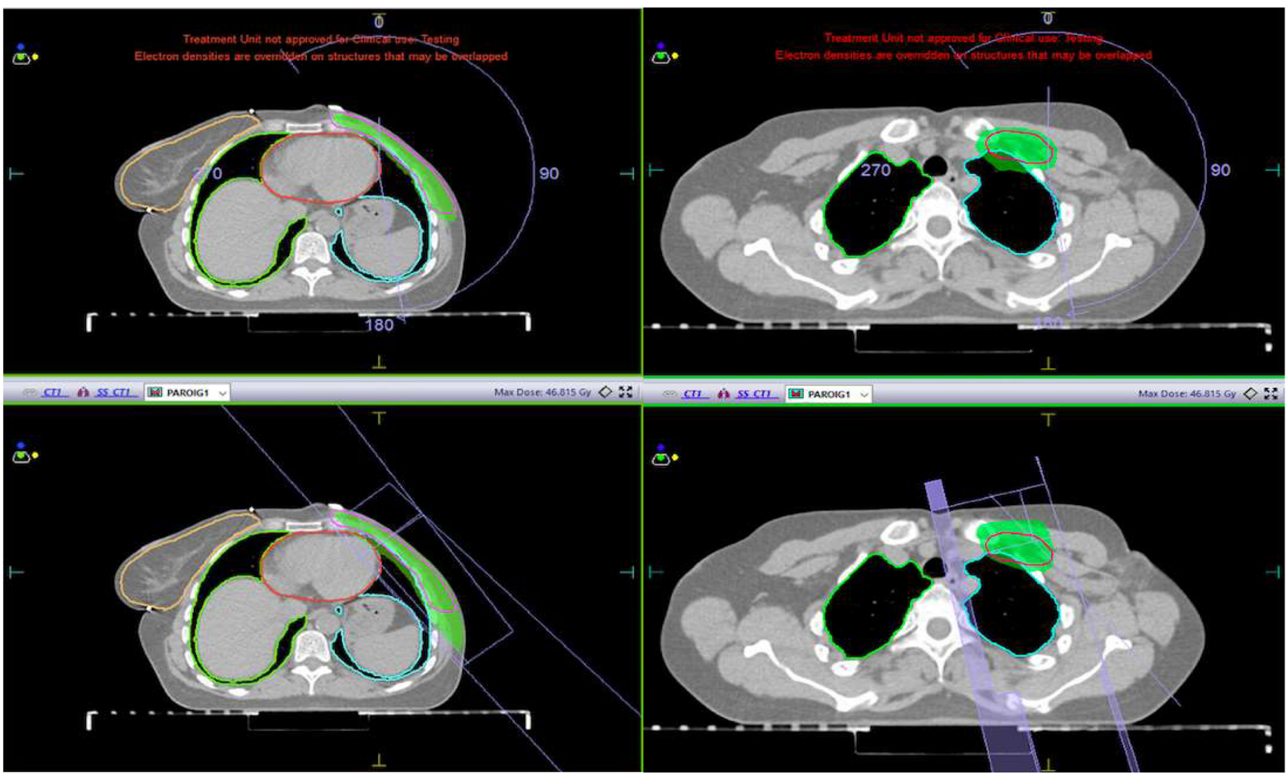

Figure 1. The two doses distribution of the cases based on one patient sample.

3. Statistical Analysis

Data collected were analyzed using SPSS version 22. We used the T-test to compare the mean difference between subgroups, which is based on as the statistical difference ($p < 0.05$).

4. Results

1) Patients and target volume criteria:

In our cohort the mean age was 45.4 years. All the patients received radiotherapy to the left breast and to the lymph nodes.

2) PTV and OAR dosimetrics (Figure 2):

Distribution of the target dose: PTV coverage for the breast and lymph nodes (PTV 95%) was better with the VMAT plan (PTVT 95 = 98.38% vs 96.25%/ PTVN95 = 97.97% vs 97%) but without significant difference between the two techniques ($p = 0.2$).

The dose received in 2% of the volume which is the Dmax was better in VMAT than in RC3D ($p = 0.03$).

The routinely reported dose constrains for the ipsilateral lung V28 was significantly different comparing the two techniques with significant difference in favor of VMAT (13.75% vs 22.34%, $p = 0.01$), while V17 was higher for 3D compared to VMAT without significant difference (30.04% vs 27.91%, $p = 0.3$).

The mean dose to the heart was higher in VMAT than in RC3D (4.56 Gy vs 3.66 Gy, $p = 0.01$). On the other hand, the V35 was significant in RC3D compared

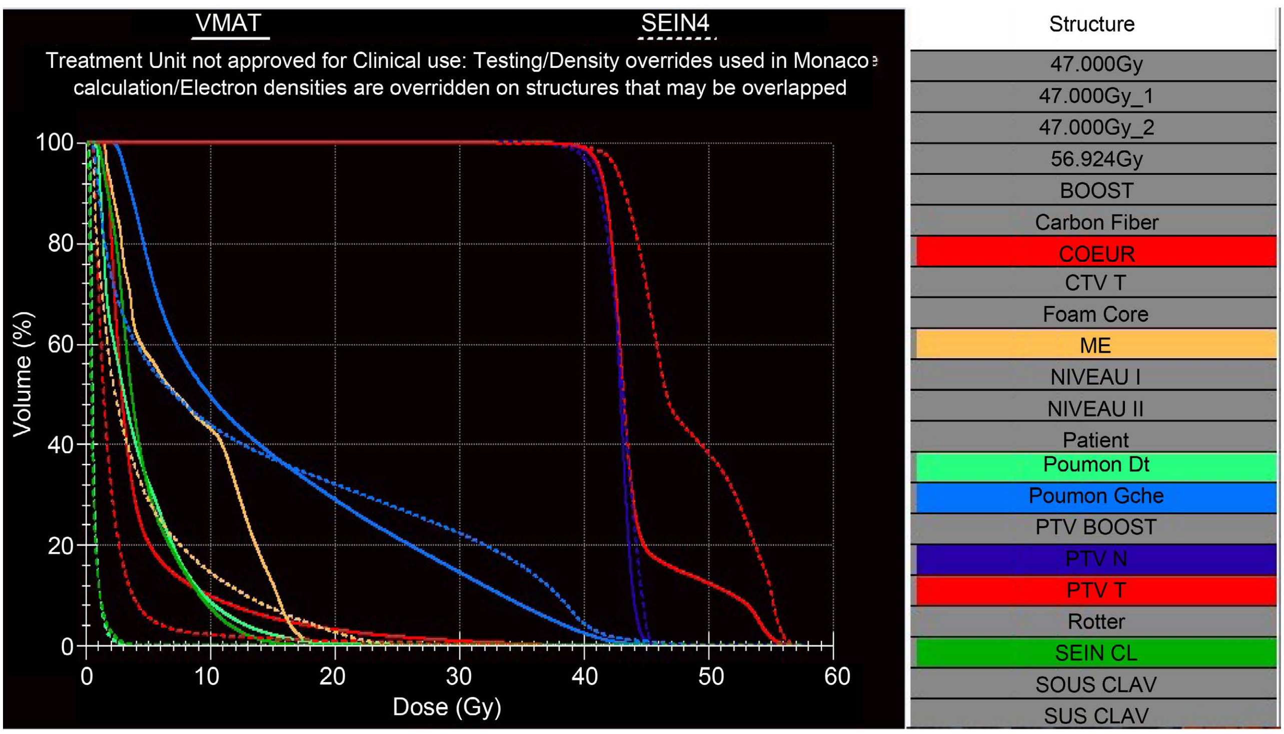

Figure 2. Dose-volume histogram distribution of the following structures: planning target volume (dark blue for nodes, red for breast), left lung (blue) right lung (green), breast (dark green), heart (red), spinal cord (orange).

Table 1. Dosimetric parameters comparison of CTV and OARs in two plans.

PARAMETERS	3D-CRT		VMAT		*P*-value
	MEAN	SD	MEAN	SD	
D95% (%)	97.25	3.25	98.38	0.90	0.3
D2% (Gy)	45.69	2.74	44.68	1.71	0.03
D98% (%)	92.54	5.81	94.56	2.75	0.33
D50% (%)	103.6	2.36	101	0.84	0.017
Dmean Heart	3.66	0.98	4.56	0.14	0.01
V35Gy Heart	2.54	1.67	0.56	0.36	0.002
V17Gy left lung	30.04	4.27	27.91	5.47	0.3
V28Gy left lung	22.34	3.27	13.75	4.24	0.00
Dmean contralateral breast	0.59	0.19	3.65	1.04	0.00
Dmax spinal cord	24.61	9.39	20.49	3.74	0.2

to VMAT (2.54% vs 0.56%, p = 0.002).

The mean dose to the controlateral breast was higher in VMAT compared to RC3D (3.65 Gy vs 0.59 Gy) with a significant difference (p = 0.01), and the maximum dose to the marrow was slightly higher in RC3D (24.61 Gy vs 20.49 Gy) but without significant difference (p = 0.2).

The results of Target volumes and OARs were shown in **Table 1**.

5. Discussion

Volumetric-modulated arc therapy (VMAT) treatment technique has been implemented rapidly for a variety of treatment sites.

The VMAT has been shown to be a feasible treatment option for adjuvant RT of the breast.

It reduces the dose to the ipsilateral lung for both left- and right-sided treatments, and to the heart for left-sided targets. It also reduces the treatment time and the number of MU without reducing dose distribution [3].

In this study, we had compared the dosimetric parameters of 3DCRT and VMAT in order to select the best technique for post-operative radiotherapy delivery to left breast ± draining lymph nodes, after breast surgery.

A limitation of this retrospective study is the small number of patients because of the lack of physicists in our institution, who are supposed to do most of the work.

1) Planning target volume coverage

The isodose of target volume and DVH of 3D-CRT were not so good as those of VMAT, which may be related to the field conditions of 3D-CRT. But there was no significant difference neither in PTV 95% (p = 0.3).

In a comparison of the two RT techniques in eight cases, Johansen *et al*. [4] showed that RapidArc VMAT was better in terms of the PTV parameters of homogeneity and conformation.

Our results are also in accordance with Sudha [5] *et al.* who found a 2% increase in VMAT coverage (98.21 ± 1.79) versus 3D-CRT (96.30 ± 2.62, $p < 0.001$).

In order to achieve excellent PTV coverage, there was a statistically significant greater hotspot in the 3D-CRT arm ($p = 0.03$) as compared to the VMAT arm ($p = 0.03$).

These results are similar to the results by Saroj Kumar who found significant greater hotspot in the 3D-CRT arm (0.17 ± 0.53) as compared to the VMAT arm (0.11 ± 0.02).

2) Dose distribution in organs at risk

The results show that the ipsilateral lung (V17 Gy) of the two plans are not significantly different (30.04% vs 27.91%, $p = 0.3$), but VMAT plan can significantly reduce the high dose volume of the ipsilateral lung (V28Gy) with significant difference ($p = 0.01$).

The study of D. Khosla *et al.* shows that Ipsilateral lung dose, V20 and V30 were significantly less in VMAT plan ($p = 0.0001$). But V5 of bilateral lungs were more in VMAT plans ($p = 0.001$).

It should be noted that the increasing of scattered radiation, increase the low dose of irradiated volume (V5, V10) in VMAT plan compared to 3D-CRT. And these volumes are the effective factors to estimate the occurrence of radiation pneumonitis [6].

In our study, the dose of controlateral lung, breast and the mean heart dose were higher with VMAT compared to 3DCRT, which is consistent with the results of Vasudevan *et al.* [7]. But the volume of heart V35 was significant in RC3D compared to VMAT ($p = 0.002$).

For heart, the results are similar to the results by D.KHOSLA *et al.*, with higher mean dose in VMAT compared to 3DCRT ($p = 0.604$), and with V30 significantly less in VMAT plans ($p = 0.001$)

The low dose in the 3D-CRT arm may be explained by changing the angle of the tangential beams, which allow a very low dose to the contralateral lung, and also the fact that low of PTV coverage may decrease the dose of contralateral lung.

In literature, the risk of second cancer is related to the low dose regions in the OARs [8].

These constrains of the contralateral organs represent the main difference between the two techniques and remain debated.

All the results are also similar to the results by Qiu *et al.* [9], Shaitelman *et al.* [10], and Sun *et al.* [11]. The PTV coverage was better in VMAT plan than 3D-CRT.

The two plans have not much difference for the heart. But for the spinal cord, contralateral lung and contralateral breast, VMAT has no advantage.

VMAT plan can obviously shorten the treatment time. And the influence of the movement during treatment, organ changes caused by respiratory motion and involuntary movement will be reduced accordingly.

6. Conclusions

In our paper, we note that both plans based on 3D-CRT and VMAT technology can achieve the basic requirements of clinical treatment. It shows better PTV coverage, lower V35 for heart and V28 for ipsilateral lung with the VMAT plans. However, low-dose volume for both the lung and mean dose of heart were significantly higher with VMAT plans.

For the high dose region volume of the normal tissue, VMAT plans are smaller, while 3D-CRT is larger; For the low dose region volume of normal tissue, VMAT plans are larger, and 3D-CRT plan is smaller.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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