Original Article

Dosimetric Evaluation of Three-dimensional Conformal Radiotherapy, RapidArc, and Hybrid RapidArc Radiotherapy Techniques for Left-sided Breast Cancer

Atul Mishra, Neha Yadav[1], Madhu Sharma[2], Kailash Kumar Mittal, Surendra Prasad Mishra[3], Teerth Raj Verma[4], Shilpa Tiwari[5]

Department of Radiation Oncology, Uttar Pradesh University of Medical Sciences, Saifai, Etawah, [1]Department of Radiation Oncology, Apollomedics Super Speciality Hospitals, Lucknow, [2]Department of Radiodiagnosis, Axis Imaging Centre, Agra, [3]Department of Radiation Oncology, Dr. Ram Manohar Lohia Institute of Medical Sciences, Lucknow, [4]Department of Radiotherapy, King George Medical University, Lucknow, Uttar Pradesh, [5]Department of Physics, Madhyanchal Professional University, Bhopal, Madhya Pradesh, India

Abstract

Objective: This study aimed to assess the irradiation techniques–three-dimensional conformal radiotherapy (3DCRT), RapidArc (RArc), and hybrid RapidArc (h-RArc)–for left-sided breast cancer patients, focusing on dose distribution in the planning target volume (PTV) and organs at risks (OARs). **Materials and Methods:** This study enrolled 20 patients diagnosed with early-stage left-sided breast cancer. All patients received a prescribed dose of 40.05 Gy in 15 fractions (2.67 Gy per fraction), optimized to achieve 95% dose coverage to 95% of the PTV. The dosimetric variations across the three treatment plans for the 20 patients were examined using a one-way ANOVA test. P <0.05 was regarded as statistically significant. **Results:** In the 3DRCT plan, D95% of the PTV was 37.21 ± 0.51 Gy. This value was significantly increased to 39.43 ± 0.27 Gy in the RArc plan (P = 0.001) and to 38.47 ± 0.19 Gy in the h-RArc plan (P = 0.630). The RArc plans demonstrated a superior homogeneity index of 0.12 ± 0.02 compared to both 3DCRT (0.18 ± 0.02) and h-RArc (0.13 ± 0.02). When comparing the increase in monitor units (MUs), h-RArc showed a 62.82% increase over 3D-CRT, whereas demonstrating a 38.05% decrease compared to RArc (P = 0.000). **Conclusions:** h-RArc treatment plans for breast cancer may be recommended due to their superior and consistent PTV dose coverage and sparing of OARs, in comparison to both 3DRCT and RArc plans. These h-RArc plans are characterized by reduced MU and beam on time, as well as a less low volume dose when compared to RArc plans.

Keywords: Breast cancer radiotherapy, chest wall, hybrid, hybrid radiotherapy planning, left sided breast cancer, monitor unit

Received on: 24-06-2024 **Review completed on:** 10-12-2024 **Accepted on:** 12-12-2024 **Published on:** 24-02-2025

Introduction

Breast cancer is a global health concern, affecting millions of women worldwide. It is the most common cancer among women, with both developed and developing countries grappling with its impact. Incidence rates vary globally, with higher rates observed in developed regions such as North America and Europe, but rising rates are also seen in developing countries due to lifestyle changes and improved detection methods.[1,2]

Radiotherapy plays a crucial role in the treatment of early-stage breast cancer following breast-conserving surgery, significantly reducing recurrence and mortality rates.[3] Traditional treatment planning involves delivering a sufficient radiation dose to the intact breast while minimizing exposure to critical organs such as the lung, heart, and contralateral breast, typically achieved through the conventional tangential field technique. However, in cases of left-sided early-stage breast cancer, the concave shape of the target area often leads to elevated doses of radiation to portions of the ipsilateral lung and heart with tangential fields. This can result in a particularly high dose to the anterior heart region, including the left anterior descending coronary artery, potentially leading to increased

Access this article online

Quick Response Code:

Website: www.jmp.org.in

DOI: 10.4103/jmp.jmp_108_24

Address for correspondence: Dr. Atul Mishra, Department of Radiation Oncology, Uttar Pradesh University of Medical Sciences, Saifai, Etawah - 206 130, Uttar Pradesh, India. E-mail: meetatulmishra@gmail.com

How to cite this article: Mishra A, Yadav N, Sharma M, Mittal KK, Mishra SP, Verma TR, *et al*. Dosimetric evaluation of three-dimensional conformal radiotherapy, rapidArc, and hybrid rapidArc radiotherapy techniques for left-sided breast cancer. J Med Phys 2025;50:93-9.

perfusion defects posttreatment.[4,5] Long-term monitoring of these patients has indicated an elevated risk of ischemic heart disease following radiation therapy.[1,4-7] A recent study demonstrated a linear relationship between the mean dose to the heart and the risk of major coronary events, with no discernible threshold.[8,9] The variability in heart doses from radiotherapy for left-sided breast cancer is substantial, ranging from 0.9 to 15 Gy.[6,10,11] Patients with unfavorable cardiac anatomy, where the heart is in close proximity to the thoracic wall, experience significantly higher cardiac doses.[12] The critical organs in left-sided breast cancer treatment include the heart, lungs, and contralateral breast. Research indicates that women under 40 years old are at increased long-term risk of developing a second primary breast cancer in the contralateral breast following radiotherapy for their initial breast cancer. This risk is inversely related to the age at exposure and varies depending on the radiation dose received.[13] The lung's response to radiation injury typically follows a gradual dose-response pattern without a clear threshold. Clinically significant radiation pneumonitis, characterized by symptomatic symptoms, occurs in approximately 1%–5% of breast cancer patients treated with radiation therapy.[14]

The treatment techniques utilizing tangent angles can limit radiation dose to the ipsilateral lung and contralateral breast but may struggle to create a concave dose distribution conforming to the breast target. Advanced methods such as intensity-modulated radiation therapy (IMRT), tomotherapy, and volumetric intensity-modulated arc radiation therapy (VMAT) offer enhanced capabilities through inverse planning. These techniques facilitate the generation of more conformal dose distributions to the breast target, sparing high-dose regions to the anterior heart, and improving dose homogeneity.[15,16] While these advanced techniques are clinically acceptable, there is a continuous need for new strategies to effectively reduce doses to the heart and lungs. This necessity has spurred the development of hybrid techniques, known as Hybrid IMRT (H-IMRT) and Hybrid VMAT, which combine open beam or field in field (FiF) with inversely planned IMRT or VMAT beams with different weightings.[17]

Mayo *et al*.[18] introduced an innovative technique that combines static and dynamic fields, termed the hybrid technique, for treating breast cancer patients. This approach was designed to prioritize for the sparing of organs at risks (OARs) while maintaining high-quality treatment plans.[19,20]

The strategic integration of these modalities aims to optimize treatment, especially for cases involving the breast and chest wall. Each modality has its own benefits and drawbacks, but by integrating these approaches, it is possible to overcome their individual limitations, offering a more sophisticated and improved treatment alternative.

This study aims to develop an optimal treatment strategy for early-stage left-sided breast cancer. Specifically, study explores the dosimetric comparison between three-dimensional conformal radiotherapy (3DCRT), rapidArc (RArc), and hybrid rapidArc (h-RArc) techniques.

Materials and Methods

Twenty consecutive patients age ranging from 35 to 79 years with mean age 48 years diagnosed with early-stage (T1-3, N0-1, M0) left-sided breast cancer were included for this study. CT (Toshiba Alexion 16 multi–Slice CT scanner) simulation of each patient was done in the supine position and immobilized using AIO breast board (ORFIT industries-Belgium) with both arms raised above the head. A copper wire was placed around the breast tissue for marking purposes and to aid in contouring. The spiral computed tomography scans were taken from the neck to the lower border of the diaphragm and then reconstructed with a slice thickness of 3 mm. The planning target volume (PTV) and OAR, including the heart, right breast (RB), ipsilateral lung, and contralateral lung, were contoured following the delineation guidelines outlined by the Radiation Therapy Oncology Group for adjuvant radiotherapy of breast cancer. A prescribed dose of 40.05 Gy in 15 fractions (2.67 Gy per fraction) was assigned to the PTV for all patients. Plans were optimized to achieve 95% dose coverage (of prescribed dose) to 95% of target volume. There were no specific reference constraints in any case. However, for the optimization procedures, almost same constraints for OAR were used in all plans followed by minor adjustments in priority of OARs and PTV based on planning experience and expertise. Plans were analyzed first for target's dose coverage using the parameters $D_{95\%,}$ mean dose and maximum dose.

For the 3DCRT treatment, two tangential fields were used, employing 6MV photon energy with a Clinac iX linear accelerator from Varian Medical Systems (Palo Alto, CA). In addition, in some patients, a combination of 6MV and 15MV photon energies was utilized to achieve the desired PTV coverage and optimize the treatment plan (version 11.0.31; Varian Medical Systems, Palo Alto, CA). For the RArc treatment plan, three partial arc angles were utilized: 300°–145°, 145°–300°, and 300°–145°, with collimation angles set at 5°, 355°, and 90°, respectively. These parameters were chosen to ensure optimal dose distribution within the target volume while minimizing exposure to surrounding healthy tissues. The h-RArc treatment plan employed a combination of 3DCRT and RArc techniques. Specifically, the plan utilized the tangential field characteristic of 3DCRT, along with the three arc angles utilized in the RArc plan. The hybrid plan includes a combination of 3DCRT and RArc, using a 60/40 ratio. This approach aimed to capitalize on the strengths of both techniques, leveraging the conformal dose distribution of 3DCRT and the rotational delivery of RArc to achieve an optimal treatment outcome. By employing these distinct treatment modalities and optimizing the treatment plans according to individual patient characteristics, the study aimed to assess the efficacy and feasibility of each approach in achieving the desired treatment objectives while minimizing potential side effects.

Dosimetric comparison and plan evaluation

The quality of treatment plans was evaluated by calculating mean dose (D_{mean}), maximum dose (D_{max}), conformity index (CI),

homogeneity index (HI), coverage monitor units (MUs), and beam-on time (BOT) for each plan. BOT refers to the duration for which the radiation beam remains active to deliver each plans prescribed MUs. Cumulative dose volume histogram (DVH) generated by TPS was used to evaluate dosimetric parameters. The CI and HI were calculated using following formulae.[21-23]

CI (for 95% of PD) = Volume receiving 95% of PD/PTV

$HI = D_{2\%}\text{-}D_{98\%}/D_{50\%}$

where $D_{2\%}$, $D_{50\%,}$ and $D_{98\%}$ are the dose to 2%, 50%, and 98% PTV volumes, respectively.

Statistical analysis

The statistical study included one-way ANOVA test and *post hoc* Tukey Honestly Significant Difference using SPSS® v. 13.0 (SPSS Inc., Chicago, IL, USA) to examine the differences between 3DCRT, RArc, and hybrid plan. When $P < 0.05$, the differences were deemed statistically significant.

Results

Planning target volume dosimetric parameters

The study compared three radiotherapy techniques 3DCRT, RArc, and h-RArc by analyzing dosimetric parameters for the PTV. The findings revealed significant differences in several key parameters.

Figures 1 and 2 present the color dose wash of 95% of the prescribed dose for all three planning techniques and the corresponding DVHs for the PTV and OARs. Tables 1 and 2 detail the dosimetric planning indices for the PTV and OARs.

For $D_{95\%,}$ which represents the dose received by 95% of the PTV, the values were highest for RArc (39.43 ± 0.27 Gy), followed by h-Arc (38.47 ± 0.19 Gy), and lowest for 3DCRT (37.21 ± 0.51 Gy). The ANOVA test indicated a highly significant difference ($P = 0.000$), and *post hoc* comparisons showed that both RArc and h-RArc had significantly higher $D_{95\%}$ values compared to 3DCRT ($P = 0.001$ for both). Dose coverage with the prescribed dose improved by 5.9% in RArc and 3.4% in h-RArc compared to 3DCRT.

Regarding D_{mean}, which is the average dose to the PTV, 3DCRT had the highest value (40.22 ± 0.39 Gy), whereas RArc (39.68 ± 0.44 Gy) and h-Arc (39.78 ± 0.29 Gy) had slightly lower values. The differences were statistically significant ($P = 0.000$), with 3DCRT showing a significantly higher D_{mean} compared to both RArc ($P = 0.001$) and h-Arc ($P = 0.002$).

In terms of D_{max}, the maximum dose to the PTV, there were no significant differences among the techniques ($P = 0.080$). The values were 43.26 ± 0.28 Gy for 3DCRT, 43.06 ± 1.25 Gy for RArc, and 42.63 ± 0.87 Gy for h-Arc. The Dmax within the PTV was lowest for h-RArc, increasing by 1.0% in RArc and 1.5% in 3DCRT.

The minimum dose to the PTV (D_{min}) varied significantly among the three techniques ($P = 0.001$). 3DCRT had the highest D_{min} (32.75 ± 4.31 Gy), followed by h-RArc (30.13 ± 4.68 Gy), with RArc showing the lowest D_{min} (27.31 ± 6.27 Gy). *Post hoc* tests revealed that D_{min} for 3DCRT was significantly higher than for RArc ($P = 0.001$). The D_{min} was found to be statistically insignificant when comparing 3DCRT with h-RArc ($P = 0.151$) and when comparing RArc with h-RArc ($P = 0.213$).

For the CI, which measures how well the treatment volume conforms to the PTV, RArc had a CI of 0.92 ± 0.11, indicating better conformity compared to 3DCRT (0.54 ± 0.12) and h-Arc (0.89 ± 0.04). The differences were highly significant ($P = 0.000$), with revealing that RArc had a significantly higher CI than both 3DCRT and h-Arc ($P = 0.000$ for both).

The HI for RArc was superior to that of (h-RArc (0.12 ± 0.02 vs. 0.13 ± 0.02, respectively; $P = 0.045$) and showed a statistically significant difference when compared to 3DCRT (0.18 ± 0.02; $P = 0.000$). RArc and h-RArc plans were 33.4% and 27.8% more homogeneous than 3DCRT plans, with the difference being statistically significant ($P = 0.000$). These results suggest that RArc offers better dose coverage and uniformity for PTV compared to the other techniques. While h-RArc also shows a significant increase in HI compared to 3DCRT, it is not markedly different from the RArc technique.

In terms of MUs, which reflect the treatment delivery efficiency, 3DCRT required the less MU (312 ± 11.20), whereas RArc required the highest (820 ± 11.17), and h-RArc was intermediate (508 ± 13.17). The differences were highly significant ($P = 0.000$), with all pairwise comparisons showing significant differences ($P = 0.000$ for each).

For Beam-On Time (BOT), which represents the duration the radiation beam is active during treatment, 3DCRT had the shortest BOT (0.55 ± 0.01 minutes), followed by h-RArc

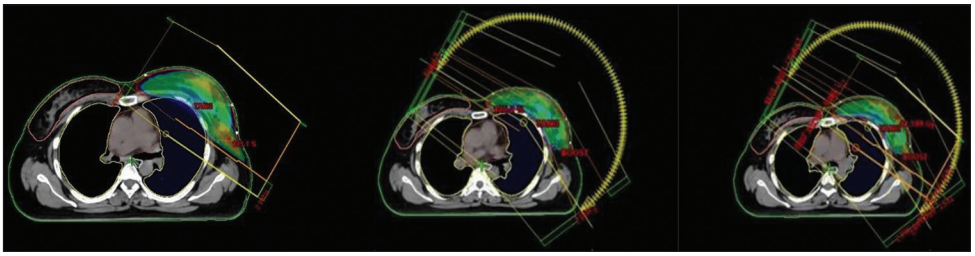

Figure 1: The beam angles and isodose distributions in Colorwash are shown for three different techniques (from left to right: three-dimensional conformal radiotherapy, RapidArc, and hybrid rapidArc)

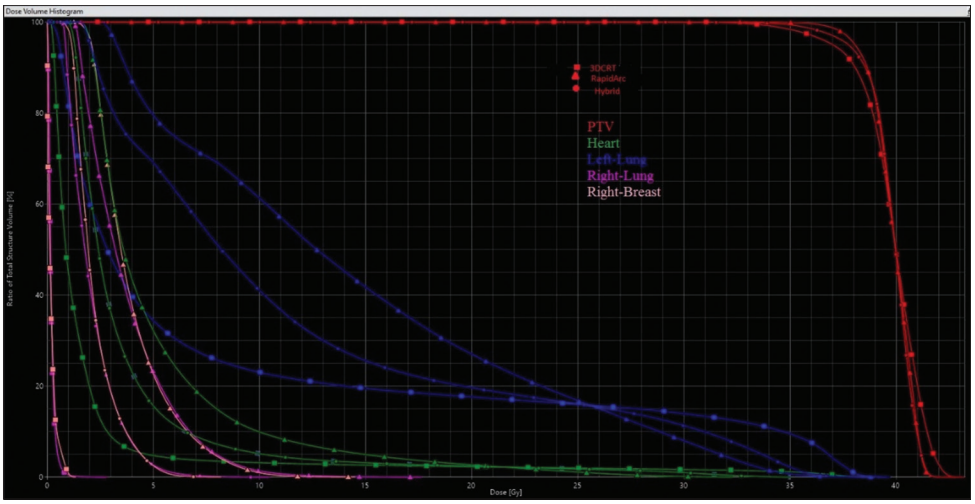

Figure 2: Dose-volume histogram representations of the planning target volume and organs at risks for the three different techniques

Table 1: Dosimetric parameters of the planning target volume (mean ± SD) for the three different techniques, along with corresponding *P*-values

Parameters	3DCRT	RArc	h-RArc	ANOVA (*P*)	*Post hoc* (*P*)		
					3DCRT versus RArc	3DCRT versus h-RArc	RArc versus h-RArc
$D_{95\%}$ (Gy)	37.21±0.51	39.43±0.27	38.47±0.19	0.000	0.001	0.001	0.630
D_{mean}	40.22±0.39	39.68±0.44	39.78±0.29	0.000	0.001	0.002	0.635
D_{max}	43.26±0.28	43.06±1.25	42.63±0.87	0.080	0.746	0.712	0.288
D_{min} (Gy)	32.75±4.31	27.31±6.27	30.13±4.68	0.001	0.001	0.151	0.213
CI	0.54±0.12	0.92±0.11	0.89±0.04	0.000	0.000	0.000	0.536
HI	0.18±0.02	0.12±0.02	0.13±0.02	0.000	0.000	0.000	0.045
MU	312±11.20	820±11.17	508±13.17	0.000	0.000	0.000	0.000
BOT	0.55±0.01	1.31±0.02	0.81±0.21	0.000	0.000	0.000	0.000

Daa%: Dose to aa percentage of volume, D_{max}: Maximum point dose, D_{min}: Minimum point dose, CI: Conformity index, HI: Homogeneity index, MU: Monitor unit, BOT: Beam on time, 3DCRT: Three-dimensional conformal radiotherapy, RArc: RapidArc, h-RArc: Hybrid RArc

Table 2: Dosimetric parameters of the organs at risk (mean ± SD) for the three different techniques, along with corresponding *P*-values

Parameters	3DCRT	RArc	h-RArc	ANOVA (*P*)	*Post hoc* (*P*)		
					3DCRT versus RArc	3DCRT versus h-RArc	RArc versus h-ARrc
Heart D_{mean}	4.59±1.38	6.38±0.84	5.63±1.16	0.000	0.000	0.017	0.101
$V_{10\%}$	9.57±4.12	14.00±3.64	11.72±4.19	0.003	0.002	0.213	0.175
$V_{20\%}$	7.14±3.85	4.71±2.6	6.78±3.24	0.047	0.057	0.936	0.121
$V_{35\%}$	3.48±2.48	0.17±0.43	0.25±0.43	0.000	0.000	0.000	0.985
LL D_{mean}	11.17±2.29	13.49±1.57	12.66±1.58	0.000	0.000	0.035	0.339
$V_{5\%}$	47.63±11.35	83.18±5.31	72.71±9.83	0.000	0.000	0.000	0.001
$V_{10\%}$	29.31±7.38	53.49±10.08	42.46±5.85	0.000	0.000	0.000	0.000
$V_{20\%}$	23.72±7.16	21.82±6.49	23.09±6.61	0.666	0.650	0.954	0.822
RL D_{mean}	0.58±0.44	3.38±0.86	2.58±0.48	0.000	0.000	0.000	0.000
RB D_{mean}	0.34±0.17	3.19±1.15	2.26±0.19	0.000	0.000	0.000	0.000

Dmean: Mean dose, Daa%: Dose to aa percentage of volume, Vbb%: Volume covered by bb percentage of dose, LL: Left lung, RL: Right lung, RB: Right breast, 3DCRT: Three-dimensional conformal radiotherapy, RArc: RapidArc, h-RArc: Hybrid RArc

with an intermediate BOT (0.81 ± 0.21 minutes), while RArc had the longest BOT (1.31 ± 0.02 minutes). The differences were again highly significant ($P = 0.000$), with RArc showing significantly longer BOT compared to both 3DCRT and h-RArc ($P = 0.000$ for both).

Organs at risks dosimetric parameters

For the heart D_{mean}, the mean dose to the heart, RArc had the highest value (6.38 ± 0.84 Gy), followed by h-RArc (5.63 ± 1.16 Gy), and the lowest was observed with 3DCRT (4.59 ± 1.38 Gy). The differences were statistically significant

(P = 0.000), with RArc showing a significantly higher D_{mean} compared to 3DCRT (P = 0.000) and h-RArc (P = 0.017).

In terms of the heart's $V_{10\%,}$ which indicates the volume of the heart receiving 10% of the prescribed dose, RArc again had the highest value (14.00 ± 3.64%), followed by h-RArc (11.72 ± 4.19%), and 3DCRT had the lowest (9.57 ± 4.12%). The differences were significant (P = 0.003), with RArc having a significantly higher $V_{10\%}$ than 3DCRT (P = 0.002). The 3DCRT versus h-RArc and RArc versus h-RArc were found statistically in significant (P = 0.213 and P = 0.175, respectively).

For the heart's $V_{20\%,}$ the volume receiving 20% of the prescribed dose, 3DCRT had the highest value (7.14 ± 3.85%), followed by h-RArc (6.78 ± 3.24%), and RArc had the lowest (4.71 ± 2.6%). The ANOVA test showed significance (P = 0.047), but the *post hoc* tests did not reveal any significant differences.

The heart's $V_{35\%,}$ the volume receiving 35% of the prescribed dose, showed significant differences (P = 0.000). 3DCRT had the highest value (3.48 ± 2.48%), whereas RArc (0.17 ± 0.43%) and h-Arc (0.25 ± 0.43%) had much lower values. Both RArc and h-RArc had significantly lower $V_{35\%}$ compared to 3DCRT (P = 0.000 for both).

For the left lung (LL) D_{mean}, RArc had the highest mean dose (13.49 ± 1.57 Gy), followed by h-RArc (12.66 ± 1.58 Gy), and the lowest was observed with 3DCRT (11.17 ± 2.29 Gy). The differences were statistically significant (P = 0.000), with RArc showing significantly higher D_{mean} than both 3DCRT (P = 0.000) and h-RArc (P = 0.035).

The left lung's $V_{5\%,}$ the volume receiving 5% of the prescribed dose, was highest for RArc (83.18 ± 5.31%), followed by h-RArc (72.71 ± 9.83%), and lowest for 3DCRT (47.63 ± 11.35%). The differences were significant (P = 0.000), with RArc showing significantly higher $V_{5\%}$ compared to both 3DCRT and h-Arc (P = 0.000 for both).

For the left lung's $V_{10\%,}$ RArc again had the highest value (53.49 ± 10.08%), followed by h-RArc (42.46 ± 5.85%), and 3DCRT had the lowest (29.31 ± 7.38%). The differences were significant (P = 0.000), with RArc showing significantly higher $V_{10\%}$ compared to both 3DCRT and h-Arc (P = 0.000 for both).

In terms of the left lung's $V_{20\%,}$ there were no significant differences among the techniques (P = 0.666). The values were 23.72 ± 7.16% for 3DCRT, 21.82 ± 6.49% for RArc, and 23.09 ± 6.61% for h-Arc.

For the right lung (RL) Dmean, RArc had the highest mean dose (3.38 ± 0.86 Gy), followed by h-Arc (2.58 ± 0.48 Gy), and the lowest dose was observed with 3DCRT (0.58 ± 0.44 Gy). The differences were highly significant (P = 0.000), with RArc showing significantly higher Dmean compared to both 3DCRT and h-RArc (P = 0.000 for both).

Finally, for the RB D_{mean}, RArc had the highest value (3.19 ± 1.15 Gy), followed by h-RArc (2.26 ± 0.19 Gy), and the lowest was observed with 3DCRT (0.34 ± 0.17 Gy). The differences were statistically significant (P = 0.000), with h-RArc demonstrating a significantly lower D_{mean} compared to RArc, whereas h-RArc exhibited a higher mean dose with 3DCRT (P = 0.000 for both).

Discussion

Our study aims to evaluate and compare the dose distribution within the PTV and the doses to OARs between three different radiation therapy techniques, 3DCRT, RArc, and h-RArc. Numerous studies have assessed the efficacy of various treatment techniques such as 3DCRT, IMRT, and VMAT in breast cancer, often debating the merits of using more advanced methods in clinical practice.

For breast cancer cases, VMAT is generally favored over IMRT and 3DCRT for its superior PTV coverage, CI, and HI, although it tends to deliver higher doses to OARs.[24-28] Standard techniques include supraclavicular fossa half-blocked fields and tangential half-blocked fields. Many studies utilize open tangential 3DCRT fields in combination with IMRT or VMAT as the primary dosage plan.[29,30] However, Lin *et al*. used tangential IMRT (T-IMRT) as the initial dose strategy, incorporating two tangential fields similar to 3DCRT combined with IMRT.[31] According to Virén *et al*., both the open 3DCRT approach and T-IMRT produce similar OAR doses, although T-IMRT results in higher MUs.[32]

Despite the potential for complications, radiation therapy improves treatment outcomes for women with breast cancer. The most serious late adverse effects include heart and lung complications and secondary cancers specific to the breast or lung.[33,34] Cardiac issues typically develop over 10 years posttreatment, contributing to a 30% increase in cardiovascular fatalities within the subsequent decade. Studies indicate that the incidence of major coronary events increases by 7.4% for every additional 1 Gy added to the standard heart dose.[8,35] The mean heart dose was lowest with 3DCRT, but increased by 39% with RArc compared to 3DCRT. When comparing 3DCRT to h-RArc, the increase was 22.67%. However, h-RArc demonstrated an 11.76% dose reduction compared to RArc. V_{20}% and V_{10}% of the heart are reliable indicators of cardiac risk. The V20% for the heart was 34.1% higher in the 3DCRT plan compared to RArc. h-RArc delivered a 5.2% lower dose compared to 3DCRT but 30.65% higher than RArc, suggesting that a larger heart volume was irradiated in the 3DCRT plan. The V10% for the heart was 46.27% higher in the RArc plans compared to 3DCRT, whereas h-RArc showed a 22.44% increase in dose relative to 3DCRT. However, h-RArc resulted in a 16.29% dose reduction compared to RArc, leading to greater low-dose exposure to the heart in RArc plans.

Pulmonary complications are the second major concern for patients treated for breast cancer. Radiation pneumonitis, followed by lung fibrosis, can lead to respiratory insufficiency. The volume of lung receiving a dose ≥20 Gy ($V_{20\ Gy}$) is a key factor in minimizing complications. If the $V_{20\ Gy}$ of the

ipsilateral lung is below 30% for breast cancer patients, clinically significant pneumonitis should be rare. In current study, $V_{20\ Gy}$ was below the limit for all strategies, with the highest values in 3DCRT and reduced by 8.1% in RArc and 2.6% in h-RArc. $V_{10\ Gy}$ and $V_{5\ Gy}$ were higher in the RArc technique compared to other plans, indicating more low-dose exposure in the RArc technique. The mean right lung dose was higher in RArc techniques compared to 3DCRT and h-RArc, with the difference being statistically significant ($P = 0.000$).

The dose to the contralateral breast (RB) is particularly important for younger patients due to the increased long-term risk of secondary contralateral breast cancer.[36] In this evaluation, RArc technique showed the highest maximum dose to the contralateral breast, which was statistically significant ($P = 0.000$).

More MUs and prolonged therapy lead to higher out-of-field leakage doses and scattered radiation to normal tissue, increasing the risk of radiation-induced malignancies. Hall and Wuu found that the rate of radiation-induced malignancy increased from 1% with 3DCRT to 1.75% with IMRT.[37] In our study, RArc plans had the highest MUs. Compared to RArc, 3DCRT plans reduced MUs by 162.8%, whereas h-RArc plans showed a 62.8% increase in MUs compared to 3DCRT. However, h-RArc plans demonstrated a 38.05% reduction in MUs compared to RArc plans. BOT is related to the treatment delivery time on the couch, excluding gantry movement and patient setup time. Higher BOT indicates more time on the couch, leading to patient discomfort and concerns for those treated with respiratory motion management. Kry *et al*. showed that IMRT plans have higher MUs and varying dose distributions compared to 3DCRT, potentially doubling the occurrence of secondary solid tumors.[38] Haldar *et al*. demonstrated that IMRT plans had a higher number of MUs, which were subsequently reduced by 57.0% in FiF plans and by 32.7% in H-IMRT plans.[39] In our study, RArc plans had higher BOT, which was significantly reduced by 138.2% in 3DCRT and by 47.3% in h-RArc. BOT directly impacts the speed of dose delivery. A higher number of MUs usually results in longer treatment times, which can reduce efficiency, particularly when managing inter/intrafraction errors or increased treatment complexity. Shorter BOT minimizes the risk of patient and organ motion, improving both precision and throughput. The study's limitations include a small sample size and retrospective design, which may introduce biases and limit generalizability. Technological variability and lack of long-term clinical outcomes further constrain the findings. Incomplete risk assessment for secondary cancers, patient comfort issues due to longer treatment times, and limited cost-effectiveness analysis are additional concerns. These factors necessitate cautious interpretation and highlight the need for further prospective study.

Conclusions

Multiple studies have shown that RArc treatment plans surpass 3DCRT in PTV coverage and OAR sparing. Our research confirms that RArc offers better target conformity and homogeneity than both 3DCRT and h-RArc. However, RArc plans come with downsides, such as higher low-dose volumes to OARs, increased MU, and longer BOT.

Based on our findings, we recommended h-RArc treatment plans for ca-breast due to their superior and comparable PTV dose coverage and enhanced OAR sparing over 3DCRT and RArc. h-RArc plans feature lower MU, reduced BOT, and less low-dose exposure to OARs, potentially lowering secondary cancer risks. They are also more time-efficient, beneficial in busy centers by cutting patient in-room time.

In summary, our study supports h-RArc treatment plans as a practical option for routine practice, offering excellent target coverage and OAR sparing while easing planners' workload and reducing patient specific quality assurance load.

Ethical approval

Since this is a retrospective study involving previously treated patients, ethical approval was exempted by the institute.

Acknowledgments

The authors thank Dr Bharat Kumar and Mr Aashutosh Kumar Mishra for their significant insight and guidance while writing the manuscript.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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