IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)
e-ISSN: 2279-0853, p-ISSN: 2279-0861.Volume 23, Issue 8 Ser. 1 (August. 2024), PP 18-23
www.iosrjournals.org

Dosimetric Comparison Of VMAT Versus 3DCRT Techniques For Left Breast Cancer Patients Post Mastectomy – An Observational Study.

Dr. Ramyaa. S, Dr. Kalyani. B, Rupesh Krishna
(Department Of Radiation Oncology, Kidwai Memorial Institute Of Oncology, Bengaluru, India)
(Department Of Radiation Oncology, Kidwai Memorial Institute Of Oncology, Bengaluru, India)
(Department Of Radiation Physics, Kidwai Memorial Institute Of Oncology, Bengaluru, India)

Abstract
Background : *To compare and evaluate the dose distribution of post-mastectomy radiotherapy (PMRT) targeting the left chest wall using three-dimensional conformal radiation therapy (3DCRT) and volumetric modulated arc therapy (VMAT).*
Materials and Methods: *30 patients were randomised for PMRT into 3DCRT (n=15) and VMAT (n=15). A total dose of 50 Gray in 25 fractions was administered to all patients. Planning target volume (PTV) parameters—Dnear-max (D2), Dnear-min (D98), Dmean , D95,homogeneity index (HI), and conformity index (CI) were compared. The mean doses of lung and heart, percentage volume of heart receiving 5 Gy (V5), 10 Gy (V10),20 Gy (V20),30Gy (V30) and 45 Gy (V45), Left ventricle maximum dose (Dmax) and mean dose (D mean), Left coronary artery – volume , mean dose , maximum dose and 0.1cc dose, Right coronary artery - volume , mean dose , maximum dose and 0.1cc dose were compared from dose-volume histograms.*
Results: *PTV parameters like D95%, maximum dose, and mean dose are statistically better with VMAT than 3DCRT. The conformity index (0.86 vs 0.75, $p < 0.05$) and homogeneity index (0.13 vs. 0.15, $p = 0.006$) are also significantly superior with VMAT. VMAT significantly reduced high-dose volumes to the heart compared to 3DCRT (V45: 47.67 ± 4.99 vs. 50.43 ± 5.69, $p = 0.027$). However, VMAT resulted in higher mean doses to the heart (1342.37 ± 704.51 vs. 1080.66 ± 503.22, $p < 0.001$) and increased low-dose volumes: V5 (323.98 ± 67.31 vs. 166.83 ± 24.22, $p = 0.018$)and V20 (124.18 ± 20.41 vs. 96.63 ± 12.81, $p = 0.019$). The Dmax received by LAD ($p<0.001$), RCA ($p<0.001$) and left ventricle ($p=0.04$) were significantly lower in 3DCRT than VMAT.*
Conclusion*: VMAT excels in PTV coverage and high dose volumes but 3DCRT excels in minimizing low-dose volumes.*
Keywords*: VMAT, Radiotherapy, breast cancer, dosimetry*

Date of Submission: 22-07-2024 Date of Acceptance: 02-08-2024

I. Introduction

According to the Global Cancer Observatory, breast cancer is the second most common cancer worldwide and the most prevalent cancer in India.(1) Unlike in the Western world, where early detection through mass screening programs is more common, most patients in India present with advanced-stage breast cancer due to limited screening programs and awareness. As a result, modified radical mastectomy (MRM) is performed more frequently than breast-conserving surgery (BCS).

For decades, post-mastectomy radiation therapy (PMRT) has been a critical component of breast cancer treatment alongside surgery. PMRT is employed to eradicate any hidden or microscopic residual disease following surgery, aiming to lower the risk of loco regional recurrence and enhance overall survival (OS).(2)

According to the current National Comprehensive Cancer Network (NCCN) guidelines, post mastectomy radiation therapy (PMRT) should be considered for patients with the following conditions: positive lymph nodes, tumors larger than 5 cm, positive or close surgical margins (with re-excision preferred), centrally or medially located tumors, or tumors larger than 2 cm that have other high-risk features such as young age or extensive lympho vascular space invasion (LVSI).(3)

PMRT often targets regional lymph nodes, such as the internal mammary nodes (IMN) and supraclavicular nodes (SCN). This targeting requires larger irradiation fields and volumes, leading to significant radiation exposure to organs at risk (OARs) such as heart and lung .This increases the likelihood of acute and late toxicity, particularly the risk of ischemic heart disease.(4)

Therefore, it is crucial to utilize advanced radiotherapy technology that provides adequate dose coverage to the target area while minimizing the radiation exposure to the surrounding normal tissues.

Techniques such as 3D conformal radiotherapy (3DCRT) with tangential fields have been used in the clinical practice for more than a decade now .(5) To enhance target dose homogeneity and conformity while reducing toxicity to normal tissues, other techniques such as intensity-modulated radiation therapy (IMRT) and volumetric modulated arc therapy has evolved in clinical practice. However, while IMRT improves dose homogeneity and conformity, these benefits are affected by target motion and extended treatment times, hence diminishes the clinical effectiveness of the therapy.(6)

VMAT is an arc-based technique that provides highly conformal dose distributions by utilizing beam fluence modulation, variable dose rates, and gantry speed. VMAT has been shown to achieve similar or better planning target volume (PTV) coverage and organ-at-risk (OAR) sparing compared to IMRT in case of PMRT. Its major advantages include fewer delivered monitor units (MUs) and reduced total treatment time.(6,7) For post-mastectomy patients with regional node involvement, the conventional approach uses an isocentric technique with tangential beams for the primary site and a parallel-opposed pair for the supraclavicular/axillary nodes.

Due to the thin chest wall, ensuring adequate dose coverage for the planning target volume (PTV) can be difficult, often leading to significant PTV heterogeneity and increased radiation exposure to nearby organs like the ipsilateral lung and heart. This potentially elevates the estimated risk of secondary tumors and radiation-induced pulmonary and cardiac toxicity.(8,9). The lack of extensive literature comparing VMAT with 3DCRT prevents clinicians from reaching a definitive conclusion on the best practice.

II. Aim

In this study we conducted a dosimetric comparison of planning target volumes (PTVs) and organs at risk (OARs) using two methods: 3D conformal technique and VMAT. Our goal was to determine if VMAT offers dosimetric advantages for chest-wall sites over the 3DCRT.

III. Materials And Methods

Our study focused on 30 female patients aged 18 and above who had been diagnosed with left-sided breast cancer at stages IA to IIIA and had undergone modified radical mastectomy without any secondary metastases. These patients had also received adjuvant chemotherapy.

Treatment Protocol:

Patients were immobilized in the supine position using a thoracic immobilization device, such as a thermoplastic orfit or breast board, on a flat couch. CT simulation was performed from the mandible to the L3 vertebral body with a slice thickness of 1.5 mm using a 6-slice CT scanner. Intravenous contrast (IOHEXOL) was administered at a dose of 1-2 cc/kg body weight. The resulting DICOM format images were then transferred to the Monaco treatment planning systems . To maintain consistency in contouring patterns, a single radiation oncologist contoured all patients.

The target structures included the clinical target volumes (CTV) for the left chest wall, left axillary , and left supraclavicular fossa (SCF) lymph nodal regions, as outlined by the Radiation Therapy Oncology Group (RTOG) guidelines (10). An isotropic margin of 5 mm was added to the CTV to create the planning target volume (PTV) for the chest wall and the PTV for the supraclavicular fossa (PTV SCF). To avoid high skin doses caused by the build-up effect, the PTV chest wall was created by cropping 3 mm from the skin surface. The final target volume used for planning, known as the planning target volume for evaluation (PTV eval), was then established.

The Organ at risk (OAR) such as lung and spinal cord were delineated on each slice of axial images. The heart was contoured along with the pericardial sac beginning at the level of the inferior aspect of the pulmonary artery and up to the apex of the heart(11,12).

Following the contouring atlas by Duane et al. (11), the left anterior descending artery (LAD) was delineated from the end of the left main coronary artery to the inter ventricular groove, extending towards the cardiac apex. The right coronary artery (RCA) was delineated from the anterior aspect of the ascending aorta to the acute heart border, extending posteriorly along the posterior inter ventricular groove to the apex.

30 patients were divided into two arms of 15 patients each. One arm were planned with 3Dconformal technique(3DCRT) and other with volumetric modulated arc therapy (VMAT). All patients received a dose of 50Gy in 25 fractions with 2 Gy per fraction, 1 fraction per day for 5 days a week. The beam arrangements are shown in figure 1& 2

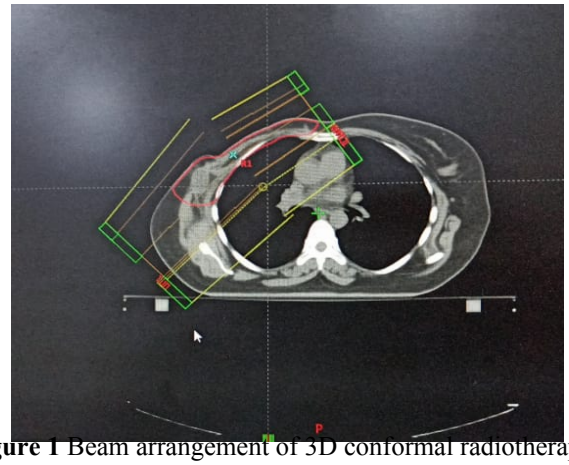

Figure 1 Beam arrangement of 3D conformal radiotherapy

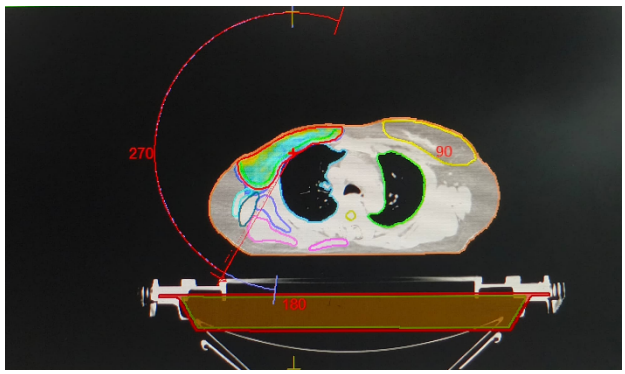

Figure 2. Beam arrangement of Volumetric modulated arc therapy

Planning target volume (PTV) parameters such as dose received by 2 % of volume (D2) , dose received by 95 % of the volume (D95),D 98 , Dmean, D max , homogeneity index (HI), and conformity index (CI) were compared. The mean doses of lung and heart, percentage volume of ipsilateral lung receiving 20 Gy (V20) and that of heart receiving 5 Gy (V5), 10 Gy (V10),20 Gy (V20) ,30 Gy (V30)and 45 Gy (V45) , Left ventricle maximum dose (Dmax) and mean dose (D mean), Left coronary artery – volume , mean dose , maximum dose and 0.1cc dose, Right coronary artery - volume , mean dose , maximum dose and 0.1cc dose were extracted from dose-volume histograms and compared.

HI was defined as the difference between the near-maximum and near-minimum dose normalised to the median dose and An ideal HI value is zero. This value indicates the better dose distribution within the PTV. Conformity index (CI) was defined as the ratio of the volume of tissue receiving at least 95% of the prescribed dose to the volume of the planning target volume (PTV) . The ideal value closer to one denotes the conformity of the plan.

Statistical Analysis

For statistical analysis, all data were recorded on Microsoft Excel and Statistical Package for Social Sciences (SPSS) version 20.0 (IBM Corp., Armonk, New York, USA). The t-test and ANOVA were used for comparison between two groups and the p-value of 0.05 was used to assess statistical significance

IV. Results

30 patients with carcinoma left breast were recruited between age of 43-65 years with median age of 53 years. Patients treated with 3DCRT technique received a mean dose of 44.64 ± 20.9 Gy and with VMAT 49.86± 19.8 Gy. Table 1 represents the dosimetric comparison of PTV parameters. It is evident that PTV parameters, such as D95%, maximum dose, and mean dose, are statistically better achieved with VMAT compared to the 3DCRT technique. Both the conformity index (0.86 ± 0.13 vs 0.75 ± 0.31, $p < 0.05$)and homogeneity index (0.13 ± 0.03 vs 0.15 ± 0.02,$p = 0.006$) are superior with VMAT than 3DCRT and statistically significant.

Table no 1 Dosimetric analysis of the Tumor volumes

PARAMETER	3DCRT	VMAT	pVALUE
PTV Dmax	54.45 ± 20	54.79 ± 39.2	0.008

PTV D mean	44.64 ± 20.9	49.86 ± 19.8	0.004
PTV D95	47.50 ± 14.50	47.94 ± 18.9	<0.001
HI	0.15 ± 0.02	0.13 ± 0.03	0.006
CI	0.75 ± 0.31	0.86 ± 0.13	<0.05

Values are depicted as Mean ± Standard deviation .PTV – Planning target volume ,3DCRT- 3D conformal radiotherapy, VMAT – Volumetric modulated arc therapy,,Dmax – maximum dose of the PTV, D mean- mean dose of PTV, D95 – dose delivered to 95 % of PTV, HI – Homogeneity index, CI – Conformity index

The beam arrangements and isodose color wash are shown in figure 1& 2. The dosimetric parameters of the organ at risk (OAR) are enlisted in table 2. For the heart, VMAT significantly reduced high-dose volumes compared to 3DCRT. (V45 - 47.67±4.99 vs 50.43± 5.69,p = 0.027). In contrary when VMAT compared with 3DCRT the mean dose to the heart (13.4 ± 7.04 vs 10.8± 5.03, p<0.001), low dose volumes of the heart V5 (323.98±67.31 vs 166.83±24.22,p =0.018), V 10 (206.78 ±35.21 vs 118.71± 23.99, p=0.002),V20(124.18 ± 20.41 vs 96.63 ± 12.81, p = 0.019) were significantly higher. Furthermore cardiac substructures such as maximum dose of LAD (p<0.001),maximum dose of RCA (p<0.001) and maximum dose of left ventricle (p=0.04) were significantly lower in 3DCRT than VMAT. The mean dose received by the Left anterior descending artery (LAD) table - were 3DCRT 36.35 ±10.33 and VMAT 32.9 ± 19.81 ,p=0.08 and the right coronary artery (RCA) 2.92 ± 0.98 and VMAT 7.4± 4.1 , p < 0.001. The dose received by the 0.1 cc volume of LAD were 3DCRT arm 51.2 ± 20.1 and VMAT 51.7 ± 23 , p <0.001 . The 0.1cc of RCA were 8.14 ± 2.1 and 13.4 ± 3.9 ,p <0.001.

Table No 2 Dosimetric analysis of the Organ At risk (OAR)

PARAMETER	3DCRT	VMAT	p- VALUE
HEART V5CC	166.83 ± 24.22	323.98 ± 67.31	0.018
HEART V10CC	118.71 ± 23.99	206.78 ± 35.21	0.002
HEART V20CC	96.63 ± 12.81	124.18 ± 20.41	0.019
HEART V30CC	81.85 ± 10.11	88.87 ± 12.39	<0.001
HEART V45CC	50.43 ± 5.69	47.67 ± 4.99	0.027
HEART D mean GY	10.80± 5.03	13.4 ± 7.04	<0.001
LT VENTRICLE Dmax	48.1± 2.1	50.7± 2.2	0.04
LAD Dmax	51.2 ± 20.04	51.7 ± 23	<0.001
0.1CC LAD	50.6 ± 28.8	50.4 ± 24	0.006
LAD Dmean	36.3 ± 10.33	33 ± 19.81	0.08
RCA Dmean	23.2 ± 10.9	22.3 ± 13.84	<0.001
0.1CC RCA	8.14 ± 2.09	13.38± 3.9	<0.001
RCA Dmean	2.92 ± 0.98	7.40 ± 4.08	<0.001
LUNG RT Dmean	0.65 ± 0.36	3.09± 2.6	0.005
LUNG LT Dmean	14.83± 2.9	14.84± 2.7	0.49
SPINAL CORD Dmax	3.94± 0.98	11.19± 3.06	<0.001

Values are depicted as Mean ± Standard deviation .,3DCRT- 3D conformal radiotherapy, VMAT – Volumetric modulated arc therapy, Dmax – maximum dose , D mean- mean dose,V5 cc – Volume of heart receiving 5 Gy& respectively,0.1 cc – Dose received by 0.1cc volume.

For the Lung the mean dose received by the right lung were significantly lower in comparison of 3DCRT with VMAT. Although not much difference were noted in the mean dose received by the left lung. The maximum dose received by the spinal cord were higher in case of VMAT than in 3DCRT and it is statistically significant
(p<0.001).

V. Discussion

With advancements in cancer research leading to increased longevity of cancer survivors, concerns about treatment-related toxicities have become more prominent. The purpose of this study is to compare the two planning techniques to achieve better tumour control and reduce the normal tissue complication rate. In our study we found that the D95 of PTV coverage is better with VMAT plans (47.94 ± 18.9) as compared with 3DCRT(47.50 ± 14.50) which is statistically significant(p<0.001). Our results are consistent with few studies

by Das majumdar et al (15) ,who stated that VMAT plans offer a better dosimetric coverage than 3DCRT .(13,14,15)

The conformity index in this study was higher in VMAT (0.86 ± 0.13) than 3DCRT (0.75 ± 0.31) and statistically significant. The value range closer to 1 denotes greater conformity. It's evident that VMAT has better conformed plans than 3DCRT. Sudha et al. (14) also noted that the effectiveness of VMAT (0.97±0.017) was higher compared to 3D-CRT (0.95±0.025).This is also confirmed by Das majumdar et al (15) ,who also found the VMAT (0.96±0.22) is more conformal than 3DCRT(0.66±0.11).

The homogeneity index of this study was lesser in VMAT (0.13±0.03) than 3DCRT (0.15 ±0.02)(p = 0.006). A lower value closer to zero indicates that VMAT plans offer a more homogeneous dose distribution, resulting in better coverage and reduced acute skin reactions. Das majumdar et al (15) also stated a similar result of 0.23±0.05 for 3D-CRT vs 0.11±0.01 for VMAT. In contrast, Sudha et al. (14) stated that VMAT plans are more inhomogeneous than 3D-CRT due to the anatomy of the chest wall, making it challenging to achieve the OAR dose constraints.

The Left lung mean dose received were 14.83± 2.9 3DCRT and 14.84 ± 2.7 in VMAT and found no significant difference between 3DCRT and VMAT (p =0.49). Although comparison studies done by Sudha et al (14) and Das majumdar et al (15) demonstrated significantly higher mean left lung dose with VMAT than 3DCRT plans. Efforts were made to minimize the dose to the contralateral right lung to the lowest level reasonably achievable. We observed that the Right lung mean dose received with VMAT was 3.09±2.6 vs 3DCRT 0.65 ±0.36 (p = 0.005). This is similar to the above mentioned study (15) , who achieved 0.89±0.36 in the 3D-CRT arm and 6.63±1.13 in the VMAT arm. The low dose in the 3D-CRT arm can be attributed to the angle of the tangential beams, which results in minimal dose spillage to the contralateral lung. Additionally, the lower PTV coverage in 3D-CRT further reduces the dose to the contralateral lung and With VMAT planning, the arc angle of the beam led to a substantial exit dose passing through the contralateral lung.

The mean heart dose values in each arm were 3DCRT 10.81 ± 5.03 and VMAT arm 13.42 ± 7.05. This coincides with Das majumdar et al (15), who also stated that the mean dose received in the 3DCRT arm (11.89±3.29) is much lesser than the VMAT arm (12.35± 3.55).The volume of heart receiving 45 Gy (V45) were 50.43±5.69 in 3DCRT arm and 47.67 ±4.99 in VMAT arm(p=0.027). This indicates that the high-dose volumes are significantly lower in VMAT compared to 3D-CRT. Similarly , the low dose volumes (Table --) such as V5 (3DCRT 166.83± 24.22 vs VMAT 323.98 ± 67.31,p = 0.018), V10(118.71± 23.99 vs 206.78 ±35.21, p 0.002), V 20(96.63 ± 12.81 vs 206.78 ±35.21,p = 0.019) .This is quite similar to those of Xu et al (16) and the above mentioned studies (14,15). The mean dose received by the Left anterior descending artery (LAD) table - were 3DCRT 36.35 ±10.33 and VMAT 32.9 ± 19.81 ,p=0.08 and the right coronary artery (RCA) 2.92 ± 0.98 and VMAT 7.4± 4.1 , p < 0.001. The dose received by the 0.1 cc volume of LAD were 3DCRT arm 51.2 ± 20.1 and VMAT 51.7 ± 23 , p <0.001 . The 0.1cc of RCA were 8.14 ± 2.1 and 13.38 ± 3.9,p <0.001. Even Tyran et al (17) demonstrated that the low dose received by the left coronary artery (LCA) (D2%(LCA) = VMAT 34.4 Gy vs 3DCRT 40.3 Gy, was significantly lower in VMAT than 3DCRT.Even the maximum dose received by the spinal cord was significantly lower in 3DCRT (3.94± 0.98) than VMAT (11.19 ± 3.06) p< 0.001.Another advantage of VMAT is the time required to generate the treatment plan, which is 45 minutes, compared to at least 120 minutes for 3DCRT.

In these cases, VMAT showed its advantage by adequately covering the tumor volume and reducing the treatment planning time . However, it was noted that better PTV coverage in VMAT came at the cost of higher doses to the low-dose volumes of the heart and lungs. This example shows that while VMAT may not be beneficial for most left chest-wall patients, there is a subgroup for whom 3D-CRT fails to provide sufficient PTV coverage. The final decision relies on the clinician's thorough assessment of each individual patient.

The drawback of this study was the shorter follow up period ,hence the clinical outcomes and treatment related toxicities were not mentioned. A randomized trial with a larger sample size and longer follow-up period would help assess the survival rate and toxicity profile, ultimately evaluating the quality of life.

VI. Conclusion:

It is evident that VMAT plans are better than 3DCRT in terms of PTV coverage and coverage of high dose volumes. Although this at the cost of low dose irradiation of the heart ,lung and the spinal cord .Hence VMAT has to be prioritize by the treating clinician after thorough assessment of the individuals. Further studies are required to determine the survival rates based on the tumor coverage , techniques and the treatment related toxicities.

References

[1] Ferlay J, Ervik M, Lam F, Laversanne M, Colombet M, Mery L, Piñeros M, Znaor A, Soerjomataram I, Bray F (2024). Global Cancer Observatory: Cancer Today. Lyon, France: International Agency For Research On Cancer. Available From: Https://Gco.Iarc.Who.Int/Today, Accessed [28 June 2024].

[2] Feigenberg Sj, Mendenhall Np, Benda Rk, Et Al. Postmastectomy Radio Therapy: Patterns Of Recurrence And Long-Term Disease Control Using Electrons. Int J Radiat Oncol Biol Phys. 2003;56(3):716–25.

[3] National Comprehensive Cancer Network. Nccn Guidelines For Treatment Of Breast Cancer [Internet]. Fort Washington, Pa: National Comprehensive Cancer Network; C2024 [Cited 28 June 2024]. Available From: Https://Www.Nccn.Org/Professionals/Physician_Gls/Default.Aspx.

[4] Darby Sc, Ewertz M, Mcgale P, Et Al. Risk Of Ischemic Heart Dis Ease In Women After Radiotherapy For Breast Cancer. N Engl J Med. 2013;368(11):987–98.

[5] Muren Lp, Maurstad G, Hafslund R, Et Al. Cardiac And Pulmonary Doses And Complication Probabilities In Standard And Conformal Tangential Irra Diation In Conservative Management Of Breast Cancer. Radiother Oncol. 2002;62(2):173–83.

[6] Popescu Cc, Olivotto Ia, Beckham Wa, Et Al. Volumetric Modulated Arc Therapy Improves Dosimetry And Reduces Treatment Time Compared To Conventional Intensity-Modulated Radiotherapy For Locoregional Radiotherapy Of Left-Sided Breast Cancer And Internal Mammary Nodes. Int J Radiat Oncol Biol Phys. 2010;76:287–95.

[7] Nicolini G, Fogliata A, Clivio A, Et Al. Planning Strategies In Volumetric Modulated Arc Therapy For Breast. Med Phys 2011;38(7):4025–31.

[8] Blom Goldman U, Anderson M, Wennberg B, Et Al. Radiation Pneumonitis And Pulmonary Function With Lung Dose–Volume Constraints In Breast Cancer Irradiation. J Radiother Pract. 2014;13(02):211–7.

[9] Stranzl H, Zurl B. Postoperative Irradiation Of Left-Sided Breast Cancer Patients And Cardiac Toxicity. Strahlenther Onkol. 2008;184:354–8.

[10] Loganadane G, Truong Pt, Taghian Ag, Tešanović D, Jiang M, Geara F, Et Al. Comparison Of Nodal Target Volume Definition In Breast Cancer Radiation Therapy According To Rtog Versus Estro Atlases: A Practical Review From The Transatlantic Radiation Oncology Network (Trone). Int J Radiat Oncol Biol Phys 2020;107:43748.

[11] Duane F, Aznar Mc, Bartlett F, Cutter Dj, Darby Sc, Jagsi R, Et Al. A Cardiac Contouring Atlas For Radiotherapy. Radiotheroncol. 2017 Mar 1;122(3):416–22.

[12] Feng M, Moran Jm, Koelling T, Chughtaia, Chan Jl, Freedman L, Et Al. Development And Validation Of A Heart Atlas To Study Cardiac Exposure To Radiation Following Treatment For Breast Cancer. Int J Radiatoncolbiolphys 2011;79:108.

[13] Ma C, Zhang W, Lu J, Wu L, Wu F, Huang B, Lin Y, Li D. Dosimetric Comparison And Evaluation Of Three Radiotherapy Techniques For Use After Modified Radical Mastectomy For Locally Advanced Left-Sided Breast Cancer. Sci Rep. 2015 Jul 21;5:12274. Doi: 10.1038/Srep12274. Pmid: 26194593; Pmcid: Pmc4508617.

[14] Sudha Sp, Seenisamy R, Bharadhwacomparison Of Dosimetric Parameters Of Volumetric Modulated Arc Therapy And Three-Dimensional Conformal Radiotherapy In Postmastectomy Patients With Carcinoma Breast. J Cancer Res Ther. 2018;14:1005–1009

[15] Das Majumdar Sk, Amritt A, Dhar Ss, Barik S, Beura Ss, Mishra T, Muduly Dk, Dash A, Parida Dk. A Dosimetric Study Comparing 3d-Crt Vs. Imrt Vs. Vmat In Left-Sided Breast Cancer Patients After Mastectomy At A Tertiary Care Centre In Eastern India. Cureus. 2022 Mar 28;14(3):E23568. Doi: 10.7759/Cureus.23568. Pmid: 35494897; Pmcid: Pmc9045011.

[16] Xu H, Hatcher G. Treatment Planning Study Of Volumetric Modulated Arc Therapy And Three Dimensional Field-In-Field Techniques For Left Chest-Wall Cancers With Regional Lymph Nodes. Rep Pract Oncol Radiother. 2016 Nov-Dec;21(6):517-524. Doi: 10.1016/J.Rpor.2016.07.005. Epub 2016 Aug 24. Pmid: 27698592; Pmcid: Pmc5036511.

[17] Tyran M, Mailleux H, Tallet A, Fau P, Gonzague L, Minsat M, Moureau-Zabotto L, Resbeut M. Volumetric-Modulated Arc Therapy For Left-Sided Breast Cancer And All Regional Nodes Improves Target Volumes Coverage And Reduces Treatment Time And Doses To The Heart And Left Coronary Artery, Compared With A Field-In-Field Technique. J Radiat Res. 2015 Nov;56(6):927-37. Doi: 10.1093/Jrr/Rrv052. Epub 2015 Sep 19. Pmid: 26386255; Pmcid: Pmc4628222.