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ORIGINAL RESEARCH

Dosimetric Comparison of Three Different External Beam Whole Breast Irradiation Techniques

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ABSTRACT

Introduction: The purpose of this study was to compare the dosimetries of three different external beam whole breast radiotherapy techniques: two-dimensional RT (2D-RT), three-dimensional conformal RT (3D-CRT), and field-in-field intensity-modulated RT (FiF-IMRT). In addition, we aimed to evaluate the patients who needed more or less complex treatment modalities. ***Methods:*** Thirty patients were included in the study. All the patients had early-stage breast cancer and conserving surgery had been performed. Plans that employed the three techniques were generated for each patient. Dosimetric comparisons were conducted, and correlations with patient characteristics and dosimetric outcomes were analyzed. ***Results:*** The 2D-RT technique was found to be suboptimal for treating the intact breast. Its dose homogeneity index (DHI) was 20.68. The authors were unable to define a patient characteristic in which 2D-RT dosimetry would perform better. FiF-IMRT was found to be the superior technique with a better homogeneity in the breast (DHI=9.35 and P=0.000002 when compared to 3D-CRT). When compared according to patient characteristics, again the FiF-IMRT planning is the best for all subgroups, but the DHI gets worse by increased breast volume and separation. While FiF-IMRT achieves better DHI in the breast, it has little effect on heart and lung doses. But the normal tissues' volume (cc) that gets the 100% of the prescribed dose (V100) was lowered because of the treatment without wedges and scatter and with less monitor unit. ***Conclusions:*** 2D-RT could not be performed safely on the intact breast in any of the subgroups. FiF-IMRT is a superior technique for breast dosimetry, and normal tissue. For patients with large breast size or separation, further intensive techniques must be investigated.

Keywords: breast cancer, conformal radiotherapy, dosimetry, field-in-field radiotherapy

INTRODUCTION

Breast cancer is the most common malignancy in women.[1] Breast-conserving surgery

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followed by adjuvant radiotherapy (RT) is the standard treatment for early-stage breast cancer.[2-4] Within the chaos and intensity of a clinic, some radiation oncologists prefer to treat patients with conventional methods to conserve the use of departmental resources. The rationale behind this practice may be that the breast is a palpable organ that can be easily targeted. The organs at risk, such as the ipsilateral lung and heart, are rarely subjected to doses that exceed the values stipulated by the International Commission on Radiation Units and Measurements (ICRU) report No. 50/62.[5] In addition, these patients survive for long periods of time. Mortality and morbidity are technique- and dose-dependent.[6-9] Therefore, optimized radiation treatment planning plays a critical role in the care of breast cancer patients. There have been exciting advances in RT techniques, but generally, these techniques require more resources and a higher work volume.[10]

Although a few departments still use two-dimensional RT (2D-RT), generally most departments use three-dimensional conformal RT (3D-CRT) as a standard.[10] The development of accelerators with multi-leaf collimators (MLC) has facilitated the creation of newer techniques, such as field-in-field intensity-modulated RT (FiF-IMRT).[11,12]

In this clinic, 3D-CRT is used as the routine planning technique for treating the intact breast. However, two major questions are raised. First, do all patients require this conformal technique, or are there patients in whom the same dosimetry can be obtained with simple conventional planning techniques? Second, because technological developments offer new modalities, such as IMRT and FiF-IMRT (an easier method of IMRT), which patients and clinical scenarios are more appropriate for the use of these techniques?

METHODS

Patients

Thirty consecutive patients with *in situ* or early-stage breast cancer, who were undergoing adjuvant whole breast RT after conservative surgery, were prospectively enrolled in this study. This group included 15 patients with left-sided involvement, and 15 patients with right-sided involvement. All of the patients were node negative. Systemic therapy was administered by the medical oncologist if necessary. The clinical and treatment characteristics of the patient population are provided in Table 1.

Treatment Planning

All of the patients were immobilized in the supine position on a breast-tilting board (MT-350; MED-TEC, Orange City, IA, USA) with the ipsilateral shoulder abducted and the head rotated slightly toward the contralateral side. The breast was palpated and marked with radio-opaque markers that were visible on the computerized tomography (CT) scan in the medial, lateral, superior, and inferior directions. In addition, the markers were used to denote the midline and mid-axillary planes in the central axis. High-resolution spiral CT scans (Toshiba Asteion Super 4, Toshiba Medical Systems Corporation, Tochigi, Japan) were obtained at a 5 mm slice thickness from the neck to the abdomen. CT data were then transferred to the treatment planning system (TPS) (Eclipse, version 8.0, Varian Medical Systems, Palo Alto, CA, USA) using a Digital Imaging and Communications in Medicine (DICOM) network connection. In addition, the Helios software package was used to generate the FiF-IMRT plans. Body and lung contours were created using an automatic contouring feature

Table 1. Clinical characteristics of the patient population.

Number of patients (*n*)	30
Median age (years) (min-max)	46 (27-63)
Median weight (kg) (min-max)	72.5 (48-109)
Median height (cm) (min-max)	158.0 (149-180)
Median BSA	1.75 (1.44-2.14)
Laterality	
Right breast (*n*)	15
Left breast (*n*)	15
Pathologic stage (AJCC/UICC)	
Stage 0	1
Stage I	18
Stage IIA	11
Median tumor size (cm) (min-max)	1.7 (0-5)
Median breast volume (cm^3) (min-max)	706.1 (330.1-1876.9)
Median separation (cm) (min-max)	22.7 (17.8-31.0)

AJCC/UICC=American Joint Committee on Cancer/ Union Internationale Contre le Cantre le Cancer; BSA=body surface area.

of the TPS. The breast planning target volume and heart volume were determined by the same radiation oncologist. Breast tissue was contoured according to the breast tissue that was visible on CT (standard window level, 0 Hounsfield unit [HU]; with 500 HU) and the markers, 5 mm underneath the skin.

For 2D planning, two tangential collimated wedged fields, based on the chest wall, were used. Midline and mid-axillary markers were used as landmarks. The superior, inferior, medial, and lateral borders of both fields were 2 cm beyond the palpable breast tissue. The medial and lateral tangential fields were aligned and adjusted so that no more than 2 cm of the lung was included in the tangential portals. Physical wedges (15°, 30°, 45°, and 60°) were used. Generally 6 MV photon beams were used for planning and if needed (ie, because of big separation, big breast size, etc) 18 MV photon beams were used. A minimum of two and a maximum of four fields were used. The dose distribution was observed in the central slice only, and doses were prescribed according to this slice.

For 3D-CRT, the breast volume was defined in all slices using the markers and the glandular breast tissue that were visible on the CT. Tangential fields that covered the contoured target volume with MLC blocks and wedges were designed. All possible combinations of wedges (wedge heel in/out right/left and wedge angles with physical and virtual wedges) were used to obtain the best planning. The plans were usually generated with 6 MV, but 6-18 MV energy combinations were used if necessary (ie, because of big separation, big breast size, etc). A minimum of two and a maximum of six tangential fields in different wedges and energies were used. Dose-volume histograms (DVH) of the breast, ipsilateral lung, and heart were taken into consideration when prescribing the reference isodose. The doses were prescribed according to the quality criteria in the ICRU reports.[5] At least 95% of the planned target should receive at least 95% of the prescribed dose, while a homogeneous dose within 95%-107% of the prescribed dose at target intended to obtain.

FiF-IMRT plans were created using the same tangential angles used in 3D-CRT. First, the two tangential fields without wedges were calculated, and then three additional subfields were generated by blocking 115%, 110%, and 105% isodose clouds with MLC blocking. If the dose inhomogeneity did not reach 115%, then blocking began with a level 1%-2% lower than the highest dose, and two to three more subfields were generated with a 3%-5% dose reduction.

Figure 1 shows the medial portal of the main field and subfields of the FiF-IMRT plans. The prescribed dose for FiF-IMRT was the same for 3D-CRT. The plans were generated with only 6 MV photon beams.

A 2.5 mm grid size and a pencil beam convolution algorithm were applied to the calculations for the plans. The heterogeneity corrections were turned on during all dose calculations.

These three techniques were evaluated in each patient. The treatment dose for each plan was 2 Gy/fraction with a total of 25 fractions. The treatment plans were reviewed by the same oncologist and physicist. The boost volumes were described, and the plans were made and performed for each patient; however, in this study, we did not plan to sum these additional therapies. All plans were compared over a total dose of 50 Gy.

The radiotherapies of the patients were made according to 3D-CRT, as it was the institute's routine. The dosimetric comparisons were made only on computer plans and didn't affect patient's routine treatment, so the study did not need any Ethics Committee approval or informed consent.

Comparison of the Plans

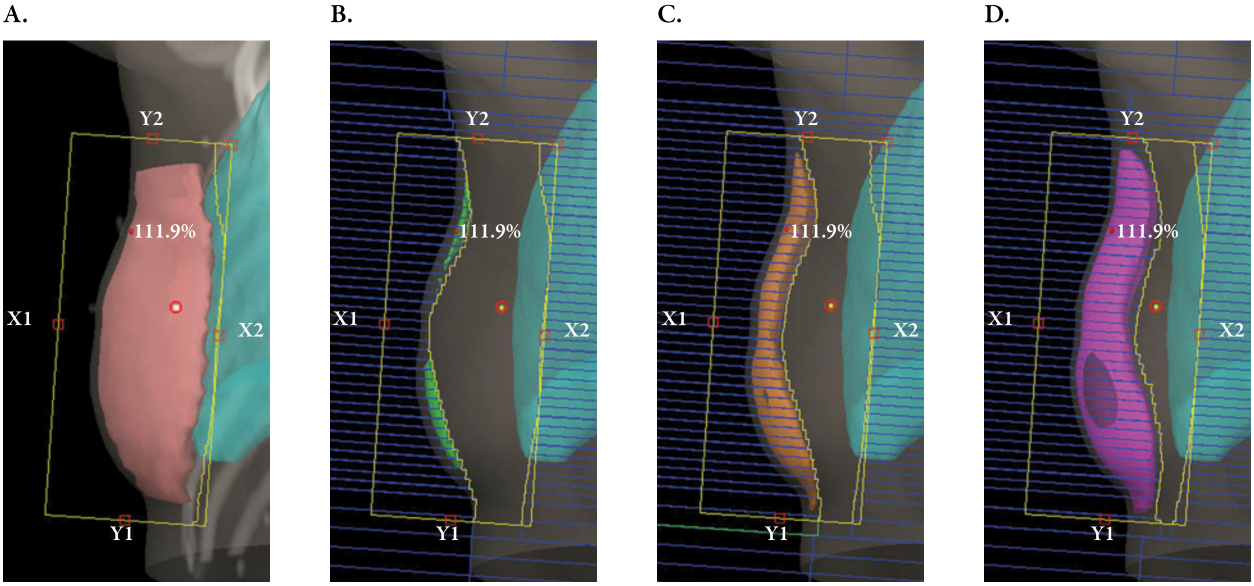
Cumulative DVH (c-DVH) for the breasts were generated using mean doses received by 99%, 98%, 95%, 90%, 85%, and 80% (D99, D98, D95, D90, D85, D80) of the breast volume and the mean volumes that received 80%, 85%, 90%, 95%, 100%, and 105% (V80, V85, V90, V95, V100, V105) of the doses. Statistical comparisons of the techniques were conducted using the V95, V100, and V105 values, as well as the dose homogeneity index (DHI) and the conformity index (CI).

The DHI is defined as follows:[13]

$$DHI=(D2-D98)/Dpres \times 100\%$$

D98 is the dose received by 98% of the target volume on the c-DVH. D2 is the dose received

Figure 1. Field-in-field intensity-modulated radiotherapy planning, a right side breast. A. Main field, breast, and right lung can be seen as contoured. Lines represents field borders. B. First subfield, dose color wash level 110%, the multi-leaf collimators can be seen as closing the 110% dose cloud. C. Second subfield, dose color wash level 107%. D. Third subfield, dose color wash level 104%.



by 2% of the target volume on the c-DVH. Dpres is the prescribed dose.

The DHI should be less than 15 for an acceptable plan, and lower DHI values indicate a more homogeneous dose distribution.[14]

The following equation was used to calculate the CI for the three techniques:[5]

$$\mathrm{CI}=\mathrm{TVref}/\mathrm{TV} \times \mathrm{TV\ ref}/\mathrm{Vref}$$

TVref is the target volume (cm^3) covered by the reference isodose. We used the prescribed dose for the reference dose. TV is the target volume (cm^3), and Vref is the volume (cm^3) covered by the reference isodose.

The CI values ranged from 0-1. A higher CI value indicates higher dose conformity to the target.

The monitor unit counts (MU) required for treatment were recorded and compared between the techniques.

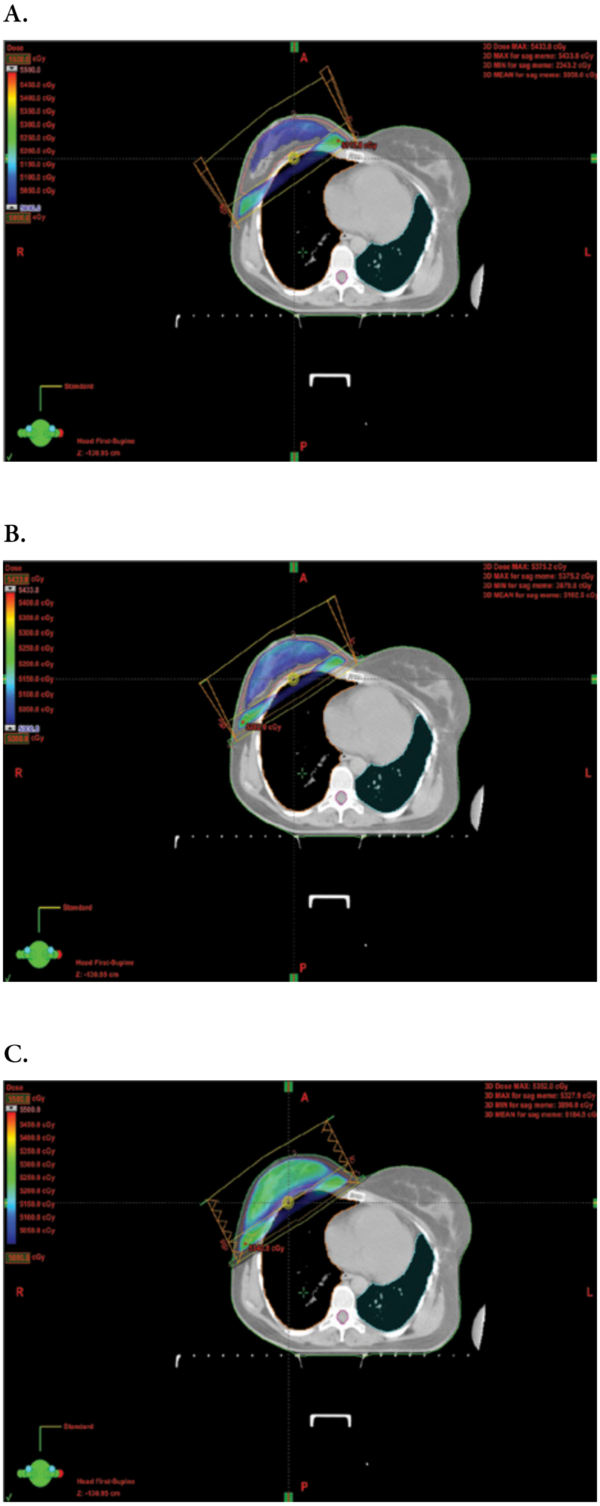
For organs at risk (OAR), a dosimetric comparison of the heart was conducted using V20, V5, and the mean dose. The ipsilateral lung was also evaluated using V20, V5, and the mean dose. The contralateral breast could not be contoured because the 70 cm bore diameter and narrow scan size of our CT scanner was not sufficient for overweight patients. Therefore, we compared the normal tissue volumes (body volume - target volume in cm^3) that received the prescribed dose to evaluate the techniques.

Patient characteristics that might have been associated with a potential planning benefit were recorded. These included age, height, weight, breast volume, and breast separation.

Statistical Analysis

All statistical tests were performed using SPSS software 10.0.1 (SPSS Inc, Chicago, IL, USA). $P \leq 0.05$ (two-tailed) was defined as statistically significant. The pairwise Wilcoxon's

Figure 2. Dose color wash showing a patient receiving 50 Gy. A. Two-dimensional radiotherapy. B. Three-dimensional conformal radiotherapy. C. Field-in-field intensity-modulated radiotherapy.



signed-rank test was used to compare the treatment techniques. The relationship between patient characteristics and treatment outcomes were evaluated with the Mann-Whitney U test.

RESULTS

Dosimetric Evaluation

In this study, the dosimetric outcomes of 2D-RT, 3D-CRT ,and FiF-IMRT in treating the intact breast were thoroughly investigated.

A 50-Gy dose with the three different techniques in a patient is shown in Figure 2.

The dosimetric comparisons of the treatment volume and MU for the three planning techniques are shown in Table 2. When comparing 2D-RT to FiF-IMRT, V105 was reduced from 15.12% to 9.62% (*P*=0.041013), V100 was increased from 79.94% to 92.29% (*P*=0.000004), and V95 increased from 94.91% to 98.90% (*P*=0.000001). When comparing 3D-CRT to FiF-IMRT, V105 was reduced from 14.46% to 9.62% (*P*=0.000978), V100 was increased from 86.14% to 92.29% (*P*=0.000011), and V95 was increased from 97.72% to 98.90% (*P*=0.000006). The DHI in 2D-RT was found to be 20.68 and could not maintain the ICRU quality criteria. The best DHI was achieved with FiF-IMRT as

Figure 3. Cumulative dose-volume histograms of patients created with two-dimensional radiotherapy (2D-RT), three-dimensional conformal radiotherapy (3D-CRT), and field-in-field intensity-modulated radiotherapy (FiF-IMRT). The isodose levels were normalized to the prescribed dose of 50 Gy.

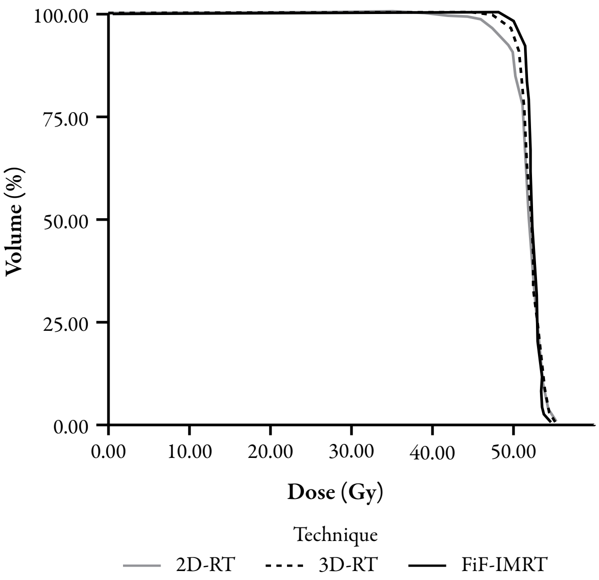


Table 2. Dosimetric summary of the treatment volumes and monitor units for the three planning techniques.

				***P* values**		
	2D-RT (mean±SD)	**3D-CRT (mean±SD)**	**FiF-IMRT (mean±SD)**	**(2D-RT vs. 3D-CRT)**	**(2D-RT vs. FiF-IMRT)**	**(3D-CRT vs. FiF-IMRT)**
V95 (%)	94.91±3.00	97.72±1.26	98.90±0.81	0.000016	0.000001	0.000006
V100 (%)	79.94±10.23	86.14±5.20	92.29±3.09	0.005832	0.000004	0.000011
V105 (%)	15.12±11.35	14.46±7.94	9.62±4.54	0.721246	0.041013	0.000978
CI	0.48±0.09	0.52±0.08	0.60±0.08	0.047162	0.000003	0.000002
DHI	20.68±17.82	12.20±2.20	9.35±1.75	0.000031	0.000002	0.000002
MU	290.27±44.46	278.30±28.94	228.46±7.94	0.104737	0.000002	0.000002

2D-RT=two-dimensional radiotherapy; 3D-CRT=three-dimensional conformal radiotherapy; CI= conformity index; DHI=dose homogeneity index; FiF-IMRT=field-in-field intensity-modulated radiotherapy; MU=monitor unit; Vx=treatment volume receiving x% or greater of the prescribed dose.

Table 3. Doses to organs at risk for the three planning techniques.

	2D-RT (mean±SD)	3D-CRT (mean±SD)	FiF-IMRT (mean±SD)	*P* values (2D-RT vs. 3D-CRT)	 (2D-RT vs. FiF-IMRT)	 (3D-CRT vs. FiF-IMRT)
Ipsilateral lung						
V20 (%)	14.11±5.85	14.80±5.20	13.93±5.00	0.813011	0.544006	0.058406
V5 (%)	19.22±6.22	19.87±5.79	19.46±5.54	0.765519	0.922484	0.318439
Mean dose (Gy)	7.77±3.00	8.29±2.35	7.81±2.32	0.813016	0.757676	0.034119
Heart (*n*=15)						
Left sided only						
V20 (%)	5.51±4.99	8.11±5.13	8.10±4.78	0.131809	0.151956	0.300170
V5 (%)	10.04±6.88	13.39±7.39	13.26±8.04	0.088402	0.211476	0.198122
Mean dose (Gy)	4.42±2.52	5.33±2.43	5.17±2.41	0.201188	0.495520	0.172761
Normal tissues						
V100 (cm^3)	267.05±151.34	269.53±133.16	214.81±125.79	0.781263	0.023038	0.000358

2D-RT=two-dimensional radiotherapy; 3D-CRT=three-dimensional conformal radiotherapy; Vx= treatment volume receiving x or greater of the prescribed dose; FiF-IMRT=field-in-field intensity-modulated radiotherapy.

9.35 and better than 3D-CRT's DHI of 12.20 (*P*=0.000002). CI was closer to 1 in FiF-IMRT (0.60) and statistically better than 2D-RT (0.48, *P*=0.000003) and 3D-CRT (0.52, *P*=0.000002). The MU that were calculated to treat the patients were 290.27 MU in 2D-CRT and 278.30 MU in 3D-CRT (*P*>0.05). It was significantly lowered to 228.46 MU in FiF-IMRT (*P*=0.000002).

The c-DVH values of the three treatment techniques are shown in Figure 3.

The average dosimetric characteristics of the OAR for the three planning techniques are presented in Table 3. FiF-IMRT only seems to reduce the mean dose of the ipsilateral lung when compared with 3D-CRT (*P*=0.034119), however, the heart dosimetry did not differ significantly among the techniques. The V100 of the normal tissue was reduced with FiF-IMRT (214.81 cm^3) compared to 2D-RT (267. 05 cm^3) (*P*=0.023038) and 3D-CRT (269.53 cm^3) (*P*=0.000358).

Predictive Patient Characteristics

Additionally, statistical analysis of patient characteristics and DHI was carried out by grouping the patient characteristics (age, weight, height, breast volume,and separation) into two groups, less than/equal to median and greater than median. FiF-IMRT was statistically superior to 2D-RT and 3D-CRT, again in all age, weight, height, volume, and separation groups, but an interesting finding was that although it was still better than the 2D-RT's and 3D-CRT's DHIs, the DHI of FiF-IMRT got statistically worse with increased breast volume (8.57 to 10.15, *P*=0.007543) and increased breast separation (8.72 to 10.19, *P*=0.034939). The results are shown in Table 4.

Table 4. Dose homogeneity index according to patient characteristics (grouped) and planning techniques.

	2D-RT (mean±SD)	3D-CRT (mean±SD)	FiF-IMRT (mean±SD)	*P* values (2D-RT vs. 3D-CRT)	*P* values (2D-RT vs. FiF-IMRT)	*P* values (3D-CRT vs. FiF-IMRT)
Age (years)						
≤46	15.36±4.63	12.53±1.95	9.46±1.47	0.005611	0.000293	0.000351
>46	27.64±25.43	11.76±2.52	9.22±2.14	0.029766	0.001473	0.001468
P values	0.109864	0.368291	0.737106	-	-	-
Weight (kg)						
≤72.5	22.34±22.71	12.00±1.95	9.02±1.26	0.005385	0.000654	0.000653
>72.5	19.03±11.69	12.39±2.49	9.70±2.14	0.002162	0.000655	0.000805
P values	0.467920	0.561316	0.455000	-	-	-
Height (cm)						
≤158	26.56±22.99	12.75±2.20	9.90±2.02	0.000531	0.000437	0.000530
>158	13.97±2.84	11.58±2.13	8.73±1.17	0.021911	0.000981	0.000981
P values	0.024542	0.120142	0.141743	-	-	-
Breast volume (cc)						
≤706.1	21.96±22.83	11.83±2.22	8.57±1.49	0.004506	0.000655	0.000655
>706.1	19.41±11.55	12.57±2.21	10.15±1.93	0.002162	0.000655	0.000805
P values	0.267097	0.187268	0.007543	-	-	-
Seperation (cm)						
≤22.7	22.18±21.47	11.62±1.76	8.72±1.07	0.004847	0.000293	0.000293
>22.7	18.73±12.08	12.96±2.56	10.19±2.15	0.001871	0.001474	0.001871
P values	0.620582	0.094466	0.034939	-	-	-

2D-RT=two-dimensional radiotherapy; 3D-CRT=three-dimensional conformal radiotherapy; FiF-IMRT=field-in-field intensity-modulated radiotherapy.

DISCUSSION

The objective of this study was to compare the dosimeters of three different radiotherapy techniques, 2D-RT, 3D-CRT, and FiF-IMRT, and to identify patient characteristics that can predict which patients would benefit the most from an intensive technique.

It is difficult to directly compare the calculated mean values to the data from the literature because most studies do not include brief technical notes, and there is great variability in the definitions of the planned targets. The margins provided for breast clinical target volume (CTV) to planned target volume (PTV) range from 0 mm to 30 mm,[15] however, in this study, we did not use any margins. The disease stages of the patients varied, and this affected doses and volumes. In addition, the volumetric parameters that were compared are very different, and different ways of calculating the DHI and CI were employed. Therefore, the results of this comparison were considered with other comparison studies in the literature.

Based on these results, among the three techniques, 2D-RT was inferior and could not maintain ICRU 50/62 quality criteria, which indicates that it is a suboptimal technique for treating the intact breast. Munshi et al.[16] reported that breast planning based solely on a single isocentric contour is an appropriate technique for patients with small breasts. In our study we grouped the breast volume as less than/equal to and greater than the median volume and DVH of less than/equal to median breast volume was still bigger than 15 and statistically was not different from the greater than median breast volume group. We were unable to define a subgroup in which the target volume dosimetry outcomes with 2D-RT were similar to more conformal techniques.

3D-CRT obtained a better dosimetry, DHI, and CI of the target volume compared to 2D-CRT, but it did not produce any dose reduction to the OAR. There are conflicting data about 3D-CRT's effect on the OAR. Teh et al.[17] analyzed irradiated lung volumes in 2D-RT and 3D-CRT planning in Stage I-III breast cancer patients. No dose reduction was found with 3D-CRT planning, and higher doses were recorded compared to 2D planning (V20 in 2D = 14%, in 3D = 22%). Leonardi et al.[18] reported a significantly reduced mean lung volume in Stage I breast carcinoma with 3D-CRT planning compared to 2D-RT planning (4.5% vs. 5.4, *P*=0.034). Kong et al.[19] concluded that the use of 3D-CRT planning for tangential breast irradiation does not decrease the heart and lung dose. The 3D-CRT treatment planning with anatomy guidance that was individualized to each patient resulted in a better breast dosimetry compared to 2D-RT, which is consistent with the literature.[20-22]

The FiF-IMRT has the most favorable dose distrubition in our study. There have been several reports on the use of FiF-IMRT to improve dose distribution.[11,12,23-27] Barnett et al.[26] reported that breast dosimetry can be significantly improved with FiF-IMRT with little impact on radiotherapy resources. In a study by Ercan et al.,[12] the targeted volumes received 105% and 110% of the prescribed dose, and the DVHs were found to be reduced. Smith et al.[11] compared different tangential planning techniques for the breast and concluded that IMRT planning significantly improved the DHI of the target volume compared to 2D-RT. They also noted that there were no significant differences in DHI between FiF-IMRT and the other two IMRT techniques, which indicates that FiF-IMRT is as effective as the other IMRT techniques. Donovan et al.[9] found a reduced breast appearance change with 5-year photographs in 3D IMRT when compared to 2D treatment (40% vs. 58%, *P*=0.008). In this study, we found statistically significant improvements in all evaluated dosimetric parameters for target with FiF-IMRT compared to 2D-RT and conformal 3D-CRT.

Ohashi et al.[27] examined the OAR and reported that FiF-IMRT improved regional node coverage while decreasing doses to the heart, lungs, and other normal tissue compared to the modified tangential irradiation technique. Ercan et al.[12] evaluated the heart volumes that are irradiated with 10, 20, and 30 Gy and reported that FiF-IMRT showed a significant decrease compared to the conventional 3D technique. The results were again in favor of FiF-IMRT when the ipsilateral lung volumes that received 10, 20, or 30 Gy were examined. Smith et al.[11] reported that IMRT lowers heart V30 and lung V20, but there were no differences in the equivalent uniform dose to the heart or lung with IMRT compared to conventional techniques. In this study, the authors found a decreased mean dose to the ipsilateral lung with FiF-IMRT only. In addition, the V100 of normal tissue was significantly reduced with FiF-IMRT. This statistically significant reduction in the V100 of normal tissue could be explained by the reduced scatter dose and the treatment time. The use of virtual wedges that were compared with physical wedges has been shown to reduce the scattered dose to the contralateral breast.[10]

In the FiF-IMRT planning technique, with increasing volume and breast separation, the dose homogeneity in the breast worsened in this study. The shoulder of the curve decreased, and the tail of the curve elongated (V95 decreased and V5 increased). Herrich et al.[24] showed that FiF-IMRT's DVH does not worsen with larger breast volumes. Moody et al.,[28] in a study that included more than 559 breast cancer patients, found a significant correlation between breast size and dose inhomogeneity. Aref et al.[22] did not find a correlation between breast volume and homogeneity in the conformal planning technique. Although the benefits of FiF-IMRT planning techniques are reduced in larger breasts and wide separation, this technique was still the best of the three. This reduction can be explained by the use of only 6 MV. For these patients, forward IMRT with more than two optimized gantry angles and higher energies could be a solution.

The IMRT plans generally require more MU, but FiF-IMRT significantly reduced the MU counts required for treatment.[12] We also found this significant reduction when using FiF-IMRT planning compared to 2D-RT and 3D-CRT.

In the arrangement of the planning the authors decided not to evaluate the time consumed with planning, but generally the time passed with FiF-IMRT was less than 3D-CRT, because for 3D-CRT all the possible wedges and energies angles for dose optimization were tried, but in FiF-IMRT only the subfields were created and so the time passed for only creating them and modifying their field weight. It did not take more time than 3D-CRT planning.

CONCLUSION

FiF-IMRT achieves a better dose homogeneity and conformity in breast than 3D-CRT and 2D-RT. 2D-RT is a suboptimal technique for treating the intact breast. The authors could not define a subgroup for which this treatment could be offered. FiF-IMRT has nearly no impact on doses for lung and heart, and it better protects normal tissue by reducing the treatment time and scatter. Its superiority decreases with bigger breast volumes and separation. More intensive techniques could be used for these patients.

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Dr Gursel is the guarantor for this article, and takes responsibility for the integrity of the work as a whole.

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