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# Dosimetric comparison of three different radiotherapy techniques (3DCRT, ECOMP & VMAT) for breast irradiation

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▶ ***Original article***

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## ABSTRACT

***Background***: The aim of this study was to compare the treatment plans of three techniques namely three-dimensional conformal radiotherapy (3DCRT), Electronic tissue compensator (ECOMP) based planning and Volumetric Modulated Arc Therapy (VMAT). ***Material and Methods:*** The planning goal was set to cover 95% of the planning target volume with 95% prescription dose for the dose plan of 40 Gy in 16 fractions. Treatment techniques with improved dose homogeneity, optimum skin dose, lung dose ($V_{20Gy}$) and contralateral breast dose were used as the criteria to select the optimized treatment plan. The treatment planning time and the number of monitor units (MU) required to execute the plan were also taken into consideration. ***Result:*** PTV coverage ($V_{95\%}$) for the patient of ca-right breast and the ca-left breast was superior in VMAT plans. Ipsilateral lung ($V_{5Gy}$ %) showed significant dose reduction in ECOMP plans compared to 3DCRT and VMAT plans. Similarly, for the heart and contralateral lung, the mean doses were least in ECOMP plans. Dose homogeneity Index (HI) and Dose conformity Index (CI) was better in ECOMP plans compared to 3DCRT, but VMAT plans were superior to both the other techniques. The skin surface dose was less in VMAT plan. ***Conclusion:*** VMAT has high CI as well as HI but at the cost of higher OAR doses (lung and heart) and large treatment planning time. For a busy center, ECOMP can be a good choice of treatment technique which can optimize the OAR doses and treatment planning time but for dose homogeneity and conformity, VMAT is superior to others.

***Keywords:*** *Electronic tissue compensator, volumetric modulated arc therapy, three-dimensional conformal radiotherapy, homogeneity index, conformity index.*

## INTRODUCTION

Breast cancer has the highest incidence rate (23%) and mortality rate (14%) among all cancers in women [(1)]. Several techniques and recommended protocols are available for the radiotherapy of breast cancer patients. Radiotherapy is the primary choice of treatment following breast conservation surgery. Many critical structures like the lungs, heart, spinal cord and contra-lateral breast make the treatment plan complex.

The goals of irradiation of intact breast are to eradicate microscopic foci of disease at the original site of the tumor and sterilize multicentric cancer with moderate doses of radiation. This therapy minimizes the local recurrence at the primary site. It can also provide good to excellent cosmetic results, maintaining the patient's quality of life (QOL). Dose inhomogeneity due to the conical shape of the breast is an important factor to consider for breast cancer patients and can be high in patients (up to 20%) with large breast size [2]. Dose homogeneity can reduce late adverse effects such as indurations and changes in breast cosmesis [3] particularly in women with large breasts, for whom inferior cosmetic outcomes using the standard wedged technique have been reported [4]. 3DCRT using two tangential fields have limitation to deliver homogeneous dose distribution because of breast shape. Use of CT makes 3-dimensional conformal radiotherapy (3DCRT) plans possible. Beam modifiers (wedges and compensating filters) are commonly used in the external beam 2D and 3D conformal radiotherapy to improve dose homogeneity up to some extent [5].

International Commission on Radiation Units and Measurements (ICRU) recommends that the planning target volume (PTV) should be within the 95% and 107% isodose surfaces [6], but radiation dose homogeneity is seldom achieved in whole breast radiotherapy using a physical wedge (PW). Electronic tissue compensator (ECOMP) based planning is a forward IMRT planning, in which Electronic compensation involves radiation beam modulation using dynamic multi-leaf collimators (dMLCs) instead of the physical wedge. The fluence of the plans is manually edited to makes the PTV homogeneous. Volumetric modulated arc therapy (VMAT) is an evolution of static gantry IMRT. Instead of delivering multiple intensity modulated beams from static gantry angles, VMAT delivers multiple segments while the gantry is rotating around the patient in a continuous arc. VMAT improves target dose uniformity and conformity. Patients treated with VMAT are at higher risk of radiation-induced secondary malignancy due to larger low dose volume irradiation and increased monitor units [7].

This study was done to evaluate the efficacy of VMAT techniques which are being used in many centers for the treatment of carcinoma breast as compared to the other conventional techniques such as 3DCRT and ECOMP. This dosimetric study of whole breast irradiation by three different techniques (3DCRT, ECOMP, VMAT) was performed by comparing dose homogeneity, PTV coverage and, normal tissue (lung, heart, skin and contra-lateral breast) sparing. Computed Tomography (CT) data set of old treated patients of carcinoma breast were used in this study. Plan generation time and delivery time was also estimated for the three types of treatment techniques to decide the optimum plan.

## MATERIALS AND METHODS

### *Patient population, simulation and structure delineation*

In this retrospective study, planning CT images of 30 already treated patients of post-lumpectomy, early stage infiltrating ductal carcinoma of left and right side breast (each 15 in numbers), in the age range from 38 to 52 years, were randomly chosen to compare the three different treatment planning approaches. Patients were simulated as per the standard protocol in the supine position on a breast board with left or right arm extended above the head and head turned towards the opposite breast at the time of their 3DCRT treatment.

A non-contrast planning CT- scan was obtained with 2.5mm slice thickness using a GE CT system (GE Healthcare) with suitable immobilization device. The clinical target volume (CTV), planning target volume (PTV) and critical normal structures (lungs, heart and contralateral breast) were contoured. PTV was defined with the 5mm margin from CTV in all the direction excluding the breast surface. The target volumes and critical structures were countered on the CT-scan as per ICRU report 50 [6]. PTV was defined as the breast tissue encompassed by the original treatment tangents that were generated by expanding CTV by 5 mm in all directions except in the direction of the skin surface. 5 mm superficial breast skin surface tissue was excluded to reduce the calculation uncertainties in the buildup region [8].

Contralateral breast, heart, and lungs were also countered as per the contouring guidelines. Plans were made for trilogy machine (Varian Medical System, Palo Alto, USA) on the Varian Eclipse (version 11.0, Varian Medical System, Palo Alto, USA) treatment planning system.





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Analytical Anisotropic Algorithm (AAA) was used for treatment dose calculation.

### *Treatment plans generation and optimization*

Three treatment planning techniques (3DCRT, ECOMP, and VMAT) described below were generated by using 6 MV X-ray beams from High energy linear accelerator (Trilogy, Varian Medical Systems, Palo Alto, CA) equipped with 120 multi leaves collimators (MLC). The goal of each planning was to cover the PTV by 95% of the prescription dose while keeping the dose to lung, heart and contra-lateral breast as low as possible. A total dose of 40Gy in 16 fractions was used to generate these treatment plans for all 30 patients.

### *Three-dimensional conformal radiotherapy plans*

3D-CRT was planned by using two parallel opposing tangential half beam block wedge fields of 6MV photons beam (figure 1A). MLCs were used to conform the shape of PTV to outbound block margin of 6 mm and to shield lung and heart volume where possible. Treatment plans were optimized by optimizing wedge angles and beam weight. 15 patients of the right breast and 15 patients of left breast were selected for this study. Central lung distance (CLD) was kept below 3.5 cm to spare large volume of the lung from radiation exposure. Mean CLD was 2.1cm (1.0 to 3.4 cm range) for the right breast plans and 2.4cm (1.6 to 3.4 cm range) for left breast plans. Figure 2A is showing dose distribution in the 3DCRT plan.

### *Electronic tissue compensator based plan*

ECOMP planning technique is a feature of the Eclipse treatment planning system. It is forward Intensity-modulated radiotherapy (IMRT). In this technique, the fluence is edited by fluence editor tool (painting the fluence map) to make the plan homogeneous (reduced hot and cold region). This will compensate for the curved surface of the breast. The electronic tissue compensator is a planar compensator that compensates to a flat plane perpendicular to the central axis of the beam known as beams eye view. To generate the electronic tissue compensator, a planar compensator must first be generated in the treatment planning system. The software will then allow for the planar compensator to be converted to an electronic tissue compensator.

Two tangential fields of 6MV beams with collimator angle 0 degrees were used for ECOMP treatment planning (figure 1B). The treatment plan was modified on the basis of the original 3D-CRT planning but without wedges. The fluence was edited with the constant percentage penetration depth of 50%. Figure 2B is showing influence edited ECOPM plan.

### *Volumetric modulated arc therapy plans*

VMAT is the inverse IMRT technique by which the dose is delivered in an arc fashion. This technique is most advanced out of others and better known for its dose conformity. The normal tissues can be easily spared by this technique. But the limitation of the technique is the time taken by treatment plan optimization and treatment delivery time.

Dynamic gantry motion and intensity modulation with the help of 60 leaf pair of MLC makes the treatment plan conformal to the PTV area. Two arcs of 10 degrees and 350-degree collimator angles (figure 1C) with variable gantry speed and dose rate modulation from 0 MU/ min to 600 MU/min makes the plan conformal to the PTV. Different priorities to different critical structures during VMAT-optimization make the plan more conformal compared to above two discussed techniques (figure 2C).

### *Dosimetric comparison*

Three different treatment plans were compared using the dose volume histogram for dose in PTV, homogeneity index (HI), conformity index (CI), mean and maximum doses to PTV. Organs at risk, skin surface doses and monitor units required for treatment were also evaluated for all the three plans. Definition of HI cited by Wu *et al.* [9] is the maximum-minus minimum absorbed dose normalized to the ICRU prescription absorbed dose. This definition for Homogeneity index was used by many authors [10, 11] as shown in equation 1:

$$HI = \frac{D_{2\%} - D_{98\%}}{D_{50\%}} \quad (1)$$

Where, $D_{2\%}$ corresponds to dose to 2% PTV, $D_{98\%}$ is the dose to 98% PTV and $D_{50\%}$ represents the dose to 50% PTV that is near to prescription dose. A Homogeneity Index of zero indicates that the absorbed-dose distribution is homogeneous. Dose conformity characterizes the degree to which the high-dose region conforms to the PTV. CI is defined as the ratio of the target volume and the volume inside the isodose surface that corresponds to the prescription dose [12]. CI is generally used to indicate the portion of a prescription dose that is delivered inside the PTV. Formulae of CI, used in this study is given as equation 2:

$$CI = (V_{PTV\,ref} / V_{PTV}) \times (V_{PTV\,ref} / V_{ref}) \quad (2)$$

Where $V_{PTV\,ref}$ represents the volume of PTV covered with the reference dose. $V_{PTV}$ represents the volume of PTV and Vref is the volume covered with the reference dose or higher [13]. CI of 1 indicates that 100% of a prescription dose is delivered to the PTV.

### *Statistical analysis*

Mean, standard deviation, and significant values were obtained for each technique. Student's paired t-test was applied to compare techniques. Because there are three techniques of interest, there are three comparisons for each parameter with a two-tailed significant level of 0.05 was used. All p values ≤ 0.05 are statistically significant. Microsoft office excels statistical software was used for this analysis.

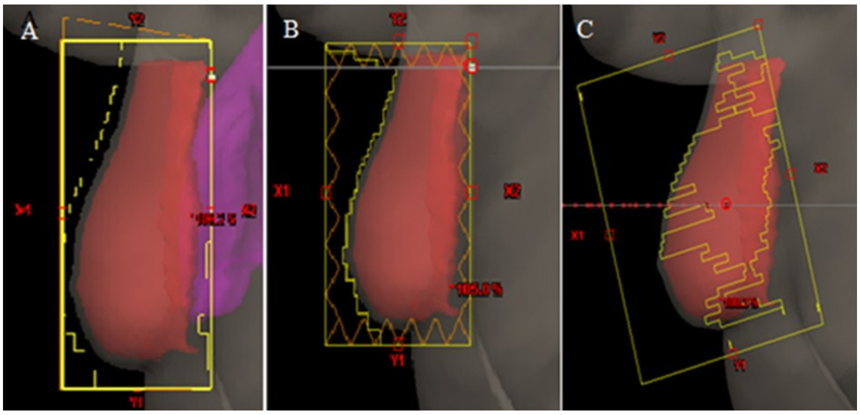


**Figure 1.** Beams Eye View of 3DCRT plan **(A)**, ECOMP plan **(B)** and VMAT plan **(C)**.

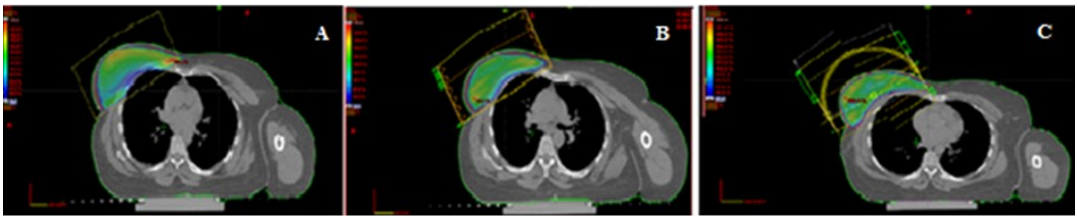


**Figure 2.** 3DCRT **(A)**, ECOMP **(B)** and VMAT **(C)** planning dose distribution in ca- rt Breast.

## RESULTS

### *Treatment planning time*

The mean treatment planning time for 3DCRT was 20 minutes, 30 minutes for ECOMP whereas for the VMAT plans the mean time of planning was 240 minutes that includes the pre-optimization phases which are preparation and contouring of dummy structures for optimization and at least two times VMAT plan optimization with intermediate-dose calculation.

All the coated treatment planning time was approximate time as observed by the author. It will depend on the speed of the planning system and the configuration of the treatment planning computer. In this study, the treatment planning system used was configured with the 64-bit





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operating system, 32GB RAM, Intel (R) Xeon (R) processor of Microsoft. Dose calculation grid size was kept the same (0.25 cm) in all the three planning techniques.

### *Treatment monitor units*

For right breast cases, MU comparison depicts that ECOMP plans show equivalent results with 3DCRT plans, (p=0.43). VMAT plans show the highest number of MU'S (p≤0.001compared with both). Similarly, for left breast patients, ECOMP plans show equivalent results with 3DCRT plans, (p = 0.87), and VMAT plans depict the highest number of MU's (p≤0.001) (tables 1 and 5).

**Table 1.** Calculated Monitor Units for the treatment of right **(A)** and left **(B)** breast cancer in three different treatment techniques.

| Right breast | | | | Left breast | | | |
|---|---|---|---|---|---|---|---|
| Patient No. | 3DCRT | ECOMP | VMAT | Patient No. | 3DCRT | ECOMP | VMAT |
| 1 | 415 | 430 | 768 | 1 | 412 | 369 | 737 |
| 2 | 401 | 342 | 686 | 2 | 409 | 395 | 670 |
| 3 | 410 | 427 | 709 | 3 | 404 | 423 | 634 |
| 4 | 398 | 414 | 795 | 4 | 403 | 407 | 579 |
| 5 | 412 | 410 | 678 | 5 | 391 | 388 | 551 |
| 6 | 408 | 369 | 734 | 6 | 379 | 374 | 694 |
| 7 | 332 | 406 | 680 | 7 | 412 | 405 | 649 |
| 8 | 414 | 406 | 637 | 8 | 408 | 371 | 524 |
| 9 | 394 | 388 | 564 | 9 | 405 | 357 | 657 |
| 10 | 400 | 366 | 570 | 10 | 479 | 433 | 664 |
| 11 | 396 | 411 | 703 | 11 | 399 | 370 | 628 |
| 12 | 411 | 367 | 589 | 12 | 407 | 414 | 788 |
| 13 | 422 | 437 | 667 | 13 | 425 | 408 | 749 |
| 14 | 331 | 411 | 526 | 14 | 553 | 839 | 663 |
| 15 | 270 | 378 | 594 | 15 | 405 | 389 | 723 |
| **Mean± SD** | **387.6± 42.6** | **396.4± 26.3** | **660± 78.5** | **Mean± SD** | **419.4± 42.8** | **422.8± 117.2** | **660.6 ±72.8** |

### *PTV- target coverage*

The mean PTV of right breast was 684.72cc (range 179.14-1020.54 cc) and 579.13cc (range 254.83-1025.6) for left breast (table 2). For right breast cases, the statistical analysis showed that average $V_{95\%}$ for ECOMP plans was (94.14% ±1.75%) higher than 3DCRT plans (93.03% ±2.98%) with no statically significant difference. VMAT plan gave superior PTV coverage (97.8% ±1.05%) over 3DCRT and ECOMP, (p≤0.001 for both). For left breast cases, the average mean $V_{95\%}$ for ECOMP plans was higher (94.5% ±2.21%) than 3DCRT plans (93.49%±2.71%) (p=0.068). VMAT plans showed superior $V_{95\%}$ coverage compared to other two techniques (p ≤ 0.001 for both 3DCRT and ECOMP) (table 3).

**Table 2.** Volume of right **(A)** and left **(B)** breast PTV.

| A. Right breast | | B. Left breast | |
|---|---|---|---|
| Patient number | Volume of right breast PTV (cc) | Patient number | Volume of left breast PTV (cc) |
| **1** | 522.08 | **1** | 751.91 |
| **2** | 517.3 | **2** | 475.07 |
| **3** | 902.54 | **3** | 549.67 |
| **4** | 664.01 | **4** | 696.61 |
| **5** | 959.62 | **5** | 845.89 |
| **6** | 542.66 | **6** | 322.24 |
| **7** | 858.58 | **7** | 456.51 |
| **8** | 1020.54 | **8** | 254.83 |
| **9** | 1001.92 | **9** | 475.52 |
| **10** | 257.93 | **10** | 685.57 |
| **11** | 570.94 | **11** | 403.56 |
| **12** | 179.14 | **12** | 768.32 |
| **13** | 901.04 | **13** | 1025.6 |
| **14** | 736.96 | **14** | 593.06 |
| **15** | 635.57 | **15** | 382.52 |
| Mean volume (range) | 684.72 (179.14-1020.54) | Mean volume (range) | 579.13 (254.83-1025.6) |

**Table 3.** Statistical analysis of PTV.

| | 3DCRT | | ECOMP | | VMAT | | P values | | |
|---|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Mean | SD | 3DCRT/ ECOMP | ECOMP /VMAT | 3DCRT/ VMAT |
| $V_{95\%}$ (right) | 93.03 | 2.98 | 94.14 | 1.75 | 97.8 | 1.05 | 0.19 | <0.001 | <0.001 |
| $V_{95\%}$ (Left) | 93.49 | 2.71 | 94.5 | 2.21 | 97.28 | 1.49 | 0.068 | 0.0011 | <0.001 |

### *Homogeneity and conformity indexes*

Table 5 showed that for the right breast patients, the mean HI was 0.19, 0.2 and 0.1 for 3DCRT, ECOMP, and VMAT plans respectively. HI for ECOMP plans was equivalent to 3DCRT plans (p=0.53) whereas VMAT plans showed superior homogeneity (p=0.01 with 3DCRT & 0.0003 with ECOMP). CI for 3DCRT, ECOMP, and VMAT was 0.62, 0.64 and 0.86, respectively. ECOMP and 3DCRT showed similar results (p=0.43) whereas VMAT plans showed superior conformity (Table 3) as compared to 3DCRT and





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ECOMP, respectively.

The mean values of HI for left breast were 0.15, 0.12 and 0.09 for 3DCRT, ECOMP and VMAT respectively. HI for ECOMP plans was higher (0.12±0.03) than 3DCRT plans (0.15±0.02, (p= 0). VMAT plans showed superior homogeneity (0.09±0.02) compared to 3DCRT (p=0.011) and ECOMP (p=0.0). ECOMP plans showed higher conformity (0.61±0.06) than 3DCRT plans (0.58±0.07) (p=0.011), VMAT plans showed superior CI (0.81±0.21), (p=0.0025& 0.0006 as compared to 3DCRT & ECOMP plans, respectively).

**Table 4.** Statistical analysis for OAR doses of the patients.

| Parameter | 3DCRT | ECOMP | VMAT | P-VALUE | | |
|---|---|---|---|---|---|---|
| | Mean± SD | Mean± SD | Mean± SD | 3DCRT / ECOMP | ECOMP/ VMAT | VMAT/ 3DCRT |
| $V_{5Gy}$ (%)* (right lung) | 27.1±9.32 | 24.94±10.14 | 71.54±14.61 | 0.007 | <0.001 | <0.001 |
| $V_{10\,Gy}$ (%)* (right lung) | 18.74±8.77 | 18.73±9.27 | 45.24±15.13 | 0.98 | <0.001 | <0.001 |
| $V_{20\,Gy}$ (%)* (right lung) | 14.9±8.22 | 15.1±8.72 | 15.2±8.35 | 0.65 | 0.94 | 0.82 |
| $V_{5\,Gy}$ (%) ** (left lung) | 27.14±5.53 | 24.53±5.33 | 65.55±12.19 | <0.001 | <0.001 | <0.001 |
| $V_{10\,Gy}$ (%) ** (left lung) | 27.67±19.53 | 26.72±18.93 | 33.8±36.3 | 0.007 | 0.0004 | 0.0005 |
| $V_{20\,Gy}$ (%) ** (left lung) | 15.8±4.70 | 15.5±4.84 | 11.5±3.98 | 0.17 | 0.046 | 0.029 |
| R- Breast surface dose* (Mean) (Gy) | 22.39±1.99 | 22.24±1.8 | 20.63±1.59 | 0.95 | <0.001 | <0.001 |
| L-Breast surface dose** (Mean) (Gy) | 22.47±1.49 | 21.96±2.15 | 20.41±1.13 | 0.21 | 0.005 | <0.001 |
| Contra-lateral Lung* mean dose (Gy) | 0.36±0.18 | 0.05±0.06 | 1.61±0.52 | <0.001 | <0.001 | <0.001 |
| Contra-lateral lung** mean dose (Gy) | 0.61±0.18 | 0.1±0.09 | 1.47±0.34 | <0.001 | <0.001 | <0.001 |
| Heart mean dose (Gy)* | 1.16±0.28 | 0.44±0.17 | 4.38±1.92 | <0.001 | <0.001 | <0.001 |
| Heart mean dose (Gy)** | 4.5±1.93 | 3.7±1.9 | 7.2±1.58 | <0.001 | 0.0001 | 0001 |

* Right breast plan ** Left breast plan

**Table 5.** Mean (with standard deviation) of parameters: PTV, MUs, CI, HI & Dmax and statistical significance.

| Parameter | 3DCRT | | ECOMP | | VMAT | | p -value | | |
|---|---|---|---|---|---|---|---|---|---|
| | Mean | S.D. | Mean | S.D. | Mean | SD | 3DCRT/ECOMP | ECOMP/VMAT | 3DCRT/VMAT |
| PTV (right) (CI) | 0.62 | 0.10 | 0.64 | 0.11 | 0.86 | 0.05 | 0.43 | 0.03 | 0.00 |
| PTV (left) (CI) | 0.58 | 0.07 | 0.61 | 0.06 | 0.81 | 0.21 | 0.011 | 0.0025 | 0.0006 |
| PTV (right) (HI) | 0.19 | 0.08 | 0.2 | 0.11 | 0.09 | 0.008 | 0.53 | 0.01 | 0.0003 |
| PTV (left)(HI) | 0.15 | 0.02 | 0.12 | 0.03 | 0.09 | 0.02 | 0.00 | 0.011 | 0.00 |
| MU(right) | 387.96 | 41.12 | 397.4 | 26.72 | 660 | 75.83 | 0.43 | 0.00 | 0.00 |
| MU(left) | 419.4 | 41.4 | 422.8 | 113.2 | 660.66 | 70.35 | 0.87 | 0.00 | 0.0008 |
| Dmax(right) | 109.4 | 1.33 | 106.7 | 0.96 | 108.5 | 1.33 | 0.00 | 0.0002 | 0.26 |
| Dmax(left) | 108.8 | 0.95 | 106.9 | 1.15 | 110.1 | 2.75 | 0.001 | 0.0007 | 0.088 |

### *The organ at Risk (OAR) doses*

### *Ipsilateral lung doses*

For left breast cases, ipsilateral lung $V_{5Gy}$ was least in ECOMP plans (24.94%±10.14%) compared with 3DCRT (p= 0.007) and VMAT (p<0.001) plans. Volume receiving 10 Gy and 20 Gy ($V_{10Gy}$ and $V_{20Gy}$) of the lung was also least in ECOMP plans but not statistically significant. For the cases of right breast, ECOMP showed statistical significant volume reduction for $V_{5Gy}$ and $V_{10Gy}$ as compared to other two plans (table 4). The lung volumes ($V_{5Gy}$ and $V_{10Gy}$) in VMAT plans were significantly higher than 3DCRT and ECOMP plans.

### *Breast surface Dose*

For right breast cases, the mean surface dose for ECOMP plans (22.24Gy±1.8) was similar to 3DCRT plans (22.39Gy±1.99), (p=0.95). For VMAT plans, the mean surface dose was least in comparison to 3DCRT and ECOMP plans, (p<0.001 for both). The mean surface dose for





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left breast cases for ECOMP plans (21.96Gy±2.15) and 3DCRT plans (22.47Gy±1.49) were not significant (p=0.21). VMAT plans showed lower surface doses as compared to 3DCRT and ECOMP plans, (p=0.005 & <0.0001 respectively) (figure 4d).

### *Contra-lateral lung doses*

For left breast cases, the mean contra-lateral lung doses for ECOMP plans were lower than 3DCRT plans, (p<0.001). VMAT plans showed higher lung doses in comparison to 3DCRT and ECOMP plans (p<0.001for both). For right breast, cases mean contra-lateral lung doses in ECOMP plans was lower in comparison to 3DCRT (plans p<0.001). VMAT plans showed higher doses in comparison to 3DCRT & ECOMP plans, (p ≤0.001 for both) (figure 4c).

### *Heart doses*

For right breast cases, the mean heart doses for ECOMP plan (0.44Gy±0.17) was lower than 3DCRT plans (p<0.001). VMAT plans showed doses at a higher end (4.38Gy±1.92) than 3DCRT & ECOMP plans (p<0.001). Similarly, for left breast cases, ECOMP plans show mean doses to heart lower than 3DCRT and VMAT plans. (p < 0.001) (table 4).

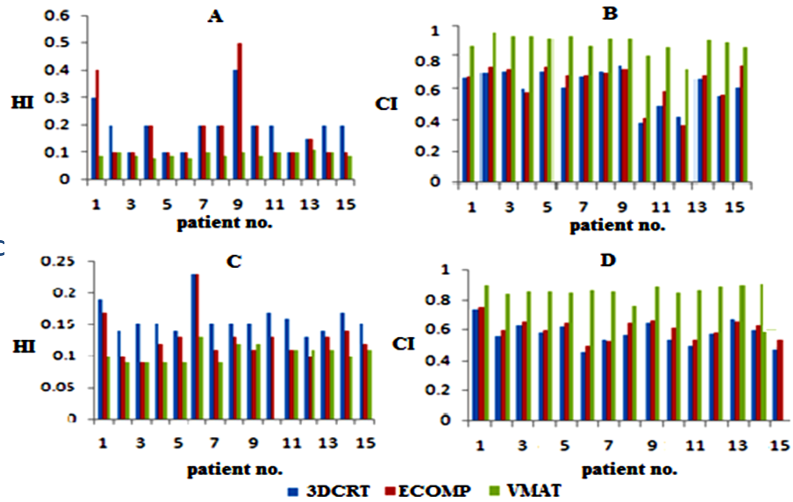


**Figure 3.** Histograms are showing HI and CI of right breast (**A** & **B** respectively), and left breast (**C** & **D** respectively) for three different techniques.

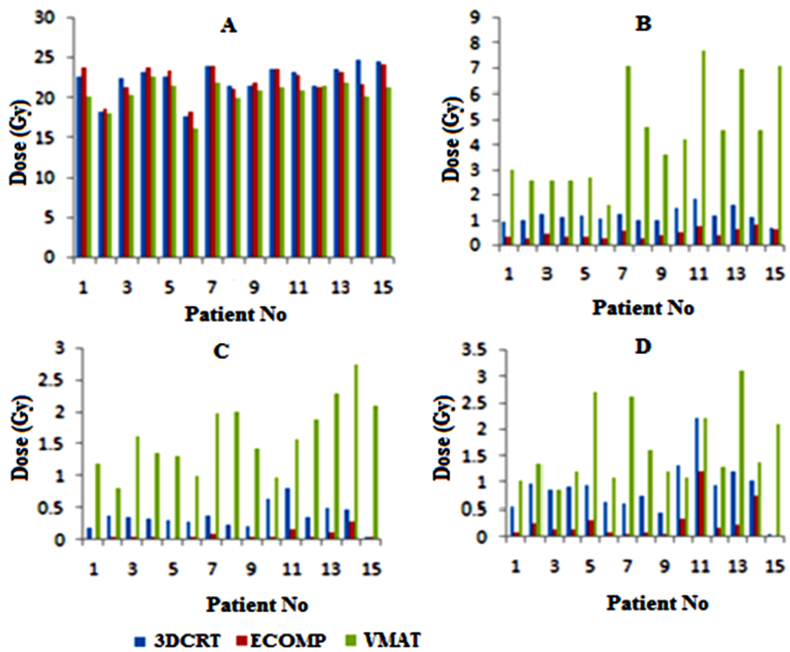


**Figure 4.** Dosimetric parameters of OARs of 15 patients of left breast plans for three different techniques **(A)** mean surface dose of the left breast, **(B)** mean heart doses of the left breast, **(C)** mean dose of contra-lateral lung and **(D)** mean dose of contra-lateral breast.



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## DISCUSSION

This study acknowledges that even though the HI and CI are better in VMAT plans but the OAR (ipsilateral lung, contralateral lung, and heart) doses were significantly higher in VMAT technique compared with two other techniques. The larger volume of normal tissue is exposed to lower doses of scattered radiation in this delivery technique (VMAT) [14].

The lower doses of radiation to a large volume can lead to secondary malignancy as mutations are more dominant than cell killing at lower doses [16, 17]. The survival rate of breast cancer patients is high so, this technique can further increase the risk of secondary malignancy especially for young patients [15]. On the other side, ECOMP plans take nearly the same time of planning as 3DCRT and less treatment delivery time. Ipsilateral lung volume receiving 5 Gy and 10 Gy were significantly less in ECOMP plans. VMAT plans showed higher mean contra-lateral lung doses in comparison to 3DCRT & ECOMP plans ($p<0.001$ for both) for both sides of breast. In VMAT plans, mean heart doses were higher (4.38 Gy±1.92) compared to 3DCRT & ECOMP plans ($p<0.001$ for both).

Average maximum doses were 108.5% and 110.1% in VMAT plans of right and left breast respectively but that was inside PTV. These maximum doses were significantly higher than that for ECOMP plans. Mean $V_{25\%}$ (Volume receiving 25 percent of the prescribed dose that is 40 Gy in 16 fractions) of heart in left breast plans was less than 2.5% volume in all the three treatment techniques. That value was well within the tolerance dose limit of 1% complication probability as per QUANTEC data [18]. VMAT requires more planning time and advanced planning skills. For VMAT, the average planning time was nearly four hours. With this technique late radiotherapy associated complications can be reduced as dose conformity of the plan is higher than the other two techniques but the heart and lung doses were observed significantly higher than the 3DCRT and ECOMP plans. ECOMP is another good technique that can improve the dose homogeneity of PTV superior to 3DCRT. Surface dose, ipsilateral breast, and ipsilateral lung dose can be reduced by using this technique.

The quality of plans was dependent on the efficacy of the fluence editor. Treatment planning time for ECOM was ~ 10 min longer than that of 3DCRT (planning time ~20 min) but treatment delivery time was nearly 3-5 minutes lesser than that for 3DCRT as 3DCRT treatment delivery needs time to put the wedges and collimator takes time to rotate through 180˚. ECOMP treatment delivery time was estimated nearly the same as VMAT delivery time. In all the cases careful attention is required for breast movement during treatment delivery.

## CONCLUSIONS

The result showed that VMAT has high CI as well as HI. But, ipsilateral lung, contralateral lung, and heart doses were found significantly higher in VMAT plans as compared to ECOMP plans. The large volume of low doses, large treatment planning & requirement of patient-specific quality assurance (QA) before the treatment plan execution are some of the limitations of VMAT that were observed during this study. ECOMP plans did not require patient-specific QA, It takes lesser time in treatment delivery compared to 3DCRT, and it minimizes the OAR doses. ECOMP can also increase the output of the patients, especially in a busy center without compromising OAR doses and with improved CI and HI as compared to 3DCRT.

***Conflicts of interest***: *Declared none.*

## REFERENCES


1. Jemal A, Bray F, Center MM, Ferlay J, Ward E, Forman D (2011) Global cancer statistics. *CA: a Cancer Journal for Clinicians, **61(2)**: 69-90.*
2. Moody AM, Mayles WP, Bliss JM, A'Hern RP, Owen JR, Regan J, Broad B, Yarnold JR (1994) The influence of breast size on late radiation effects and association with radio-








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therapy dose inhomogeneity. *Radiotherapy and Oncology, **33(2)**: 106-12*.
3. Taylor ME, Perez CA, Halverson KJ, Kuske RR, Philpott GW, Garcia DM, Mortimer JE, Myerson RJ, Radford D, Rush C (1995) Factors influencing cosmetic results after conservation therapy for breast cancer. *Int J Radiat Oncol Biol Phys, **31(4)**: 753-64*.
4. Gray JR, McCormick B, Cox L, Yahalom J (1991) Primary breast irradiation in large-breasted or heavy women: analysis of cosmetic outcome. *Int J Radiat Oncol Biol Phys, **21 (2)**: 347-54*.
5. Warlick WB, James HO, Earley L, Moeller JH, Gaffney DK, Leavitt DD (1997) Dose to the contralateral breast: a comparison of two techniques using the enhanced dynamic wedge versus a standard wedge. *Medical Dosimetry, **22 (3)**: 185-91*.
6. Jones D (1994) ICRU report 50—prescribing, recording and reporting photon beam therapy. *Medical physics, **21(6)**: 833-4*.
7. Hall EJ and Wuu CS (2003) Radiation-induced second cancers: the impact of 3D-CRT and IMRT. *Int J Radiat Oncol Biol Phys, **56(1)**: 83-8*.
8. Su M, Ayzenberg V, Li W (2008) SU-GG-T-488: Dosimetric Parameter Comparison of the Electronic Tissue Compensator Technique with the Conventional Physical Wedge Technique for the Whole Breast Treatment. *Medical Physics, **35(6Part17)**: 2837-7*.
9. Prescribing, I. C. R. U. (2010). recording, and reporting photon-beam intensity-modulated radiation therapy (IMRT). ICRU report, 83(10), 27-40.
10. Flejmer AM, Josefsson D, Nilsson M, Stenmarker M, Dasu A (2014) Clinical implications of the ISC technique for breast cancer radiotherapy and comparison with clinical recommendations. *Anticancer Research, **34(7)**: 3563-8*.
11. Hideki, Fujita (2013) Improvement of dose distribution with irregular surface compensator in whole breast radiotherapy. *Journal of Medical Physics/Association of Medical Physicists of India, **38(3)**: 115*.
12. Ma C, Zhang W, Lu J, Wu L, Wu F, Huang B, Lin Y, Li D (2015) Dosimetric comparison and evaluation of three radiotherapy techniques for use after modified radical mastectomy for locally advanced left-sided breast cancer. *Scientific Reports, **21(5)**: 12274*.
13. Feuvret L, Noël G, Mazeron JJ, Bey P (2006) Conformity index: a review. *Int J Radiat Oncol Biol Phys, **64(2)**: 333-42*.
14. Braunstein S and Nakamura JL (2013) Radiotherapy-induced malignancies: review of clinical features, pathobiology, and evolving approaches for mitigating risk. *Frontiers in Oncology, **3(3)**: 73*.
15. Storm HH, Kejs AM, Engholm G, Tryggvadóttir L, Klint Å, Bray F, Hakulinen T (2010) Trends in the overall survival of cancer patients diagnosed 1964–2003 in the Nordic countries followed up to the end of 2006: the importance of case-mix. *Acta Oncologica, **49(5)**: 713-24.*
16. Paganetti H (2012) Assessment of the risk for developing a second malignancy from scattered and secondary radiation in radiation therapy. *Health Physics, **103(5)**: 652*.
17. Xie L, Lin C, Zhang H, Bao X (2018) Second malignancy in young early-stage breast cancer patients with modern radiotherapy: A long-term population-based study (A STROBE-compliant study). *Medicine*, ***97*(17).**
18. Marks LB, Yorke ED, Jackson A, Ten Haken RK, Constine LS, Eisbruch A, Bentzen SM, Nam J, Deasy JO (2010) Use of normal tissue complication probability models in the clinic. *Int J Radiat Oncol Biol Phys, **76(3)**: S10-9*.



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