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Dosage Assessment and Differentiation between Various Planning Techniques using3D Conformal and Intensity Modulated Radiotherapy for Left-sided Breast Cancer

Rehab Omar[1], A. Mustafa[2], A.R. Al-Sayeh[3*], A.H. Oraby[3]
[1]*Radiation Oncology and nuclear medicine Department, Mansoura University Hospital, Mansoura, 35516, Egypt*
[2]*Mathematics Department, Faculty of Science, Mansoura University, Mansoura, 35516, Egypt*
[3]*Physics Department, Advanced Material Research Lab, Faculty of Science, Mansoura University, Mansoura, 35516, Egypt*

Abstract
Purpose: *This work aims to investigate which technique is better covering the planning target volume (PTV) with its prescribed dose, while minimizing the dose to organs at risk (OARs).*
Materials and Methods: *Three techniques were included in the study; 3-Dimensional Conformal Radiation Therapy (3D-CRT), Field in Field with Conformal Radiation Therapy (FIF) and Inverse-Planned Intensity-Modulated Radiation Therapy (IP-IMRT). The study was done on nine patients with left sided breast cancer. We used the Prowess panther 3D planning system (version 5.21).*
Results: *Good dose coverage was archived by the three techniques. A 95% of the dose covering (96.711% ± 1.178), (95.878% ± 0.733) and (95.522% ± 0.471) of the volume of PTV for 3D-CRT, FIF and IP-IMRT respectively. Also, the HI was (0.127 ± 0.023), (0.146 ± 0.012) and (0.138 ± 0.037) for 3D-CRT, FIF and IP-IMRT respectively. And the CI for 3D-CRT, FIF and IP-IMRT were (0.967 ± 0.012), (0.959 ± 0.007) and (0.955 ± 0.005) respectively.*
Conclusion: *The organs at risk sparing were much better with the IP-IMRT plans when compared to the 3DCRT and FIF plans. The FIF technique is better with its low monitor unit number.*
Keywords: *Breast cancer, early-stage breast cancer, 3DCRT, FIF, IMRT, breast conserving surgery.*

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I. Introduction

One of the most common neoplasm types in women is breast cancer. It is considered as a major global cause of deaths in women. Treatment of breast cancer includes many gradual steps; surgery and it is usually mastectomy, chemotherapy, radiotherapy, and targeted therapy[1]. The most usual breast cancer treatment methods are mastectomy or breast conserving surgery followed by the adjuvant radiotherapy[2]. Promising results can be seen when the adjuvant radiotherapy is given after the breast conserving surgery. And the risk of regional and local recurrence can be reduced. Also the overall survival of patients can be improved[2-4].

The purpose of radiotherapy planning is to protect and minimize doses to the neighbouring healthy tissues as possible. Also, to give the best treatment dose to the tumor in the same time. However, ideal planning is not always possible to be Compatible with the constraints enjoined by normal tissues. As the target volume should be treated in a homogeneous and conformal manner [4]. Many radiotherapy treatment planning techniques can be used for the treatment of breast cancer [5].

It was shown by many studies that volume of breast affects the homogeneity of the dose. For larger breasts, it was found that the inhomogeneity is more bad. Also, the side effects of radiotherapy like poor cosmetic outcome and breast pain may be resulted from dose distribution [6, 7].

This study is to compare three techniques that control the performance of Linear Accelerator (LINAC). The comparison aims to know which one of them can deliver the prescribed dose to the whole tumor in early breast cancer while sparing the radiation dose to the organs at risk (OAR). The three techniques are 3-Dimensional Conformal Radiation Therapy (3D-CRT), Field in Field with Conformal Radiation Therapy (FIF) and Inverse-Planned Intensity-Modulated Radiation Therapy (IP-IMRT). The values of doses in our study were obtained by the related cumulative Dose volume histogram (DVH).

II. Materials and Methods

Twenty-seven plans were generated for nine early-stage breast cancer patients. They had breast conserving surgery. All of the nine were diagnosed with left-sided breast cancer. The patients were imaged using the computed tomography (Siemens Biograph Horizon PET/CT) simulation in supine position. Three plans were made for each patient using 3DCRT, FIF and IP-IMRT techniques. The plans were made using Prowess panther 3D planning system (version 5.21). From the dose-volume histograms we were able to obtain the dosimetric parameters used in our comparison. The radiation distribution delivering 40 Gy in 15 fractions.

2.1 Patients

Nine patients of females have been chosen for this dosimetric study. The nine patients were diagnosed with left-sided breast cancer; they were diagnosed with left-sided breast carcinoma without axillary or supraclavicular lymph nodes. All patients had undergone breast conserving surgery. Three Plans were created for each patient by 3D-CRT, FIF and IP-IMRT then the results were compared.

2.2 Delineation of target volume and organs at risk

Transverse computed tomography images for all patients were taken by computed tomography (Siemens Biograph Horizon PET/CT) scan machine**.** Images were taken with a slice thickness of 3.0 mm. Patients lay immobilized in the supine position with raised arms above the head to be excluded from the field of treatment**.**

Contouring of planning target volume (PTV) was done according to the atlas of radiation therapy planning for breast cancer of the Radiation Therapy Oncology Group (RTOG). Delineation of target volumes and OAR were done by the radiation oncologist with the help of the radiologist as shown in (Figure 1).

2.3 Breast volumes

Patients in our study had different breast volumes. The volume of breast divided into three groups when ≤1500 cc small breast volume, 1500 - 2000 cc medium breast volume, and > 2000 cc large breast volume[8]. There was no limitation of age for patients (Table 1).

Table 1: The percentage ratio of the number of patients to the three sizes for the Breast volumes (PTV).

PTV Volume	percentage of patients' number
Small	88.89%
Medium	11.11%
Large	0%

2.4 Treatment planning

To deliver an ideal dose distribution to the target a radiotherapy plan was achieved. The three types of plans in our study were designed using Prowess panther 3D planning system (version 5.21). A6 MV energy beams of a linear accelerator was used. The patients were treated with radiotherapy after their breast conserving surgery to a prescribed dose of 4000 cGy in 266.66 cGy fractions for 5 days per week.95% of PTV for the three plans should be covered with the prescribed dose of 4000 cGY.

2.5 Analysis of dose difference (Dosimetric Evaluations)

To compare between these three treatment planning techniques in our study many parameters were evaluated as shown in tables (1-4). The conformity index (CI), homogeneity index (HI) and uniformity index (UI) were calculated using the following formulae.

$$\textbf{Conformity index (CI)} = V_{RI} / TV \qquad (1)$$

In formula number (1), the CI was calculated from the ratio between V_{RI} and TV. Where, V_{RI} represents the volume of the reference isodose and VT represents the volume of the target [9, 10].

$$\textbf{Homogeneity index (HI)} = (D_{2\%} - D_{98\%}) / D_{50\%} \qquad (2)$$

In formula number (2), HI is one of the evaluating parameters, it indicates to the homogeneity of the dose distribution within the volume of the target. The HI was calculated from the ratio between Subtract of $D_{2\%}$ and $D_{98\%}$ to $D_{50\%}$. Where, $D_{2\%}$, $D_{98\%}$ and $D_{50\%}$ represent the doses delivered to 2%, 98% and 50% of PTV [11, 12].

$$\textbf{Uniformity index (UI)} = (D_{5\%} / D_{95\%}) \qquad (3)$$

In formula number (3), the UI was calculated from the ratio between $D_{5\%}$ and $D_{95\%}$.Where, $D_{5\%}$ and $D_{95\%}$ represent the doses delivered to 5% and 95% of PTV [13].

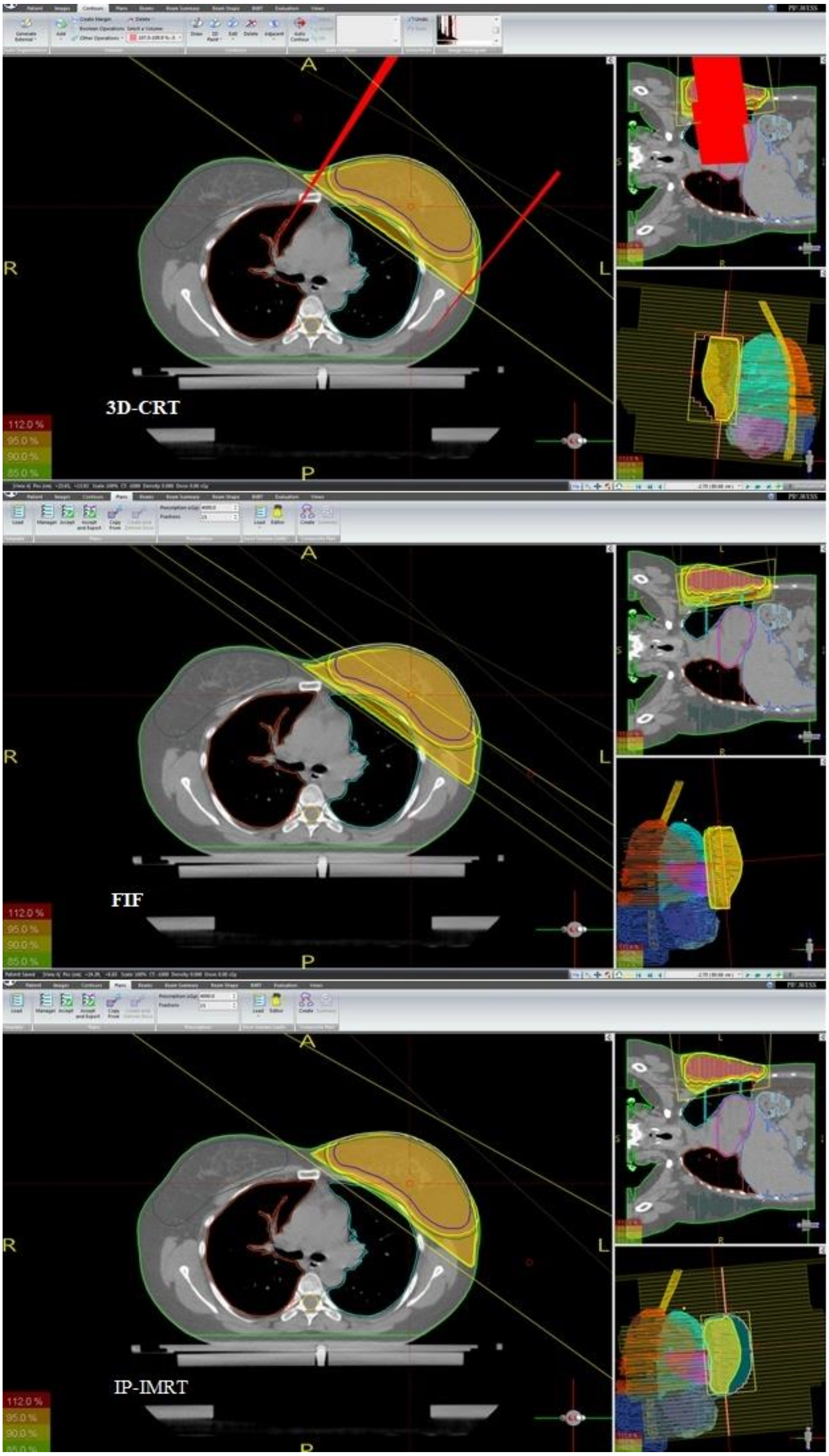

Figure 1: Shows the contouring of PTV and OARs. It also shows the arrangement of beams for the three radiotherapy techniques.

III. Results

Twenty-seven 3D-CRT, FIF and IP-IMRT plans were generated for patients with left-sided breast cancer. All the patients were treated by these three techniques received a dose of 40 Gy/15 fractions to the chest wall.

3.1 Statistics

The Statistical Package for the Social Sciences (IBM SPSS Statistics 20) was the software used in this study. For making statistical analysis of our data, first we must examine the normal distribution for the plans using the test of normality to choose the suitable test for comparing the means.

3.2 Comparison of CTV dose and volume between the three plans

One of the main issues of the following study is to give shade and compare between CTV dose and volume as listed in Table 2:

Table 2: Comparison of CTV dose, volume

Parameters	3D-CRT		FIF		IP-IMRT		p-value		
	Mean	S.D	Mean	S.D	Mean	S.D	a vs. b	a vs. c	b vs. c
D_{max} (%)	109.756	1.639	110.189	1.037	108.522	1.509	0.216	0.233	0.027
D_{mean} (%)	100.789	0.810	99.422	8.332	101.889	1.094	0.027	0.027	0.790
D_2 (%)	107.056	1.820	107.886	0.840	106.006	1.214	0.085	0.309	0.005
D_{50} (%)	100.578	0.823	102.460	1.113	102.096	1.222	0.001	0.006	0.475
D_{95} (%)	96.767	1.192	97.249	0.463	98.009	1.000	0.286	0.010	0.098
D_{98} (%)	95.422	1.803	94.856	2.049	96.714	0.844	0.894	0.034	0.007
V_{95} (%)	98.267	1.070	98.156	0.888	99.400	0.240	0.775	0.007	0.003

Mean: the mean of percentages for doses at (D%) and for volumes at (V%)
S.D: Std. Deviation
Notes: a= 3D-CRT; b= FIF; c= IP-IMRT

The mean of percentage of D_{max} is higher for FIF plans than 3D-CRT and IP-IMRT ones. The mean of percentage of D_{max} shows significant difference ($P < 0.05$) for FIF plans compared to IP-IMRT ones, although there is no significant difference ($P > 0.05$) for 3D-CRT plans compared to FIF and IP-IMRT ones.

The mean of percentage of D_{mean} is higher for IP-IMRT plans than 3D-CRT ones and it is higher for 3D-CRT plans than FIF ones. The mean of percentage of D_{mean} shows significant difference ($P < 0.05$) for 3D-CRT plans compared to FIF and IP-IMRT ones, although there is no significant difference ($P > 0.05$) for FIF plans compared to IP-IMRT ones.

The mean of percentage of D_2 is higher for FIF plans than 3D-CRT ones and it is higher for 3D-CRT plans than IP-IMRT ones. The mean of percentage of D_2 shows significant difference ($P < 0.05$) for FIF plans compared with IP-IMRT ones, although there is no significant difference ($P > 0.05$) for 3D-CRT plans compared to FIF and IP-IMRT ones.

The mean of percentage of D_{50} is higher for FIF plans than IP-IMRT ones and it is higher for IP-IMRT plans than 3D-CRT ones. The mean of percentage of D_{50} shows significant difference ($P < 0.05$) for 3D-CRT plans compared to FIF and IP-IMRT ones, although there is no significant difference ($P > 0.05$) for FIF plans compared to IP-IMRT ones.

The mean of percentage of D_{95} is higher for IP-IMRT plans than FIF ones. And it is higher for FIF plans than 3D-CRT ones. The mean of percentage of D_{95} shows significant difference ($P < 0.05$) for 3D-CRT plans compared to IP-IMRT plans, although there is no significant difference ($P > 0.05$) for FIF plans compared to 3D-CRT and IP-IMRT ones.

The mean of percentage of D_{98} is higher for IP-IMRT plans than 3D-CRT ones. And it is higher for 3D-CRT plans than FIF ones. The mean of percentage of D_{98} shows significant difference ($P < 0.05$) for IP-IMRT plans compared to 3D-CRT and FIF ones, although there is no significant difference ($P > 0.05$) for 3D-CRT and FIF plans.

The mean of percentage of V_{95} is higher for IP-IMRT plans than 3D-CRT ones. And it is higher for 3D-CRT plans than FIF ones. The mean of percentage of V_{95} shows significant difference ($P < 0.05$) for IP-IMRT plans compared to 3D-CRT and FIF ones, although there is no significant difference (P > 0.05) for 3D-CRT and FIF plans.

3.3 Comparison of PTV dose and volume, CI, HI and UI between the three plans

Table (3) gives a clear comparison between PTV dose and volume, CI, HI and UI between the three planes.

Table 3: PTV dose, volume, CI, HI and UI among the three plans (%).

Parameters	3D-CRT		FIF		IP-IMRT		p-value		
	Mean	S.D	Mean	S.D	Mean	S.D	a vs. b	a vs. c	b vs. c
D_{max} (%)	110.033	1.517	110.267	1.092	108.856	1.394	0.565	0.216	0.057
D_{mean} (%)	100.589	0.706	101.644	0.720	101.000	0.849	0.007	0.263	.085
D_2 (%)	107.189	1.696	107.769	0.859	105.928	1.203	0.232	0.076	0.006
D_5 (%)	105.986	1.525	106.803	0.813	105.108	1.124	0.158	0.130	0.006
D_{50} (%)	100.456	0.781	102.018	1.024	101.649	1.184	0.003	0.019	0.446
D_{95} (%)	95.962	1.132	95.493	0.361	95.289	0.224	0.507	0.102	0.156
D_{98} (%)	94.356	0.981	92.879	0.880	91.887	3.249	0.005	0.015	0.965
V_{95} (%)	96.711	1.178	95.878	0.733	95.522	0.471	0.110	0.021	0.198
CI	0.967	0.012	0.959	0.007	0.955	0.005	0.111	0.019	0.183
HI	0.127	0.023	0.146	0.012	0.138	0.037	0.019	0.536	0.077
UI	1.105	0.023	1.118	0.009	1.103	0.013	0.077	0.836	0.051

Mean: the mean of percentages for doses at (D%) and for volumes at (V%)
S.D: Std. Deviation
Notes: a= 3D-CRT; b= FIF; c= IP-IMRT

The table contains PTV dose and volume, CI, HI, and UI of the target region in the three different plans. These three studied plans show no statistically significant difference (P > 0.05) in D_{max} of PTV and UI of the target region.

The mean of percentage of D_{mean} is higher for FIF plans than 3D-CRT and IP-IMRT ones. The mean of percentage of D_{mean} shows significant difference (P < 0.05) for 3D-CRT plans compared to FIF ones, although there is no significant difference (P > 0.05) for IP-IMRT plans compared to 3D-CRT and FIF plans.

Also, the mean of percentage of D_2 is higher for FIF plans than 3D-CRT and IP-IMRT plans. The mean of percentage of D_2 shows significant difference (P < 0.05) for FIF plans compared to IP-IMRT ones, although there is no significant difference (P > 0.05) for 3D-CRT plans comparing to FIF and IP-IMRT ones.

The mean of percentages of D_5 was higher for FIF plans than for 3D-CRT ones, but they were not statistically significant. Also, it was higher for 3D-CRT plans than IP-IMRT ones, but they were not statistically significant, although the mean of percentages of D_5 for FIF plans were statistically significant (P<0.05) compared to that of IP-IMRT plans.

The D_{50} mean of percentages for 3D-CRT plans were lower than the mean of percentages of D_{50} for FIF and IP-IMRT plans. The D_{50} mean of percentages for 3D-CRT was statistically significant (P<0.05) compared to FIF and IP-IMRT.

The mean of percentages of D_{95} for the three plans of the three techniques were not statistically significant compared to each other. For D_{98} it's mean of percentage is higher for 3D-CRT plans than FIF and IP-IMRT ones. The mean of percentage of D_{98} shows significant difference (P < 0.05) for 3D-CRT plans compared with FIF and IP-IMRT ones, while there is no significant difference (P > 0.05) for FIF plans comparing to IP-IMRT ones.

The mean of percentage of V_{95} is higher for 3D-CRT plans than FIF and IP-IMRT ones. The mean of percentage of V_{95} shows significant difference (P < 0.05) for 3D-CRT plans compared to FIF and IP-IMRT ones, while there is no significant difference (P > 0.05) for FIF plans compared to IP-IMRT ones.

The mean of CI for 3D-CRT plans is the closest value to the right one and it is better than FIF and IP-IMRT ones. The mean of CI shows significant difference (P < 0.05) for 3D-CRT plans compared to IP-IMRT ones, although there is no significant difference (P > 0.05) for FIF plans compared to 3D-CRT and IP-IMRT ones.

The mean of HI for 3D-CRT plans is lower and better than FIF and IP-IMRT ones. The mean of HI shows significant difference ($P < 0.05$) for 3D-CRT plans compared with IP-IMRT ones, although there is no significant difference ($P > 0.05$) for FIF plans compared to 3D-CRT and IP-IMRT ones.

3.4 Comparison of Irradiation doses and volumes in the OARs of the three plans

Table 4 shows a comparison between irradiation doses and volumes in the OARs of the three studied planes.

Table 4: Irradiation doses and volumes in the OARs of the three plans (%).

Organ at Risk	Parameters	3D-CRT		FIF		IP-IMRT		p-value		
		Mean	S.D	Mean	S.D	Mean	S.D	a vs. b	a vs. c	b vs. c
Heart	D_{mean} (%)	10.244	2.841	10.733	3.810	10.478	6.574	0.791	0.402	0.377
	V_5 (%)	14.176	3.615	14.584	4.699	20.417	28.893	0.825	0.310	0.233
	V_{10} (%)	10.188	3.170	10.362	3.983	11.279	8.288	0.791	0.566	0.691
	V_{20} (%)	7.103	2.795	7.662	3.668	6.653	2.911	0.710	0.764	0.503
	V_{25} (%)	5.981	2.595	6.548	3.501	5.359	2.404	0.679	0.650	0.389
	V_{30} (%)	4.951	2.418	4.941	3.527	4.117	2.015	0.994	0.523	0.528
Left Lung (Ipsilateral lung)	D_{mean} (%)	15.433	4.501	15.678	4.025	15.511	7.557	0.927	0.977	0.950
	V_5 (%)	22.168	6.675	20.397	5.199	26.768	24.874	0.659	0.453	0.757
	V_{20} (%)	12.958	4.243	12.594	4.225	12.378	5.099	0.867	0.789	0.920
	V_{43} (%)	13.771	4.268	13.864	3.794	13.461	5.656	0.966	0.888	0.855
Right Lung (contralateral lung)	D_{mean} (%)	0.133	0.206	0.478	0.755	1.433	2.318	0.224	0.001	0.050
	V_5 (%)	0.157	0.235	0.183	0.284	1.203	3.004	0.873	0.445	0.544
	V_{20} (%)	0.079	0.167	0.158	0.264	0.158	0.264	0.538	0.538	1.000
	V_{43} (%)	0.122	0.186	0.122	0.186	0.111	0.176	1.000	0.958	0.958
Right Breast (contralateral breast)	D_{mean} (%)	0.356	0.309	0.344	0.317	0.722	0.653	0.964	0.082	0.074
	D_2 (%)	4.922	2.915	4.389	2.660	1.930	1.335	0.329	0.047	0.070
	V_5 (%)	0.000	0.000	0.000	0.000	0.000	0.000	-	-	-
Spinal cord	D_{max} (%)	0.000	0.000	0.622	1.235	2.267	4.598	-	-	0.052
	D_{min} (%)	0.000	0.000	0.000	0.000	0.156	0.151	-	-	-
	D_{mean} (%)	0.000	0.000	0.322	0.640	1.067	1.970	-	-	0.051
	V_{45} (%)	0.000	0.000	0.000	0.000	0.000	0.000	-	-	-
Stomach	D_{mean} (%)	2.933	1.565	3.311	2.349	4.044	5.121	0.965	0.791	0.930
	V_{30} (%)	0.052	0.157	0.079	0.237	0.118	0.236	0.936	0.496	0.634
	V_{45} (%)	0.249	0.457	0.380	0.905	0.340	0.697	0.737	0.780	1.000
Liver	D_{mean} (%)	0.644	0.667	0.889	0.796	1.556	2.648	0.625	0.374	0.894
	V_{20} (%)	0.261	0.490	0.470	0.512	0.288	0.598	0.308	0.780	0.315
	V_{30} (%)	0.170	0.396	0.262	0.381	0.209	0.432	0.269	0.952	0.315
Spleen	D_{mean} (%)	1.778	1.796	2.011	2.005	2.989	4.985	0.929	0.479	0.401
Skin Margin	D_{mean} (%)	81.067	1.630	79.367	1.626	87.967	3.585	0.156	0.000	0.000

Mean: the mean of percentages for doses at (D%) and for volumes at (V%)
S.D: Std. Deviation
Notes: a= 3D-CRT; b= FIF; c= IP-IMRT

In the heart; the three studied plans show no statistically significant difference ($P > 0.05$) in D_{mean}, V_5, V_{10}, V_{20}, V_{25} and V_{30}.

In the left lung (Ipsilateral lung); the three studied plans show no statistically significant difference ($P > 0.05$) in D_{mean}, V_5, V_{20} and V_{43}.

In the right lung (contralateral lung); the three studied plans show no statistically significant difference ($P > 0.05$) in V_5, V_{20} and V_{43}. But the mean of percentage of D_{mean} is lower for 3D-CRT plans than FIF and IP-IMRT ones. The mean of percentage of D_{mean} shows significant difference ($P < 0.05$) for IP-IMRT plans compared to 3D-CRT and FIF ones, although there is no significant difference ($P > 0.05$) for 3D-CRT plans compared to FIF ones.

In the right breast (contralateral breast); the three studied plans show no statistically significant difference ($P > 0.05$) in D_{mean}, V_5. But the mean of percentage of D_2 is lower for IP-IMRT plans than FIF ones. And it is lower for FIF plans than 3D-CRT ones. The mean of percentage of D_2 shows significant difference ($P < 0.05$) for 3D-CRT plans compared to IP-IMRT ones, although there is no significant difference ($P > 0.05$) for FIF plans compared to 3D-CRT and IP-IMRT ones.

In the spinal cord; the mean of percentage and volume of D_{max}, D_{min}, D_{mean} and V_{45} is zero for 3D-CRT plans. These three studied plans show no statistically significant difference ($P > 0.05$) in D_{max}, D_{min}, D_{mean} and V_{45}.

In the Stomach; the three studied plans show no statistically significant difference ($P > 0.05$) in D_{mean}, V_{30} and V_{45}.

In the Liver; the three studied plans show no statistically significant difference ($P > 0.05$) in D_{mean}, V_{20} and V_{30}.

In the Spleen; the three studied plans show no statistically significant difference ($P > 0.05$) in D_{mean}.

In the Skin Margin; the mean of percentage of D_{mean} is lower for FIF plans than 3D-CRT ones. And it is lower for 3D-CRT plans than IP-IMRT ones. The mean of percentage of D_{mean} shows significant difference ($P < 0.05$) IP-IMRT plans compared with 3D-CRT and FIF ones, although there is no significant difference ($P > 0.05$) for 3D-CRT plans compared to FIF ones.

3.5 Comparison of total monitor unit

Table 5 reveals the total monitor units. The FIF plans show lower MU than IP-IMRT ones. And IP-IMRT plans show lower MU than 3D-CRT ones. The difference between the MU of the three studied plans show statistically significant difference ($P < 0.05$).

Table 5: Total monitor unit.

Parameters	3D-CRT		FIF		IP-IMRT		p-value		
	Mean	S.D	Mean	S.D	Mean	S.D	a vs. b	a vs. c	b vs. c
MU	455.771	31.501	309.534	11.472	322.986	11.731	0.000	0.000	0.024

IV. Discussions

Till nowadays, radiotherapy is known as an effective treatment after breast-conserving surgery for early breast cancer. In literature, they concluded that using adjuvant chemoradiotherapy for patients with breast-conserving surgery can effectively reduce the risk of local recurrence. It also decreases the rate of distant metastasis and significantly increases the rate of survival and the patients quality of life[2, 14, 15].

Because of the hemispherical shape of the breast the distance between the skin and the source significantly is not the same at different parts of the breast [16, 17]. As a result the CI and HI will be poor in the target region for patients with breast conserving surgery and may also results in cardiac trauma, radiation pneumonitis and skin ulcer[15]. Therefore, the scientific research focuses on the ways that can better reduce the doses given to OARs and improve the dose homogeneity for the target [18].That's what we have done in this study.

Our study is a dosimetric comparison between three treatment planning techniques which were created for left-sided breast cancer treatment; 3D-CRT, FIF and IP-IMRT. Results enabled us to know the doses given to the target and OAR using each technique and to know which one of them better protects the healthy tissues. Results also showed us which technique gives a better dose Homogeneity and Conformity for the target. The OARs included in our study are Heart, Left Lung (Ipsilateral lung), Right Lung (contralateral lung), Right Breast (contralateral breast), Spinal cord, Stomach, Liver, Spleen and Skin Margin.

This study is applied to compare the dose distribution of the IP-IMRT, FIF and 3D-CRT plans for breast cancer patients after lumpectomy. Good dose coverage can be achieved to the target region using any one of these three techniques. Comparing the dose of PTV shows no statistically significant, but a slight decrease was found when using the IMRT technique.

Patients with left-sided breast cancer whose chest walls were treated using radiotherapy, and who have geometrically different breast structures may have different results in dose distribution[4, 19].

Some studies have shown that the risk of secondary tumors increases when patients with breast cancer are treated using older radiation techniques[20, 21].

There is a relationship between uniformity of the dose in the target region and the number of fields and subfields in the plan [15]. From our results the 3D-CRT was found to have slightly lower HI than IP-IMRT. And it was significantly lower than FIF. That is because of the relationship between uniformity of the dose in the target region and the number of fields and subfields in the plan. FIF and IP-IMRT plans have higher numbers of radiation subfields than 3D-CRT plans. Better HI means that the dose distribution is more homogeneous in PTV.

Also, form our results the 3D-CRT showed better CI value than FIF-CER and IP-IMRT plans. Where better CI means that a well protection was applied for the healthy tissues.

For patients with left breast cancer the intensity modulated radiotherapy technique better decreases the high doses areas in ipsilateral lung and heart[21].And that matched with our results.

In spite of the dose decrease for high-doses-areas of OARs when using IMRT, it increases the dose for low-doses-areas of OARs. this increase for low-doses-areas increases the risk of secondary cancer than the high-doses-areas[22]. And that resembles the results we have obtained from the IMRT technique. The before mentioned results are because of the difference in intensity of each segment in IP-IMRT technique.

Total body dose is higher for IMRT technique than 3D-CRT[4]. We found that D_{mean} is higher for IP-IMRT than other techniques, although it reduces the dose for high-doses-areas of OARs.

In terms of monitor unit Al-Rahbi et al., concluded that higher MU results in a higher treatment time [23].Our results showed that the monitor unit was significantly lower for the FIF technique than IP-IMRT technique. And it is significantly lower for IP-IMRT technique than 3D-CRT technique. The use of wedges in the 3D-CRT technique was the cause for its high number of MU as what Chan et al., showed in their study [24].

V. Conclusion

From the results we found that all the three techniques allow good dose coverage to the PTV where 95% of the target volume is covered with 95% of the prescribed dose. But IP-IMRT technique showed superior results in decreasing the doses to the high-doses-areas of the surrounding OARs compared to other techniques. And that is so fatal in the treatment of breast cancer to avoid secondary cancer in the normal surrounding tissue. In the other hand 3D-CRT and FIF reduces the doses to the low-doses-areas of the surrounding OARs comparing to IP-IMRT. Also, 3D-CRT plans showed better results for conformity and homogeneity index than FIF and IP-IMRT ones. Finally, FIF plans showed the lowest monitor unit number which in turn reduces the time of treatment which allows large number of patients to be treated in a short time. Although IP-IMRT gives better result in avoiding heart disease, 3D-CRT can be used in case of there is no IMRT. So, we concluded that to be able to choose the convenient technique for each patient, there should be careful evaluation to the patient's profile. Then the suitable technique can be chosen according to the evaluation.

Abbreviations

3D-CRT: Three Dimensional Conformal Radiation Therapy; FIF: Field in Field with Conformal Radiation Therapy; IP-IMRT: Inverse-Planned Intensity-Modulated Radiation Therapy; PTV: Planning Target Volume; OAR: Organs at Risk; HI: Homogeneity Index; CI: Conformity Index; MU: Monitor Unit; DVH: Dose-Volume Histogram, LINAC: Linear Accelerator. CT: computed tomography, MLC: Multileaf collimator.

Disclosure statement

The authors report no conflicts of interest.

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