Analysis of Dose Distribution in Patients with Breast Cancer Treated with Adjuvant Rapid Arc versus Conventional Radiotherapy

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Abstract:

Background: Breast cancer is one of the most prevalent cancers among women. The objective of this research is to compare adjuvant Rapid Arc radiotherapy with conventional modality in respect of dose distribution in target volume and critical organs in patients with breast cancer post-surgery.

Patients and Methods: This prospective research enrolled 98 cases diagnosed with primary breast cancer post conservative or mastectomy surgery recruited from Clinical Oncology Department, Zagazig University and International Medical Center, Egypt between January 2021-December 2022. They were categorized into 2 groups; group A underwent therapy by 3D-Conformal Radiotherapy (3DCRT) whereas group B was managed by Rapid Arc radiotherapy (RA). Both groups received 50 Gy in 25 fractions.

Results: Each group had 49 patients. Both plans achieved similar target coverage; however RA had significantly increasing in minimum dose to the target more than 3D (66.21% vs 28.86%, p=0.001), moreover the Homogeneity Index (HI) & Conformity Index (CI) of RA were better than 3D-CRT (HI 1.05 vs 1.2, p=0.08 and CI 0.76 vs 0.38, p=0.034). Both plans had comparable results regarding to mean heart dose, V25 of heart, mean lung dose, V20 of ipsilateral lung and contralateral lung dose, however; 3D-CRT had better sparing in case of V5 & V10 of heart, V10 of ipsilateral lung and contralateral breast dose.

Conclusion: Both RA & 3D-CRT have similar target coverage; however RA had better CI & HI at the expense of organs at risk sparing so RA may be used in sophisticated cases for whom optimal target coverage cannot be achieved by 3D-CRT.

Keywords; breast, Rapid arc, conventional radiotherapy

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Background:

Breast cancer is the most common type of cancers and the first cause of cancer related death among females. There is decrease in incidence and mortality in high income countries while increasing in low income ones [1].

In Egypt, awareness about breast cancer data may be deficient so national awareness and screening are ongoing to help in improving early diagnosis and treatment outcomes [2].

Adjuvant irradiation in breast cancers has important role in reducing local failure in 70% and increasing disease free survival in 85-90% of cases [3].

Modern irradiation techniques like 3D-CRT and Intensity Modulated Radiotherapy have a main role in increasing target volume dose and decreasing critical organs doses to achieve high therapeutic ratio [4].

One of the most serious side effects post irradiation is the cardiac one which may be developed late post 10 years of therapy especially the left side, and also development of second malignancies like lung and contralateral breast which are also depend on other carcinogenic factors [5].

The aim of this work is to compare the Rapid Arc radiotherapy (RA) with the 3D-conventional modality (3D-CRT) regarding dose distribution in target volume and critical organs.

Patients and Methods:

Study design

This study is prospective analysis of patients diagnosed with primary breast cancer recruited from Clinical Oncology Department, Zagazig University and International Medical Center (IMC), Egypt for 2 years (January 2021 -December 2022). These patients were categorized into group A managed by 3D-CRT and group B managed by RA radiotherapy.

Inclusion criteria:

1. Female patient.
2. Age more than 18 years old.
3. Unilateral breast cancer.
4. Pathology proven breast carcinoma.

Exclusion criteria:

1- Bilateral breast cancers.
2- Previous history of cancer.
3- Male patient.
4- Any other pathology other than breast carcinoma.

Methods:

Informed consent was obtained from all patients after full explanation about irradiation details. All subjects underwent the following prior to irradiation:

- Full history taking.
- Full physical examination.
- Chest X ray, ultrasound of pelvis and abdomen in early cases while bone scan and CT chest, abdomen and pelvis scan in locally advanced cases.
- Echocardiography.
- Complete blood count, liver functions test, kidney functions test.

Administrative design:

The protocol was approved by institutional review board.

Radiotherapy

Simulation

Positioning and CT Scanning

Patients were put on breast boards with arms over their heads. CT scanning of 5 mm slice was done from upper neck down to mid abdomen.

Contouring

Organs at risk (OAR), breast volume, Chest wall, boost to the tumor bed and nodal targets were Contoured based on clinical and radiographic volumes according to Radiation Therapy Oncology group. Ipsilateral lung, heart, contralateral lung and contralateral breast are OAR.

Treatment Planning System

Planning system at Zagazig university is a precise plan while at IMC is Eclipse. The prescribed dose was 50 Gy in 25 fractions in addition to a sequential boost in breast conservative surgery (BCS) cases of 10 Gy to the tumor bed in 5 fractions. Plan arrangement and energy are selected according to patient separation and breast volume.

Target and dose constraints

Regarding to Planning Target Volume (PTV), 95% of the PTV should receive at least 95% of prescribed dose (47.5 Gy) and maximum dose ≤ 107%. For ipsilateral lung, V20 < 30% and mean dose <22Gy. For heart, mean dose < 4Gy and volume 5 ≤ 10% & volume 25 ≤ 5%. For contralateral lung V5 < 26% & V15 < 5%. The contralateral breast maximum dose ≤ 3%.

Treatment Plan Evaluation

Dose-volume histogram and indices of conformity & homogeneity were analyzed to compare treatment plans.

Statistical Analysis

SPSS version 22 was used to process the data. The paired-sample T-test was used for the comparison of dosimetric variations between 2 plans, according to the statistical variations ($P < 0.05$).

Results:

Each arm had 49 patients; BCS was higher in both groups (61.2% in 3D-CRT and 53.1% in RA). Regional nodal irradiation was less than 50% of patients in both arms (46.9% in 3D-CRT and 42.9% in RA). Moreover, a tumor bed boost in 3D group was in 42.9% and 46.9% in RA group. Patient's characteristics are showed in table 1.

Target Coverage

Regarding to PTV coverage, both plans were similar but the minimal PTV of RA plans was better than those of 3D plans and statistically significant (66.21% vs 28.86%, p=0.001), in addition to the volume covered by 107% dose was lower in RA than 3D plan (18.49cc vs 39.97cc respectively and marginally significant, p=0.008) Table 2.

Dosimetric Parameters

The CI and HI of RA were better than 3D plans however; CI is statistically significant (p=0.034) and HI is marginally significant (p=0.08).

OAR Sparing

Dose constraints were achieved and similar in both plans especially V25 of heart, mean heart dose, V20 of lung, mean lung dose and contralateral lung dose; however, 3D plans had superior sparing of the lung (V10 20.68% vs 39.75%, p=0.015), heart (V5 & V10, p=0.001 & 0.001respectively) and contralateral breast dose (p=0.03 & 0.04 of mean and maximum doses) Table 2.

Table 1: Patient Criteria in current study

		3D-CRT		**RA**	
		Mean	Count (%)	Mean	Count (%)
Age (mean)		58		59	
PTV (CC)		1085.7		1198.3	
Type of Surgery: BCS vs. MRM	BCS		30(61.2%)		34(53.1%)
	MRM		19(38.8%)		15(44.1%)
Separation: 25 cm as a cut-off	Separation up to 25 cm		47(95.9%)		47(95.9%)
	Separation more than 25 cm		2(4.1%)		2(4.1%)
Nodal Irradiation	Yes		23(46.9%)		21(42.9%)
	No		26(53.1%)		28(57.1%)
Boost to the Tumor Bed	Yes		21(42.9%)		23(46.9%)
	No		28(57.1%)		26(53.1%)

PTV Planning Target Volume, BCS Breast Conservative Surgery, MRM Modified Radical Mastectomy,

Table 2: 3D-CRT and RA dosimetric analysis

	Technique of Radiotherapy				P value
	3DCRT		RA		
	Mean	Standard Deviation	Mean	Standard Deviation	
PTV mean	102.5	-	101.5	-	0.68
PTV maximum	109.71%	1.76%	109.84%	3.51%	0.338
PTV minimum	28.86%	20.05%	66.21%	13.65%	**0.001**
107% volume (cc)	39.97	44.17	18.49	43.71	**0.008**
Heart V5	12.43%	5.43%	54.97%	16.71%	**0.001**
Heart V10	7.04%	4.16%	23.97%	13.26%	**0.001**
Heart V25	7.12%	13.45%	6.26%	12.25%	0.267
Heart mean (Gy)	4.05	1.69	7.54	2.31	**0.33**
Lung V20	16.84%	7.341%	15.95%	6.749%	0.49
Lung V10	20.68%	8.275%	39.75%	15.526%	**0.015**
Lung mean	9.10	3.54	11.69	2.92	0.33
Contralateral lung mean (Gy)	0.35	0.28	0.35	0.28	1.000
Contralateral breast mean (Gy)	0.38	0.28	2.81	1.35	**0.03**
Contralateral breast max (Gy)	15.96	17.44	22.88	8.48	**0.043**
HI	1.2	-	1.05	-	**0.08**
CI	0.38	-	0.76	-	**0.034**

PTV Planning Target Volume, V volume, CI Conformity index, HI Homogeneity index

Discussion:

Variations in geometry of breast cancer irradiation either post BCS or MRM make radiation therapy administration is difficult. These variations may affect dose distribution especially with conventional plans so choosing the optimal irradiation technique is needed. (6, 7)

Target Coverage and Dosimetric Parameters

Most of the studies including our study concluded that target coverage of both RA and 3D-CRT is comparable [8-14] except Ahmed et al and Vasudevan et al where RA had better target coverage [15, 16]; however in our study, RA had significantly increasing in minimum dose to the target more than 3D (66.21% vs 28.86%, p=0.001), moreover in our study; the HI & CI of RA were better than 3D-CRT (p=0.08 & 0.034 respectively) with similar outcomes noted by others [7, 10-12, 16].

Contrary to that; Haertl et al and Ahmed et al noted similar CI & HI of both plans [13, 15] while Badakhshi et al reported that HI was better in 3D plans and CI was better in RA plans [8], but Piras et al noted that CI was better in RA while HI was similar by both 3D & RA plans [14].

Normal Tissue Sparing

There are conflicting results regarding to organs at risk sparing which may be attributed to target geometry variations and medical physics team experience.

Regarding to heart; our study showed comparable V25 and mean heart dose between two plans, while V5 & V10 of heart were better by 3D-CRT plan, similar to results by Liu et al [10] & Piras et al [14] while contrary to results by Mo et al, Nantavithya et al and Haertl et al [11-13] who reported better heart V20 & V30 by RA plan. Also Giri et al reported lower heart dose by RA plan [9] while Ahmed et al noted high V25 of heart by 3D plan [15].

Regarding to lung dose; in this study both plans had similar V20 of lung, mean lung and contralateral lung doses; while 3D plans had lower V10 of the lung, Contrary to studies which recorded lower contralateral lung dose by 3D plans [10, 11, 13&16].

Ipsilateral lower lung dose by 3D plans was noted in studies by Badakhshi et al and Liu et al [8, 10] contrary to other studies [9, 11-14] which noted lower doses by RA plans.

Vasudevan et al recorded higher mean lung dose by RA with similar V20 of lung by two plans [16].

Regarding to contralateral breast dose which was lower in 3D-CRT plan in our study similar to results recorded by Mo et al and Piras et al [11, 14], but contrary to Liu et al and Haertl et al who noted lower contralateral breast dose by RA plans than 3D-CRT ones [10,13].

Conventional techniques may present a better critical organ sparing option at the cost of target volume coverage, conformity and homogeneity indices while recent irradiation techniques improve the target coverage with exposure of critical organs to higher low dose volumes [17].

Finally, as breast irradiation is very common so we can suggest that it should be simple in order to save resources. RA provides a perfect plan when complex targets need to be treated and critical organs need to be avoided in challenging breast cancer cases.

Conclusion:

Both RA & 3D-CRT have similar target coverage; however, RA had better CI & HI at the expense of organs at risk sparing so RA may be used in sophisticated cases for whom optimal target coverage cannot be achieved by 3D-CRT.

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