Section: Radiation Oncology

Original Research Article

TO ASSESS AND CONTRAST THE EFFECTIVENESS OF INTENSITY-MODULATED RADIATION THERAPY (IMRT) AND THREE-DIMENSIONAL CONFORMAL RADIATION THERAPY (3DCRT) IN THE CONTEXT OF POST-MASTECTOMY CHEST WALL IRRADIATION IN WOMEN WITH LEFT BREAST CARCINOMA - SINGLE INSTITUTIONAL STUDY

Anita Kumari C[1], Sakthipriya S[2], M G Rahul[2], Punitha K[2]

[1]Associate Professor, The Tamilnadu Dr. M.G.R medical university, Thanjavur, Tamilnadu, India.
[2]Assistant Professor, The Tamilnadu Dr. M.G.R medical University, Thanjavur, Tamilnadu, India.

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Corresponding Author:
Dr. Punitha K,
Email: ruby41288@gmail.com

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ABSTRACT

Background: Breast cancer is the most prevalent cancer among women, with a significant proportion presenting at an advanced stage. Post-mastectomy radiation therapy (PMRT) is crucial for reducing locoregional recurrence. This study aims to evaluate and compare the dosimetric efficacy of IMRT and 3D-CRT in post-mastectomy chest wall irradiation. **Materials and Methods:** This retrospective study included 50 patients who underwent modified radical mastectomy (MRM) and received PMRT via 3D-CRT. IMRT plans were generated using the same CT-simulation data. Target volume coverage and organ-at-risk (OAR) doses were compared between IMRT and 3D-CRT plans. **Result:** IMRT plans showed improved target volume coverage, with 95% of the prescribed dose (D95) received by the planning target volume (PTV), compared to 88% in 3D-CRT plans. 3D-CRT plans showed superior sparing of organs at risk, including the heart (mean dose: 7.5 ± 2 Gy vs. 11 ± 2 Gy) and left lung (mean dose: 15 ± 3 Gy vs. 18 ± 3 Gy). Additionally, 3D-CRT plans resulted in lower volumes of the contralateral breast receiving low doses. **Conclusion:** 3D-CRT offers superior sparing of organs at risk and reduced doses to the contralateral breast compared to IMRT in post-mastectomy chest wall irradiation. 3D-CRT excels in minimizing low-dose volumes. These findings suggest that 3D-CRT may be a more suitable treatment option for patients requiring PMRT in a high volume centre based on appropriate patient selection.

INTRODUCTION

Breast cancer is the most prevalent cancer among women, with a significant proportion of cases presenting at an advanced stage. In developing countries like India, the majority of breast cancer patients are diagnosed at a late stage, resulting in a substantial burden on outpatient services. According to the data reported by the hospital-based cancer registry's, the majority of cases diagnosed with cancer breast in females, showed locoregional 57.0% spread, followed by 29.0% and 10.3% of cases with localized disease and distant metastasis, respectively.[1] In contrast to Western countries, many Indian patients present with advanced-stage breast cancer due to limited access to mass screening programs and low awareness.[2,3] Consequently, modified radical mastectomy (MRM) is often the preferred treatment option over breast-conserving surgery (BCS). However, the increasing use of mammography and neoadjuvant treatment has led to a rise in BCS frequency.[4,5] Post-mastectomy radiation therapy (PMRT) is crucial for reducing locoregional recurrence in patients with four or more positive axillary lymph nodes (ALN). PMRT is also recommended for patients with one to three positive ALN and those with negative lymph nodes but large tumors or positive pathological margins.[6]

Intensity-modulated radiation therapy (IMRT) has demonstrated superiority over three-dimensional conformal radiation therapy (3DCRT) in various clinical contexts. IMRT utilizes multileaf collimators to deliver precise radiation doses, minimizing damage to surrounding organs. When irradiating the chest wall, the lung and heart are primary organs at risk. The cardiotoxic potential of chemotherapeutic agents, such as anthracyclines and trastuzumab, further complicates treatment. IMRT employs sophisticated computer algorithms to accurately delineate radiation dose distribution, taking into account tumor dimensions, morphology, and spatial coordinates. This approach enables precise radiation delivery while minimizing damage to healthy tissue.[7,8] However, IMRT may increase cumulative radiation doses to surrounding healthy tissue, raising concerns about secondary malignancies in long-term survivors. Studies have shown that inverse-planned IMRT yields more desirable dose distributions compared to 3D-CRT for whole breast radiotherapy following BCS. This study aims to evaluate and compare the dosimetric efficacy of IMRT and 3DCRT in post-mastectomy chest wall irradiation.[9]

MATERIALS AND METHODS

This retrospective study compared the efficacy of intensity-modulated radiation therapy (IMRT) and three-dimensional conformal radiation therapy (3DCRT) in post-mastectomy chest wall irradiation. The study received institutional ethics committee approval. The study included 50 patients above 30 years with histopathologically confirmed infiltrating ductal carcinoma, who underwent modified radical mastectomy (MRM) and received post-mastectomy chest wall irradiation via 3DCRT at the Department of Radiation Oncology, Thanjavur Medical College Hospital, between January and June 2022. Inclusion criteria consisted of patients with no distant metastasis, second malignancy, or prior chest wall irradiation. Data from the selected patients' medical records were analyzed. All patients underwent non-contrast computed tomography (CT) simulation. Target volume delineation and organ-at-risk contouring were performed according to Radiation Therapy Oncology Group (RTOG) guidelines. The CT-simulation imaging data from the 50 patients' 3DCRT plans were utilized to generate IMRT plans.

RESULTS

Patient Characteristics and Treatment Outcomes
This study analyzed a cohort of 50 individuals, with an average age of 50 ± 3 years in the 3D-CRT group. The average body mass index (BMI) was 24 ± 3 Kg/m².

Treatment Plan Comparison
Target Volume Coverage [Figure 1 and Table 1]

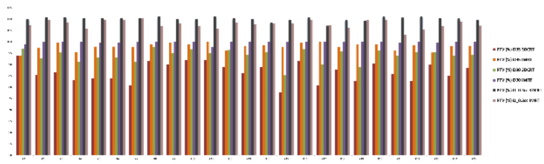

Figure 1: X axis: Patient 1 to patient 25, Y Axis: Percentage of PTV Coverage.

Table 2

PTV						
	3DCRT	**IMRT**	**3DCRT**	**IMRT**	**3DCRT**	**IMRT**
Max (%)	93.7	100	96.8	100	111	110.5
Min (%)	77.8	93.8	85.2	98.8	108.5	103.2
Avg (%)	87.2	98	94.1	99.6	110.2	107.7

- IMRT plans: 95% of the prescribed dose (D95) was received by the planning target volume (PTV).
- 3D-CRT plans: 88% of the prescribed dose (D95) was received by the PTV.
- IMRT plans: 99% of the prescribed dose (D90) was received by the PTV.
- 3D-CRT plans: 94% of the prescribed dose (D90) was received by the PTV

Table 3: Organ-at-Risk (OAR) Doses

Parameters	Heart		Lung _Lt				Lung _Rt				Breast_C/L				Oesophagus				Trachea				Spine (0.3cc)	
	Mean		Mean(Gy)		V20		Mean(Gy)		V20		Mean(Gy)		D10		Mean(Gy)		Max(Gy)		Mean(Gy)		Max(Gy)		Mean	
	3DCRT	IMRT	3DCRT	IMRT	3DCRT	IMRT	3DCRT	IMRT	3DCRT	IMRT	3DCRT	IMRT	3DCRT	IMRT	3DCRT	IMRT	3DCRT	IMRT	3DCRT	IMRT	3DCRT	IMRT	3DCRT	IMRT
Max (Gy)	9.4	13	18.6	23.7	35	63.7	0.44	7.4	-	3.17	1.9	7.8	6.8	23.7	22.8	38.6	50.3	50.9	12.1	19.2	52	51	43	40
Min (Gy)	4.8	8.9	12.1	15.7	23.4	26.7	0.2	3	-	0.1	0.44	2	1	7.5	4.4	23	42.6	39	3.6	11.6	44.5	46	14	23.8
Avg (%)	7.6	11.3	15.4	20.3	30.3	43.3	0.4	5.8	-	1.2	0.8	2.8	3.2	11.3	10.8	31.3	46.9	48.4	7.3	15.7	47.4	50	36	31.1

Left Lung
- Mean dose: 15 ± 3 Gy (3D-CRT) vs. 18 ± 3 Gy (IMRT).
- V20: 30 ± 5% (3D-CRT) vs. 35 ± 5% (IMRT).

Heart
- Mean dose: 7.5 ± 2 Gy (3D-CRT) vs. 11 ± 2 Gy (IMRT).

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Right (Contralateral) Lung
- Mean dose: 0.3 ± 0.1 Gy (3D-CRT) vs. 5 ± 2 Gy (IMRT).
- V20: 0% (3D-CRT) vs. nearly 1% (IMRT).

Right (Contralateral) Breast
- Mean dose: 0.9 ± 0.5 Gy (3D-CRT) vs. 5 ± 2 Gy (IMRT).
- D10: 3% (3D-CRT) vs. 10% (IMRT).

DISCUSSION

A number of studies have highlighted the dosimetric advantages of Intensity-Modulated Radiation Therapy (IMRT) over Three-Dimensional Conformal Radiation Therapy (3DCRT) for whole breast irradiation in patients with early-stage breast cancer.[10] Research has consistently shown that Intensity-Modulated Radiation Therapy (IMRT) for whole breast radiotherapy results in reduced radiation exposure to critical organs, including the ipsilateral lung, contralateral lung, contralateral breast, heart, and left anterior descending artery. Research has revealed distinct geometric variations in breast tissue structures among patients with left-sided breast cancer undergoing chest wall radiotherapy, potentially influencing the distribution of radiation doses.[11] The existing body of research offers limited insights into the effects of Intensity-Modulated Radiation Therapy (IMRT) on adjuvant radiotherapy for chest wall treatment in postmastectomy patients. This study aimed to assess and compare the dose distribution profiles of Intensity-Modulated Radiation Therapy (IMRT) and Three-Dimensional Conformal Radiation Therapy (3D-CRT) for chest wall irradiation in postmastectomy breast cancer patients. Fiorentino et al,[11] conducted a comparative analysis of 3DCRT and 4-field IMRT treatment plans for early breast cancer, evaluating target dose coverage, integral dose, and doses to organs at risk (OARs). Their findings indicated that the 4-field IMRT technique yielded significant reductions in doses to OARs and normal tissue, while achieving improved target coverage compared to 3DCRT. Notably, the IMRT technique yielded lower volumes of high-dose areas in the contralateral breast, left lung, and heart compared to 3D-CRT. Given the relatively young age and long life expectancy of breast cancer patients, minimizing secondary cancer risks is crucial in radiation therapy applications. Therefore, thorough risk assessments of potential complications associated with radiation doses to intact tissues, particularly in young patients vulnerable to secondary cancer risks, are essential when utilizing both planning techniques. The radiation dose received by the contralateral breast during breast radiotherapy is a significant factor in assessing the risk of secondary cancer. Although studies by Stovall et al,[12] and Berrington et al,[13] found no direct link between radiotherapy and secondary cancer formation in a cohort of 2107 patients, they did observe a increased risk of secondary cancer in younger women over the long term. Specifically, the research suggested that women under 40 years old are at higher risk of developing secondary cancer when exposed to breast doses exceeding 1 Gy. In radiation therapy applications, a primary objective is to maximize the protection of surrounding healthy tissues and organs while delivering the optimal dose to the target tissue. Therefore, it is crucial to carefully evaluate the cardiac dose in treatment plans for patients with left-sided breast cancer. According to Rancati et al,[14] the primary predictor of increased cardiac mortality is the volume of the heart exposed to 25Gy and 30Gy. Notably, the study recommends that, to minimize long-term cardiac mortality in breast cancer patients, the volume of the heart receiving 25Gy (V25) should be limited to less than 10%. Similarly, lung dose is a critical consideration in breast radiation therapy planning. Marks LB et al,[15] conducted an in-depth analysis of the radiation dose-volume relationship in the lung, revealing a strong correlation between the rate of symptomatic pneumonitis and various dosimetric parameters. Notably, the study found significant volume and fractionation effects, but no apparent "tolerance dose-volume" thresholds. Furthermore, a study by Stewart et al,[16] demonstrated that, compared to 3D-CRT, IMRT significantly reduced the risk of radiation-induced heart disease, particularly in patients with right-sided breast cancer.

Intensity-Modulated Radiation Therapy (IMRT) offers significant advantages over Three-Dimensional Conformal Radiation Therapy (3D-CRT) for post-mastectomy radiotherapy of the left chest wall, providing improved plan conformity and reduced high-dose volumes to the ipsilateral lung and heart. However, 3D-CRT excels in minimizing low-dose volumes. Ultimately, the selection of radiotherapy techniques in breast cancer treatment plays a critical role in protecting adjacent normal structures and identifying associated risks. Therefore, careful evaluation of individual patient profiles is essential to determine the most suitable approach.

CONCLUSION

3D-CRT offers superior sparing of organs at risk and reduced doses to the contralateral breast compared to IMRT in post-mastectomy chest wall irradiation. 3D-CRT excels in minimizing low-dose volumes. These findings suggest that 3D-CRT may be a more suitable treatment option for patients requiring PMRT in a high volume centre based on appropriate patient selection.

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