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RESEARCH ARTICLE

A COMPARATIVE DOSIMETRIC STUDY OF LEFT SIDED BREAST CANCER AFTER BREAST CONSERVING SURGERY WITH 3D-CRT AND VMAT

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Abstract

Purpose: This paper aims to compare dosimetric differences based between three-dimensional conformal radiotherapy (3D-CRT), and volumetric modulated arc therapy (VMAT) techniques of radiotherapy plans for postoperative left breast cancer after breast conserving surgery.

Materials and Methods: Nineteen patients with left breast cancer who had received breast conserving surgery without nodal involvement. Two separate treatment plans with an identical isocenter were created to each patient: 3D radiotherapy plan with 2 tangent isocentric beams with field-in-field technique and VMAT plan with Two duplicate sets of partial arcs.

Results: The VMAT plan showed superior to PTV dose conformity index (CI), homogeneity index (HI), protection of the ipsilateral lung, and heart compared with 3D plan. However, it increases significantly dose to the contralateral breast with D mean which were 0.1 ± 0.003 Gy and 5.31 ± 1.04 Gy, respectively.

Conclusion: VMAT greatly decreases the radiation doses delivered to the OAR with maintained therapeutic efficacy. However, further studies evaluating the clinical outcome of treatments are needed to proof the clinical value of this radiation technique.

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Introduction:-

Breast cancer is the most frequently diagnosed and the leading cause of cancer death in women and its treatment is multidisciplinary that involves input from surgery, radiation oncology, and medical oncology[1].

Randomized studies provide evidence that breast conserving surgery (BCS) combined with postoperative radiation therapy (RT) results in local control rates and long-term overall survival comparable to modified radical mastectomy[2], [3].

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In addition, the recent meta-analysis of the Early Breast Cancer Trialists Collaborative Group (EBCTCG) showed that the addition of RT after BCS improve significantly the overall survival for patients with node positive breast cancer[3].

However, radiotherapy can cause side effects such as breast fibrosis, changes in the breast appearance and late pulmonary and cardiovascular complications[4].

In recent years, remarkable progress has been made in breast cancer as new surgical techniques, new systemic therapeutic options, better understanding of the biology of the disease and advances in the field of radiation oncology.

Historically, breast radiotherapy treatment planning consisted of two-dimensional planning, used a fluoroscopic technique to establish treatment fields. This was followed by 3-D CRT with two conventional tangential radiotherapy fields[5].

In the modern era of radiotherapy, Volumetric modulated arc therapy (VMAT) is a modern form of Intensity-modulated radiation therapy (IMRT) that delivers the radiation dose continuously as the treatment machine rotates. This technique is much faster than that for fixed field IMRT delivery concentrating the radiation dose to the tumor while minimizing the dose to the organs surrounding the tumor[6].

However, this technique has been reported to increase the low dose volumes in contra- and ipsilateral lung and contralateral breast increasing, consequently, the risk for second cancer.

This paper aims to compare dosimetric differences based between three-dimensional conformal radiotherapy (3D-CRT), and VMAT techniques of radiotherapy plans for postoperative left breast cancer.

Materials and Methods:-

Patient selection

We included nineteen patients treated in our department during January 2020 and June 2020

The patients were chosen according to the following criteria:

Inclusion criteria:

1. Localized left breast cancer. without nodal involvement
2. Histological type: carcinoma
3. Conservative surgery.

Exclusion criteria:

1. Right breast cancer.
2. Mastectomy.
3. Indication of bilateral irradiation.
4. Metastatic breast cancer.
5. Histological type: sarcoma and lymphoma.

Target and normal tissue delineation:

The patients were imaged with a CT scanner in treatment position (supine, arms up). CT images were acquired from the level of mandible to the basis of lungs with a slice thickness of 2,5 mm.

The breast Clinical Target Volume (CTV) was delineated based on the RTOG guidelines. Its included all visible breast parenchyma, retracted 5 mm from the skin surface. The Planning Target Volume (PTV) comprised the CTV with a 7 mm circumferential margin to allow for daily set-up variations and account for setup uncertainties and respiratory motion. The volumes outside the body contour and inside the lung were excluded from the PTV.

The organs at risk (OARs) included ipsilateral lung, contralateral lung, contralateral breast, heart, and the spinal cord were delineated.

Treatment planning:

Plans were normalized in terms of planning target coverage with a standard dose of 50 Gy in 2-Gy fractions according to the ICRU report number 83 recommendations. The treatment energy was 6 MV.

Two separate treatment plans with an identical isocenter were created to each patient:

1. VMAT plans were optimized for the RapidArc technique in the Eclipse treatment planning system (Varian). Two duplicate sets of partial arcs were used. One set rotated counterclockwise with collimator rotation of 30° and the other set rotated clockwise with collimator rotation of 330°.
2. 3D CRT radiotherapy consisted of the isocentric field-in-field technique plan included 2 tangent beams. Beam weights and wedge angles were adjusted to provide homogeneous dose distribution and conformal dose to the CTV and PTV.

All plans used the anisotropic analytical algorithm (AAA version 10.0.28) for dose calculation with 2.5 mm calculation grid and heterogeneity correction.

Dosimetric evaluation parameters:

1. For the PTV, the dose to 98 and 2 % of the volume (D98 % and D2 %, respectively) and the part of the PTV receiving more than 107 % of the prescribed dose (V107 %) were evaluated.
2. The plan qualities were compared by the homogeneity index (HI) and conformity index (CI) as proposed by Paddick et al, as follow:
 - $HI = (D2 \% - D98 \%) / D50 \%$
 - $CI = V47.5 / PTV$

Statistical analysis

All results were compared and analyzed using SPSS software, version 10.0, and a statistical significance level of 0.05 was used ($p < 0.05$).

Ethical considerations

The different treatment techniques have been applied to the patients' dataset without any clinical application. This activity does not require an ethical approval

Results:-**Dose analysis of planning target volume**

We have summarized the dosimetric results of PTV in Table 1.

Both VMAT and 3D FIF achieved 95 % coverage of the PTVs.

Compared with VMAT plans, 3D technique had a statistical significance only for Dmean, D2.

We found that both of the two radiotherapy plans achieved good dose homogeneity across the whole breast for all patients in this study. However, The VMAT plans have significantly better HI and CI than the 3D plans which were 0,375 +/- 0.005 Gy and 1,30+/- 0,4 Gy vs. 19.08 +/- 0,003 Gy and 1,16 +/- 0,16 Gy respectively .

Table 1 also shows that MUs per 2 Gy fraction for the 3D plan was significantly lower than other plan (230+/- 57,419+/- 62, p: 0.003).

Dose analysis of OARs

The results of OARs were shown in Table 2

The homolateral lung:

The volumes receiving 20Gy and 30Gy are not statistically different between the VMAT and 3D FIF techniques which were 14.11 +/- 6,9 Gy and 12,24 +/- 6,12 Gy vs. 19.08 +/- 9,67 Gy and 11.27 +/- 7,24 Gy respectively .

The heart:

The mean dose for heart is higher for 3D CRT technique than the value for VMAT with average dose of 3,96 +/- 1,31 vs 5,2 +/- 1,11 (p: 0.018).

In contrast there was no statically significant difference in the volume receiving 10Gy.

The contralateral breast and spinal cord:

Dmean of the contralateral breast were higher in VMAT plan, which were 0.1 ± 0.003 Gy and 5.31 ± 1.04 Gy, respectively. while D max for the spinal cord were significantly higher in 3D plan which were 0.99 ± 0.44 Gy vs 0.47 ± 0.14 Gy respectively.

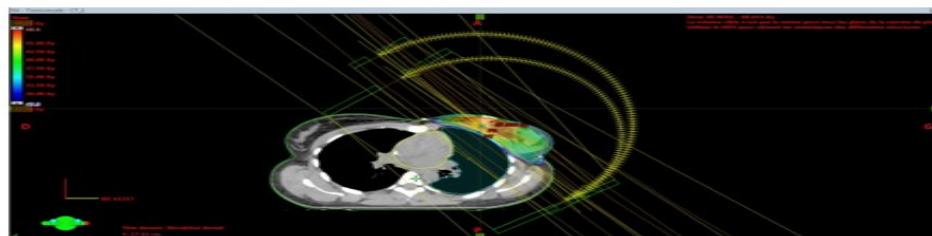
Table1:- The PTV whole breast dose parameters of two plans.

		3D FIF		VMAT		p (value)
		Average	standard deviation	Average	standard deviation	
PTV whole breast	CI (Gy)	1,30	0,4	1,16	0,2	0.03
	HI	0,63	0,05	0,375	0,09	0.001
	PTV 95 (Gy)	48,22	3,15	48,3	1,41	0.915
	D2% (Gy)	54,58	1,33	51,82	0,49	0.001
	D98%(Gy)	43,01	8,53	47,12	1,95	0.138
	Dmean (Gy)	51,85	1,32	50,21	0,55	0.004
	D105% (Gy)	40,07	0,97	46,16	1,91	0.138
	D95%(Gy)	44,35	8,78	48,56	2,03	0.167
	D95%(Gy)	15,36	0,37	15,59	0,75	0.473
MU		230	57	419	62	0.003

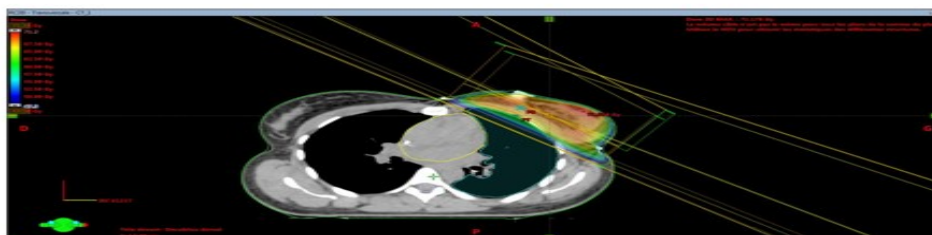
Table 2:- Dose comparison of the organs at risk between the two plans.

		3D FIF		VMAT		p (value)
		Average	standard deviation	Average	standard deviation	
Heart	Dmean (Gy)	5,2	1,11	3,96	1,31	0.018
	V10 (%)	9,86	3,09	6,85	4,88	0.103
	V5 (%)	24,68	4,12	17,56	10,49	0.001
Spinal cord	Dmax (Gy)	0,9	0,44	0,47	0,14	0.020
Left lung	V14 (%)	12,15	6,9	11,08	9,67	0.097
	V20 (%)	10,24	6,12	9,27	7,24	0.588
Controlateral breast	Dmean	0.1	0.003	5.31	1.04	0.0001
	D1 (Gy)	0,344	0.03	11.16	2.67	0.0001
	V10(%)	0	0	2,373	0.89	0.002

(a)



(b)

**Figure 1:-** Typical dose distributions for one patient planed with (A) FIF, (B) VMAT techniques.

Discussion:-

Volumetric modulated arc therapy (VMAT) is a radiation technique delivers radiation on a linear accelerator using a cone beam that continuously rotates around the patient, which can achieve highly conformal dose distributions with improved target volume coverage and sparing of normal tissues compared with conventional radiotherapy techniques[7].

It's also used fewer MU and reduced treatment time compared with conventional radiotherapy.

Certainly, artherapy is an innovative technique which has shown its superiority over conventional radiotherapy in the treatment of several cancers such as: head and neck, prostate, brain tumors. However, its use to irradiate mobile tumors is controversial given the obligation to add large margins to the target volume in order to account for respiratory movements thus exposing healthy tissue to higher doses and therefore it is not considered a standard irradiation technique in breast cancer[8].

At present, the main methods of postoperative radiotherapy for patients with advanced breast cancer include three-dimensional conformal radiotherapy.

In this dosimetric study, we demonstrated that artherapy improved coverage of the PTV with $\geq 99.6\%$ of the PTV and the best target volume conformity, thus overcoming the problem of inhomogeneity encountered during irradiation of the breast in conformational radiotherapy with a significant reduction in the percentages of overdose "hot spots".

Planning is harder especially if the cancer is in the left breast, considering the risk of ischemic heart disease after radiotherapy for breast cancer increases linearly with the mean dose to the heart by 7.4% per gray (Gy) [8], [9].

Radiation-induced pneumonitis risk is a rare radiotherapy complication in breast cancer patients after radiotherapy not exceeding 2%. Willner et al. [10] suggested that the incidence of radiation induced pneumonitis increased by 10% for every 10% increase in V10Gy.

Our study confirms these findings especially in higher-dose areas. However, all low dose parameters of ipsilateral lung, including V14Gy, and V20 Gy, are non-significantly smaller in VMAT plans compared with those in the corresponding 3D plans.

Conventionally, the whole breast radiation treatment is delivered with patient in the supine position and its the position we have chosen for our patients. The prone treatment position is often proposed for patients with large or pendulous breasts to reduce the dose to ipsilateral lung and heart, and to increase the dose homogeneity by displacement of breast tissue away from chest wall and torso. The usage of VMAT techniques to decrease the dose to heart might be beneficial also in prone position. However, further studies are needed to evaluate the potential of VMAT techniques in prone treatment position. [11]

Conclusion:-

In our study, we note that VMAT compared with 3D plan has demonstrated the combined advantages in PTV dose coverage with better conformity.

The doses to heart, the ipsilateral lung and spinal cord were significantly reduced with VMAT.

However, further studies evaluating the clinical outcome of treatments are needed to proof the clinical value of this radiation technique.

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