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*RESEARCH ARTICLE*

# COMPARATIVE RADIATION DOSIMETRY OF WHOLE BREAST RADIOTHERAPY USING IMRT AND VMAT TECHNIQUES IN LEFT SIDED BREAST CANCER PATIENTS AFTER BREAST CONSERVING SURGERY

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## Abstract

**Background:**The radiotherapy of left sided breast cancers is mandatory and integral part of treatment and challenging because of surrounding critical structures posing increased risk of complications. The main objective of this study was to quantify doses toorgan at risk(OARs) including left lung, heart, contralateral breast, spinal cord, and planning target volume (PTV) using different radiation techniques like Intensity modulated radiation therapy (IMRT)&volumetric modulated arc therapy (VMAT) and comparison of radiation dosimetry.

**Methods**: A prospective study of 30 patients of left sided breast cancer who had undergone Breast Conservative Surgery (BCS) and chemotherapy was done for adjuvant radiation. For every patient radiation planning was done by two different techniques IMRT and VMAT. Then the comparison of radiation dosimetry parameters was done for all the techniques including the parameters like PTV coverage, doses to OAR like heart, left lung, contralateral breast and spinal cord and head of humerus. The Homogenity Index (HI) were calculated.

**Result:** The Mean age of the patient was 46.7 years. When comparing the doses delivered in IMRT and VMAT Technique for left sided breast cancer post breast conservation surgery there was significant difference in PTV Breast and axilla V95 Gy. It was 96.2±1.9% (IMRT) vs 94.8±1.71% (VMAT), (p=0.004). However significant sparing of Organs at Risk was seen. With ipsilateral lung dose mean V5 Gy was 77.86± 9.68% (IMRT) v/s 83.04± 9.86 % (VMAT), (p=0.0446). Also mean V30 Gy was 14.6±4.82% with IMRT vs 16.54±5.86% with VMAT, (p=0.0169). Heart mean dose was 8.8±1.49 Gy with IMRT and 10.98±3.7 Gy with VMAT, (p=0.0227). Further V30 Gy for Heart was 4.61±3.8% with IMRT and 6.72±4.0% with VMAT, (p=0.0132).No significant difference was seen with IMRT and VMAT technique for contralateral lung, contralateral breast and spinal cord.

**Conclusion**: In treatment of patients with radiation with left breast cancer patients post BCS using IMRT and VMAT technique it is seen significant dose reduction with IMRT Technique for ipsilateral lung and Heart as compared to VMAT technique. Significant V95 coverage for PTV Breast and axilla with IMRT as compared to VMAT. Hence in our Study IMRT technique was found to be superior for better sparing of Organ at risk and better PTV coverage.

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## Introduction:-

Breast cancer is the most common cancer worldwide, as per Globocan statistics 2020, the worldwide burden of breast cancer is 11.7 %.[1] The treatment of breast cancer is a multidisciplinary approach. In early breast cancer, breast conserving surgery (BCS) followed by post-operative chemotherapy and post op radiotherapy is the most common approach. While in advanced stages of cancer neoadjuvant chemotherapy followed by either BCS or MRM surgery is done followed by adjuvant chemo and post op radiotherapy and hormonal therapy according to hormone receptor sataus[2].

PORT reduces the rate of local relapse and improve long term survival but at the cost of increased risk to the heart [3, 4] and lung as well as increased risk of secondary breast cancer in contralateral breast. Among all, heart is the most important organ at risk in relation to Radiotherapy for left sided breast cancer where if higher dose is given results in increased cardiac mortality.[5]

With traditional 2D planning, the tangential fields are used for giving radiotherapy which include all large volume of thoracic cavity, increasing dose to organ at risk particularly heart and lung. Now, with advancement of External Beam Radiation treatment, the delivery techniques have been revolutionized, improving the radiation dose conformity with limiting the normal tissue toxicity.

The role of two Radiation techniques like IMRT & VMAT have been compared so that maximal dosimetric benefit and least harm to OAR's can be achieved.[6]

IMRT is a technique to treat patient from different directions with beams of non-uniform fluence, which have optimized to deliver a high dose to the target and an acceptable low dose to surrounding normal structures. Treatment planning program divides each beam into a large number of beamlets and determines optimum setting of their fluence or weights. Optimization process involves inverse planning in which beamlet weights or intensities are adjusted to satisfy predefined dose criteria. Optimum intensity profiles are calculated by inverse planning. Computer controlled MLC is most commonly used to deliver intensity modulated beams.[7]

### VMAT:-

The delivery of rotational cone beam with variable shape and intensity is called as VMAT. In VMAT treatment the gantry moves continuously, with MLC leaves and dose rate varying throughout the arc. For satisfactory dose plan with single arc, it is necessary to optimize field shapes and beam intensities from large number of gantry angles. Advantage of VMAT is in its delivery efficiency with significant reduction in treatment time and MU over conventional IMRT.[8]

The present study was undertaken to quantify doses to OARs including left lung, heart, contralateral breast, spinal cord, and PTV using different radiation techniques like IMRT &VMATand comparison of radiation dosimetry.

## Material And Methods:-

Prospective analysis of 30 patients of early left Breast cancer who underwent BCS was done in present study.

### Simulation Technique:-

Patient lying supine on CT simulator couch immobilized with thermoplast and baseplate. Head turned towards Right side and left arm raised over head to exclude it from the treatment field. The surgical scars were delineated with radio-opaque wires made of lead. The markers were also placed along the mid-sternum & mid axillary line, as well as 2 cm below the healthy breast limits. Images were acquired from the top of the head to the mid-abdomen using a 5mm slice thickness. A SIEMENS SOMATOTOM sensation open CT scanner was used to obtain the CT scans. The image sets were transferred to the focal system for contouring and to the Monaco 5.11.03 TPS for planning.

### Target And Normal Tissue Delineation-

All organs and treatment volume delineations were based on the report 83 of international commission on Radiation Units and Measurements (ICRU).

Target volumes and OAR were determined by the radiation oncologist at the treatment planning system (TPS) Monaco 5.11.03.

**Target Delineation:-**
The CTV breast included all the visible breast parenchyma and was defined as the tissue delineated by the lead marker as mentioned before. On each slice, the Breast volume extended from the pectoralis major muscle to the skin, excluding the pectoralis muscle, the ribs and the first 5mm of skin. The PTV was planned by giving margin of 5mm in all directions around CTV breast except for the skin surface, including the set-up margin and patient movement.

The target delineation of axilla includes level 1, level 2, level 3 lymph node that is lateral to pectoralis minor, behind the pectoralis minor and medial to pectoralis minor respectively. Starting from the level of axillary vessels to the insertion of pectoralis minor into coracoid process. If internal mammary lymph node are included that first three interspace including thoracic vessels. 5mm of margin is given to the CTV and tucked away from skin by 5 mm. Indications for axillary radiotherapy includes ruptured lymph node capsule, lymphovascular space invasion, involvement of three or more lymph nodes and lack of hormone receptor expression.

**OAR Delineation:-**
The contouring of all the involved organs at risk including the entire Heart, Ipsilateral lung, Contralateral Lung, Contralateral Breast and Spinal Cord were done by the Radiation Oncologist. All targets and OARs were outlined. Slice by slice CT image in the treatment planning system and the three-dimensional contour was reconstructed automatically by Radiation physicist.

The Heart was contoured from the level of the pulmonary trunk to the apex and included the Pericardium. Rest of the OAR's were also contoured.

**Treatment Planning-**
IMRT and VMAT planning was done on Monaco system version 5.11.03 TPS of the Elekta Synergy linear accelerator, with 80 Leaf multileaf collimator (MLC) and designed to replace the tongue and groove system and allow complete interdigitation and non-continuous field shape. The maximum speed of the dynamic leaf guide is 2.5 cm/s. The MLC maximum speed is 4.6 cm/s and can approach 6.5 cm/s with the aid of dynamic guide. The minimum segment width was set at 5mm for IMRT and VMAT with minimum monitor units (MUs) of control points (CPs) at 1MU. The final dose Calculation and segment optimization used the X-ray vowel Monte Carlo (XVMC) algorithm for IMRT & VMAT with a calculation grid of 3 mm and 3% standard deviation.

**Treatment Dose-**
A total dose of 50Gy/25#/5-6 weeks was planned for the Whole Breast Radiotherapy i.e. Single fraction dose of to 2Gy by 6MV Photon energy followed by electron Boost of Dose 15 Gy / 6# by 12MeV electron energy.

**Planning Technique**
**IMRT-**
A 5 to 7 beam plan was reported to be more appropriate for step and shoot IMRT technique for the left sided breast cancer, the beam angles were set as follows: - 0°, 110°, 125°, 140°, 295°, 310°, 330° as shown in (Figure 1).

**VMAT-**
VMAT in which the arc direction is such that the beam enters Breast before exiting through the lungs may increase the dose volume of the lungs and contralateral Breast. The VMAT plan used the arc field for which the starting angle and ending angle were the same as the tangential beam angle and sub-field interval of 5° was used. The single curve angle designed for left Breast cancer was 300° to 145°. The maximum CPs for IMRT was 30 and for VMAT was 180. Which has been shown to be adequate for both efficiency and plan for quality in our department. (Figure 2)

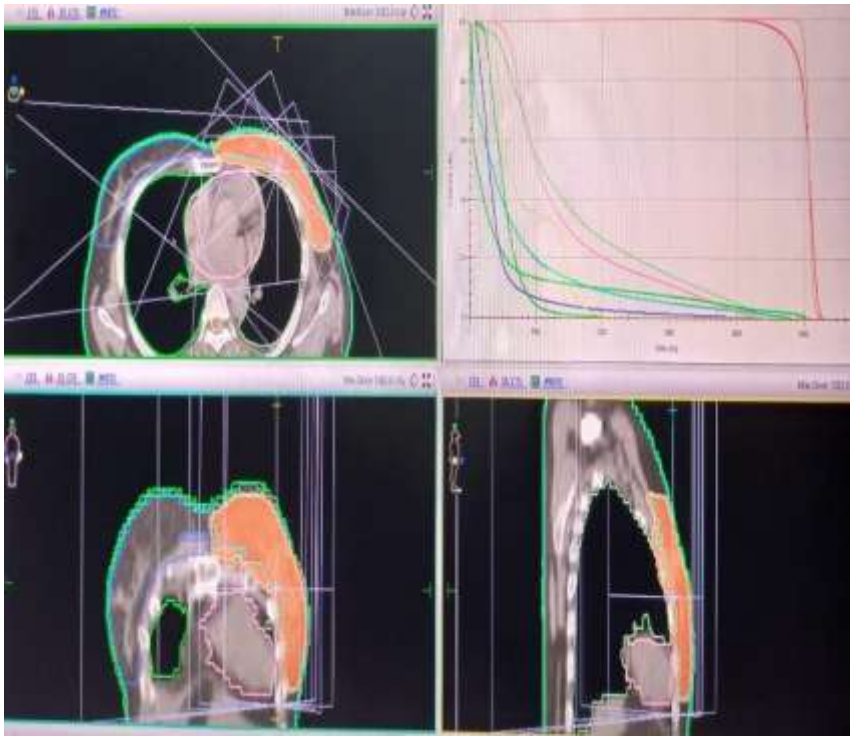

Figure 1: IMRT Technique: Dose volume histogram (DVH) showing planning target volume (PTV), Spinal Cord, Contralateral Breast, Ipsilateral Lung, Heart.

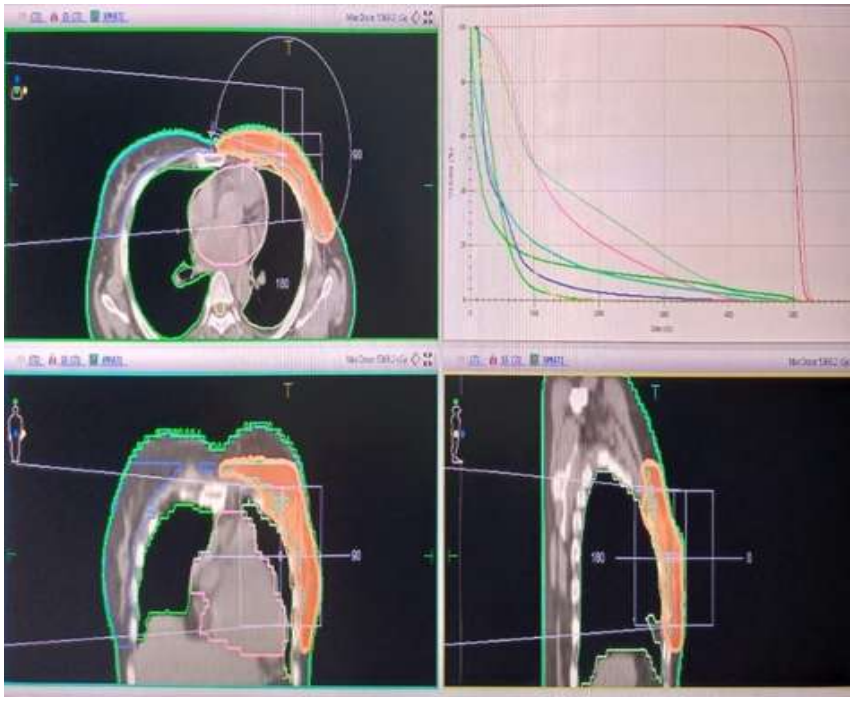

Figure 2: VMAT Technique: Dose volume histogram (DVH) showing planning target volume (PTV), Spinal Cord, Contralateral Breast, Ipsilateral Lung, Heart.

**Data Comparisons-**
All the data are based on DVHS calculated using the Monaco system version 5.11.03 TPS of the Elekta Synergy linear accelerator. Dose information was collected to evaluate PTV Left Breast and dose to OARs. Mean dose, Homogeneity Index (HI) and V 95% were documented for PTV left Breast. HI was calculated using the formula recommended in ICRU report 83. Formula: HI= (D2%-D98%)/D50%. HI value closer to zero indicates greater homogeneity. MUs for both the plans were documented. The normal tissue doses of the IMRT & VMAT Plans were calculated. Mean dose, V5 Gy, V20 Gy& V30 Gy to OARs were also calculated and documented.

**Statistical Analysis**
IMRT and VMAT plan parameters derived from the same patients were tested for statistically significant differences using ANOVA. All the results were reported as mean ± standard deviation differences were significant for P– value < 0.05.

## Results:-
The total of 30 patients of left sided Breast cancer who had undergone Breast conserving surgery were selected in our study. The mean age of the patients was 46.7 years. All patients were planned with both the techniques IMRT & VMAT for the Dose of 50Gy/ 25# followed by electron boost.

**DosimetricEvaluation:-**
**Target Volume-**
The mean PTV dose for left Breast and axilla was 50.8 ±0.63Gy for IMRT while 50.6 ± 0.86Gy for VMAT. Mean V95 for left Breast and axilla for IMRT was 96.2 ± 1.9% and for VMAT it was 94.8 ± 1.71%. Showing significant difference between the two techniques. All values are listed in Table-1.

**Organ At Risk-**
**Ipsilateral Lung-**
Mean dose for IMRT was 15.7 ± 1.34Gy and for VMAT 15.6±1.67 Gy. Showing comparable dose between the two techniques while V5 Gy for Ipsilateral lung in IMRT Mean was 77.86 ±9.68 % while for VMAT 83.04 ±9.86 %. Showing significant difference between the two techniques. V30 Gy for Ipsilateral Lung in IMRT Mean was 14.6±4.82% while for VMAT 16.54±5.86% showing significant difference between the two technique.(Table-2)

**Contralateral Lung-**
The mean dose for contralateral lung in IMRT was 7.34 ± 2.33Gy and in VMAT 7.12 ±2.68Gy. Stating No significant difference between the two techniques.

**Contralateral Breast-**
The mean dose for Contralateral Breast was 4.49 ± 0.87Gyfor IMRT and 4.71 ±1 Gy for VMAT which was also not statistically significant.

**Spinalcord-**
The mean for Max. Dose of spinal cord for IMRT technique was 25.1 ±8.8Gy and for VMAT 26.6 ± 9.4Gy.Stating no significant difference between the two techniques.

HEART- For IMRT technique the heart mean dose in our study was 8.8 ±1.49 Gy. While for IMRT it was 10.98 ± 3.7Gy for which the P value was significant. Mean for V30 Gyfor IMRT was 4.61 ±3.8% and for VMAT it was 6.72 ± 4% for which again the P value was significant. (Table-3)

## Discussion:-
With the recent advances in Radiotherapy techniques, the Radiotherapy of Breast cancer has been focussed on two main goals: - Improving Disease Control while reducing the dose to the OARs. With the introduction of CT based planning the conformity of treatment has been improved which also takes in to account the patient's anatomy. With the advent of IMRT & VMAT techniques dose to lung and heart can be properly monitored. The introduction of MLC's has led to the two important changes in Breast Cancer Radiotherapy. Firstly, the local control can be improved by reducing the treatment length and increasing the dose per fraction received by the tumor bed. Second, advanced techniques such as dynamic IMRT & VMAT techniques can increase the homogeneity of treatment and

translate to a decrease in acute toxicity by decreasing the dose to OARS.The eventual risks for breast cancer patients given radiotherapy depend on the doses to the heart and lungs.[9]

In this study, we have evaluated the plan parameters of two different radiation treatment planning techniques i.e. IMRT & VMAT in left sided Breast cancer patients treated with breast conservation surgery and have evaluated that IMRT technique is superior to VMAT especially in terms of target coverage and sparing of ipsilateral lung and heart from exposure to radiation beyond expected dose range.[10]The cardiotoxicity induced by doxorubicin was taken into consideration for patients receiving doxorubicin and cyclophosphamide based chemotherapy. Therefore, the doxorubicin lifetime dose of 450mg/m2 along with radiation therapy and 550mg/$m^2$ without further radiation therapy was considered.

In present study, we found that PTV coverage for Breast and axilla in terms of V95% was better in IMRT techniques in comparison to VMAT with P value significant (P= 0.004). But the Homogeneity Index was almost similar in both techniques. Ipsilateral lung mean V5 Gyand V30 Gy were less in IMRT than VMAT with significant P-value again (0.0446,0.0169). Mean dose for contralateral lung was not having significant difference for both the techniques. Similarly, Mean dose for contralateral Breast also was not statistically significant for comparison of both the techniques. Similar results were for the Mean and Max dose of spinal cord.

Furthermore, heart dose which is of more concern in left sided Breast cancer patients, is better attained by the IMRT technique as Mean dose for Heart and V30 Gy were both less in IMRT technique with significant P value of 0.0227 & 0.0132 respectively. To decrease the toxicity of the Heart, Mean dose <26, V30 < 46%, V25 < 10% , for ipsilateral lung , V20 < 30% (for combined lung) , mean dose 20 Gy<20% , for contralateral breast < 10% of total dose of irradiated breast.

Due to better PTV coverage of the target volume and lower doses to OAR IMRT technique proved to be superior to VMAT in current study.

**Tables:**

**Table 1:-** Dose Comparison and Delivery Efficiency Left Sided Breast Cancer.

| | PARAMETER | IMRT (Mean) | VMAT (Mean) | p Value |
|---|---|---|---|---|
| 1 | PTV BREAST AND AXILLA - MEAN DOSE | 50.8 ± 0.63 | 50.6 ± 0.86 | 0.3084 |
| | PTV BREAST AND AXILLA - V95 | 96.2 ± 1.9 | 94.8 ± 1.71 | 0.004 |
| | PTV BREAST AND AXILLA – HI | 0.12 ± 0.039 | 0.12 ± 0.466 | 1 |
| 2 | CONTRALATERAL LUNG- MEAN DOSE | 7.34 ± 2.33 | 7.12 ± 2.68 | 0.7356 |
| | CONTRALATERAL LUNG-V5 | 68.79 ± 22.47 | 65.35 ± 21.45 | 0.5465 |
| 3 | CONTRALATERAL BREAST- MEAN DOSE | 4.49 ± 0.87 | 4.71 ± 1 | 0.3671 |
| | CONTRALATERAL BREAST- MAX DOSE | 48.4 ± 2.7 | 49.4 ± 2.3 | 0.128 |
| 4 | SPINAL CORD- MEAN DOSE | 8.2 ± 5.8 | 8.4 ± 5.3 | 0.8896 |
| | SPINAL CORD-MAX DOSE | 25.1 ± 8.8 | 26.6 ± 9.4 | 0.5259 |
| 5 | DELIVERY EFFICIENCY- MU | 798.31 ± 102.23 | 782.7 ± 63.1 | 0.4795 |
| | DELIVERY EFFICIENCY- Integral dose | 115.3 ± 10.4 | 116.3 ± 21.6 | 0.8201 |

**Table2:-** Comparison Total left Lung Doses with IMRT & VMAT Technique.

| LEFT LUNG | | | |
|---|---|---|---|
| | IMRT | VMAT | p Value |
| MEAN | 15.7 ±1.34 | 15.6 ±1.67 | 0.799 |
| V 5 | 77.86±9.68% | 83.04±9.86% | 0.0446 |
| V 20 | 77.5±3.82% | 28.8 ±4.77% | 0.2487 |
| V 30 | 14.6±4.82% | 16.54±5.86% | 0.0169 |

**Table3:-** Comparison Total Heart Doses with IMRT & VMAT Technique.

| TOTAL HEART | | | |
|---|---|---|---|
| | IMRT | VMAT | p Value |
| MEAN | 8.8 ± 1.49 | 10.98 ± 3.7 | 0.0227 |
| V 5 | 96.42 ± 4.5% | 94.06 ± 6.7% | 0.1147 |

| | | | |
|---|---|---|---|
| V 20 | 22.42 ± 5.9 % | 25.32 ± 7.1 % | 0.0905 |
| V 30 | 4.61 ± 3.8 % | 6.72±4.0% | 0.0132 |

## Conclusion:-

With IMRT a better PTV coverage for target volume can be achieved as comparison to VMAT technique. With lower dose to OAR Radiation induced pneumonitis and Cardiac toxicity in future can be avoided with the IMRT technique for treating left sided Breast cancer after Breast conservation surgery.So, it can be concluded that treatment of Breast cancer is a multimodality approach and IMRT can be considered as an ideal Radiotherapy treatment planning technique for left sided Breast cancer after BCS.Further studies can be carried out in consideration with Breast size which is an important determinant of Breast dose homogeneity and with a large sample size to have a better result, comparison and outcomes for future perspectives.

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