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A Comparison of Dosimetric Parameters of Volumetric Modulated Arc Therapy and Three - Dimensional Conformal Radiotherapy in Left-Sided Chestwall Radiation Therapy.

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Abstract: *The standard of care for left sided Chestwall radiotherapy is conformal radiotherapy technique, however dose to left lung and heart remain organs at risk. With newer techniques like Intensity-modulated radiotherapy (IMRT) and Volumetric arc therapy (VMAT), the doses to the heart and Left lung can be reduced. This study aims to compare dosimetric parameters of two forms of radiotherapy, VMAT and 3DCRT for left-sided chest wall radiotherapy. The results showed low doses to lung and heart (V5, H20) was higher in the VMAT plans with statistical significance (p=0.001 and 0.013), other dosimetric parameters were better with VMAT but the difference was not statistically significant.*

Keywords: *Chest wall, radiotherapy, IMRT, VMAT, 3DCRT*

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I. Introduction

The most common cancer among women globally is breast cancer and it is also the leading cause of cancer deaths globally among women.[1] In developing countries, locally advanced breast cancers (LABCs) account for the majority of the cases.[2] Treatment of LABC involves a multimodality approach including surgery, chemotherapy, radiotherapy. Large randomized trials and meta‑ analysis have shown that postmastectomy radiotherapy (PMRT) improves both local control and overall survival.[3,4] PMRT to the chest wall is usually delivered using tangential photon beams in two‑ dimensional and three‑ dimensional conformal radiotherapy (3DCRT). The regional nodes are usually treated using a direct anterior neck field supplemented by a posterior axillary field.

Many studies have shown that chest wall radiotherapy with such tangential beams includes a large portion of the lung and heart.[5] This significantly increases the morbidity and mortality due to cardiac damage, especially in patients with left‑ sided breast cancer.[5,6] Volumetric modulated arc therapy (VMAT), an improved method of radiation delivery, can achieve highly conformal dose distributions while sparing critical organs at risks (OAR) like the lungs and heart. This is achieved in VMAT by simultaneously changing the position of the multileaf collimators (MLCs), the dose rate, and the gantry speed during patient treatment. The most important advantage of VMAT when compared to other intensity-modulated treatments like intensity‑ modulated radiation therapy (IMRT) is a substantial reduction in treatment time.

Very few studies compared this novel technique with 3DCRT, especially in the Indian setting. In our study, we compared the dosimetric parameters of VMAT and field‑ in‑ field 3DCRT treatment plans of breast cancer patients receiving PMRT.

II. Materials And Methods

Ten patients who underwent mastectomy for left‑ sided LABC were chosen for this study. The patient was immobilized in the supine position on a vacloc. The left arm was abducted, and the head was turned towards the right side. Radio‑ opaque wires were used to mark the field borders and the mastectomy scar. Thermoplastic masks were used for immobilizing the patient. Computed tomography (CT)‑ simulation was performed using GE Bright Speed. A noncontrast CT scan of the thorax was performed from the level of C2 vertebral body to the level of L2 vertebral body using 3 mm slice thickness with 3 mm reconstruction.

Contouring the planning target volume (PTV) was contoured according to the breast cancer atlas for radiation therapy planning consensus definitions of the Radiation Therapy Oncology Group (RTOG) The PTV included the chest wall with the pectoralis muscle, serratus anterior, ribs, and intercostal muscles. If the skin was not involved by the tumor, the contour was cropped from the skin surface. The skin was included in cases where there was pathological involvement of the skin. The PTV was generated using a 7 mm margin in the medial, anterior, posterior, and inferior direction. Lungs, heart, contralateral breast, and spinal cord were contoured as organs at risk. Three‑ dimensional conformal radiotherapy planning 3DCRT planning was performed using a mono‑ isocentric technique. The chest wall was irradiated using two tangential beams. Gantry angles ranged from 300° to 335° for the medial fields and from 130° to 155° for the lateral fields. The dose was prescribed to the isocenter. Field‑ in‑ field technique with MLCs was used to provide adequate coverage of the PTV (95% of the prescribed dose to 95% of the target volume) and to reduce the hot spots to <110%. Bolus with 5 mm thickness was used to improve the coverage of the skin. The SCF was treated with a single anterior field angled 10–15° away from the spinal cord. An overlap of 1 mm was given into the tangential field if there was an area of under‑ dosage in either field. Similarly, any hot spot at the junction of the two fields was taken care by adjusting the MLCs. The dose was prescribed usually at a depth of 3 cm for the SCF. The depth was adjusted according to the dose maximum, and if there was under‑ dosage of rest of the axilla, a small posterior field was added to supplement the dose. For all plans, 6 MV photons with a dose rate of 600MU were used. The treatment planning system used AAA algorithm for calculation of 3DCRT plans.

Volumetric modulated arc therapy planning The VMAT plans consisted of two optimized coplanar partial arcs (2P‑ VMAT), one with beam‑ on gantries rotating in the clockwise direction from 305° to 179° and the other arc used the same beam‑ on gantries but rotating in the counter‑ clockwise direction oriented tangentially. Collimation of 30° was used for all plans. Two separate arc plans were used for treating the chest wall and supraclavicular fossa. Both used the same gantry angles. Each arc was set with 98 control points. The 2P‑ VMAT plans were optimized using the progressive resolution optimizer 3 algorithm. Bolus with 5 mm thickness was used to improve the coverage of the skin. For all plans, 6 MV photons with a dose rate of 600 MU were used. Treatment planning was performed to achieve at least 95% of PTV volume received 95% of the prescription dose (50 Gy) and with 2% of PTV volume receiving <107% of prescribed dose.

DVH parameters studied, Mean dose in Gy, V5 (%), V10 (%), V20 (%), V40 (%), of Left Lung (volume of lung receiving 5Gy, 20Gy, 40Gy, Mean dose in Gy, V5 (%), V10 (%), V20 (%), V40 (%), of heart (volume of heart receiving 5 Gy, 20 Gy, 40 Gy), mean dose received by the contralateral breast.

The data on parameters of VMAT and 3DCRT were expressed as mean with standard deviation. The comparison of the difference in parameters between VMAT and 3DCRT were carried out by using the unpaired t‑ test. The dosimetric profiles of the OAR were expressed as frequencies and percentages and were compared by using the Chi‑ square test. All statistical analysis was carried out at 5% level of significance, and $P < 0.05$ was considered significant. The unpaired t‑ test was used for comparing the means of all the dosimetric parameters, and the two‑ tailed P values were obtained using the SPSS (IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp.) software.

III. Results

VMAT and 3DCRT plans were generated for PMRT of the chest wall and drainage areas for ten patients. All the patients were treated by the 3DCRT and received a dose of 50 Gy in 25 fractions to the chest wall and drainage areas.

The mean volume of PTV was 1386 ± 239 cc. The mean left lung dose was lower for the VMAT plans (13.85 ± 2.33 for the 3DCRT plans and 14.3 ± 2.01 for the VMAT plans). The mean values of V5 Gy and V10 Gy were 53.09 ± 14.28 and 34.75 ± 7.89 for the 3DCRT plans and 74.99 ± 10.28 and 40.4 ± 6.72 for VMAT plans, respectively. The mean values of V20 Gy and V40 Gy were higher for the 3DCRT plans (26.12 ± 8.06, 11.89 ± 2.24, for the 3DCRT plans and 21.89 ± 5.34 and 7.83 ± 1.17 for the VMAT plans, respectively). The mean dose to the heart was lower for the VMAT plans (10.83 ± 3.73 in the 3DCRT plans and 9.29 ± 3.38 in the VMAT plans). The mean values of V5 Gy and V10 Gy were 36.23 ± 13.50 and 25.65 ± 10.05 for the 3DCRT plans and 45.35 ± 14.81 and 19.80 ± 8.49 in the VMAT plans, respectively. The mean values of V20 Gy and V40 Gy were higher for the 3DCRT plans (18.81 ± 7.44, and 8.87 ± 2.37 for the 3DCRT plans and 10.40 ± 6.09, and 4.92 ± 2.82 for the VMAT plans, respectively).Contralateral breast The mean doses were 2.49 ± 1.46 and 2.65 ± 1.06 for the 3DCRT and VMAT plans, respectively. The V5, H20 was higher in the VMAT plans with statistical significance (p=0.001 and 0.013)suggesting that normal tissue receiving low doses was considerably higher in the VMAT plans. Although other parameters of plans were better with VMAT the difference was not statistically significant.

IV. Discussion

The possible limitations of VMAT are that 95% dose will adhere strictly to the PTV and tight margins at the time of contouring, especially at the rib‑ pleural interface will limit the dose. Any setup errors and breathing movements can potentially lead to severe under‑ dosage of the PTV. The possible ways to circumvent these include techniques like respiratory gating. However, if VMAT is used in centers where such a facility is not available, it is better to give a wider PTV margin and accept an increase in OAR dose. However, in 3DCRT since the isocenter is located inside the lung, positional errors and breathing do not pose a significant problem in 3DCRT unlike in VMAT. However, since the contour of the chest wall in not uniform and can be highly irregular in many patients, achieving adequate coverage is challenging in 3DCRT. This can lead to the overdosage of all the OAR. We selected V20 <20–25% and V30 <10–15% as the optimization parameter in our center. If the optimizing constraints for V30 were not achieved, we went with a higher V30 dose but kept the mean dose <17 Gy. This was done so as to avoid compromising the PTV coverage.

In a study by Swamy et al., the average values of Dmean and V20 Gy in the VMAT plans for the left lung were 13.2 Gy and 21.7%, respectively, and was comparable to the values obtained in our study (14.3 ± 2.01 Gy and 21.89 ± 5.34%).[8] We used two tangentially oriented partial arcs for the chest wall fields. This resulted in a much lower dose to the lung and heart.[8]In our study, V5 was much higher in the VMAT plans than in the 3DCRT plans (74.99 ± 10.28 vs. 53.09 ± 14.28). Since we used 180° tangentially oriented arcs in our study, this reduced the high dose areas to the ipsilateral lung but increased the low dose areas. However, V10 was <50% in our study in both the 3DCRT and VMAT plans. Goldman et al. reported that the complication rate could be expected to be more than 20% if V10 was >50%.[9]However, care should be taken not to compromise on PTV coverage which can have a deleterious impact on the disease‑ free survival.

In our study, the angles of radiation beams in VMAT were the same as those of the corresponding tangential beams. The constraints were optimized to achieve the best balance of PTV coverage and heart and left lung sparing.

In the VMAT plans, Dmean of heart was 9.29 ± 3.38 Gy which was lesser than the values reported in the literature (11.4–12.9 Gy).[10‑ 12]. The mean dose was 9.29 ± 3.38 and 10.83 ± 3.73, respectively, in the VMAT and 3DCRT plan. However, the V5, H20 was higher in the VMAT plans with statistical significance (p=0.001 and 0.013)suggesting that normal tissue receiving low doses was considerably higher in the VMAT plans.

V. Conclusion

VMAT is dosimetrically superior to 3DCRT for patients with left‑ sided breast cancer owing to its superior PTV coverage and better sparing of heart and left lung. The disadvantage of this technique is that it needs stringent pretreatment dosimetric verification. Normal tissues receiving low doses is still a concern with VMAT plans We can minimize the PTV expansion by respiratory gating.The advantages of this technique are that it uses fewer monitor units and reduces treatment time when compared to IMRT.

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