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Dosimetric outcomes of the breast field-in-field (FIF) radiotherapy technique in patients with mastectomy and lumpectomy surgeries

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▶ ***Original article***

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ABSTRACT

Background*:** Field-in-field (FIF) technique for treatment of breast cancer has become a widely performed method over the recent years. However, there was no study in the application of FIF technique in patients with breast cancer undergoing mastectomy and lumpectomy. This study is an attempt to compare dosimetric outcomes after applying the FIF technique in these patients. ***Materials and Methods*:** Twenty-four patients with right and left breast cancer participated in this study. The FIF planning technique was carried out for patients undergoing mastectomy and lumpectomy using the TiGRT treatment planning system (TPS). For the comparison purpose, we used two main indices, i.e. dose homogeneity index (HI) and conformity index (CI), the number of subfields, as well as mean, maximum, and minimum doses, doses received by 2% (D_2) and 98% (D_{98}) of the target volume, volumes received greater than 107% (V>107%) and less than 95% (V<95%) of the prescribed dose, doses to organs at risk (OARs), and total monitor units (MUs). ***Results: The results indicated that CI and HI are better in patients with right and left breast lumpectomy surgery ($p<0.038$ and $p<0.047$) relative to mastectomy patients ($p<0.037$ and $p<0.029$), respectively. Other parameters mentioned in Materials and Methods did not show any significant difference between the two groups of patients ($p>0.05$). ***Conclusion:*** The use of alternative subfields resulted in better dose distribution in target volume with the increase in breast volume. Moreover, to disappear the hot spot areas in isodose curves, it is essential to elevate the number of subfields.

Keywords: *Field-in-field technique, dosimetric parameters, radiotherapy, lumpectomy and mastectomy.*

INTRODUCTION

Female breast cancer is the most common type of cancer worldwide. Surgery is one of the treatment methods in patients with breast cancer [1, 2]. There are two surgical approaches to breast cancer treatment, mastectomy and lumpectomy that may also be followed by postoperative adjuvant chemotherapy and/or radiotherapy. The role of radiotherapy in the management of breast cancer is very essential and is preferred for T1, T2, and selected T3 tumors [3-6]. During radiotherapy, the goal is homogeneous delivering of maximum dose to the target volume and of minimum dose to the normal surrounding tissues. However, in the radiotherapy of breast cancer, it is difficult to obtain a homogenous dose across the whole breast volume, which is due to the continuous changing of breast shape across multiple planes and the effect of the low-density lung tissues included in the irradiated volume. Moreover,

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dose delivery in tangential breast irradiation can be limited due to the presence of several organs at risk (OARs) such as heart, ipsilateral lung, and contralateral breast [7, 8].

In the last few decades of progress and developments in medical imaging, radiation therapy technology, treatment planning system (TPS) software, and dosimetric devices have enabled to obtain a homogenous dose distribution in the target volume. To achieve this goal, there are various facilities such as appropriate intensity modifiers and the visualization of the spatial dose distribution within the target volume. As a result of these developments, the computerized TPSs are now available so that the user can evaluate different plans to select one that is clinically superior [9, 10]. In developing countries, 3D-CRT (three dimensional conformal radiation therapy) and FIF (field-in-field) are two common radiotherapy techniques used for the treatment of breast cancer. FIF is a radiation therapy technique that uses several less-weighted fields with a small treatment field size to optimize dose distributions. Studies have shown that the FIF technique potentially leads to a more favorable dose distribution in post-surgical radiotherapy of the breast cancer, as compared to 3D-CRT technique [1, 11-13]. In Japan, Tanaka *et al.* [14] applied an optimal method for the FIF technique in breast cancer patients with different breast sizes. They concluded that alternative subfield method (ASM) has superiority to a single pair of subfield method and to multiple pairs of subfield method (MSM) due to its better dose distribution regardless of the breast size. Baycan *et al.* [1] indicated that breast volume is an important parameter in the dosimetric evaluation, such as dose homogeneity index (HI), but they did not provide more information about it. FIF technique has been indicated to provide a better dose distribution because of its ability in enhancing the homogeneity and conformity in target volume [15-17]. Until recently, no study has been published on the application of FIF technique in breast cancer patients undergoing mastectomy and lumpectomy. Therefore, this study attempted to compare dosimetric outcomes resulted from employing the FIF technique in patients with mastectomy and lumpectomy. The present study also evaluates the importance and the impact of breast volume on dosimetric parameters of the FIF radiotherapy technique.

MATERIALS AND METHODS

The current study was conducted following the approval by Ethical Committee of Urmia University of Medical Sciences (Iran, approval number: IR.UMSU.REC.2015.297). Twenty-four female patients with right and left breast cancer participated as candidates for radiotherapy. The entire 24 patients were divided into two groups; half of them underwent mastectomy and the other half underwent lumpectomy. The number of patients enrolled for this study was determined based on the pertinent literature [1, 16, 18].

There was no age limit for participation, and written informed consents were obtained from all the patients. CT scanning was performed on all the patients using a multidetector CT scanner (Siemens SOMATOM Sensation, Germany) for breast treatment planning. The CT scan images with slice thicknesses of 2 mm were obtained from the patients in the supine position with a MammoRx® carbon fiber breast board. To preserve the treatment position, the breast board was fixed to the CT table, and then CT datasets were transferred to TiGRT TPS through a DICOM network [19-21]. TiGRT uses an exclusive algorithm, namely full scatter convolution (FSC), which enables fast and accurate dose calculations [20]. The radiation oncologist then contoured the gross tumor volume (GTV), planning target volume (PTV), and OARs on the planning CT slices according to the guidelines of International Commission of Radiation Units and Measurements (ICRU), Reports 50 and 62. Treatment plans (3D-CRT and FIF) were generated in the TiGRT TPS using the 6-MV photon beam of linear accelerator (Siemens Primus, Germany), equipped with 51 pairs of multileaf collimators (MLC).

In the present study, the subfields were first added to medial field, and the number of subfields and the weight of each subfield were adjusted until the high-dose cloud disappeared. The process was then performed on the lateral field. Finally, uniform isodose curves without high-dose regions were presented in the plans. Through a trial and error process, the optimized FIF plans were determined by the evaluation of the 3D dose distribution and dose-volume histogram. Subsequently, the subfields and the main field were merged together. The regions with high dose, i.e. more than 107% of the maximum dose, were shielded with MLCs through different steps using beam's eye view projection. The weights of the MLC segments were adjusted manually to reduce the hot spots until the distribution of an optimal dose, with better dose homogeneity, was achieved inside the target volume. If the resulting maximum dose was still high, additional subfields and weights were created by the same procedure. Two or more subfields were created for each conformal field through repeating these steps.

The dose of 50 Gy was prescribed for the PTV in 25 fractions with 6-MV X-ray. Plans were assessed and compared in terms of mean, maximum, and minimum doses, doses received by 2% (D_2) and by 98% (D_{98}) of the target volume, volumes received greater than 107% (V>107%) and less than 95% (V<95%) of the prescribed dose, total monitor units (MUs), the number of subfields, dose HI, conformity index (CI) representing the ratio of volume enclosed by the prescription isodose over the target volume, and CI values ranging from 0-1; the higher CI value, the higher dose conformity to the target volume [22, 23].

$$HI = \frac{D_2 - D_{98}}{D_p} \times 100\%$$

Where D_2 and D_{98} are the minimum dose to 2% and maximum does of 98% of the target volume, respectively, and D_p is the prescribed dose. The reason for choosing these doses (D_2 and D_{98}) is that the calculation of true minimum or maximum dose is sensitive to the dose-calculation parameters [24].

We herein chose the maximum and minimum doses at a point instead of a volume because the true minimum or maximum doses are usually not reliable. Thus, in all definitions, HI basically indicates the ratio between the maximum and minimum doses in the target volume, and the lower HI value shows a more homogenous dose distribution within this volume [24, 25].

In addition, treatment plans were assessed and compared in terms of maximum doses of typical contralateral OARs and irradiated volumes of typical ipsilateral OARs. Dose constraints for contralateral OARs were maximum dose, and for ipsilateral OARs were V20 for lung and V30 for heart [1, 11].

Statistical analysis was performed by SPSS version 20.0 (SPSS Inc., IL, and USA). The normality of the data was assessed using the Kolmogorov-Smirnov (K-S) test. After verification of the data with normality test, the independent sample *t*-test was used to compare the mean values of the parameters between the two patient groups. *p* value <0.05 was considered to be statistically significant.

RESULTS

Demographic characteristics of the patients under study and the breast and PTV volumes are given in table 1. The mean numbers of subfields in patients with mastectomy and lumpectomy were 4 and 5, respectively.

The isodose distributions of the FIF-based treatment planning amongst patients are demonstrated in figures 1 and 2. Moreover, the main fields and subfields for disappearing hot spots in patients with lumpectomy and mastectomy are demonstrated in Figures 3 and 4, respectively. The dose-volume histogram (DVH) comparisons of FIF in patients with mastectomy and lumpectomy are presented in figures 5 and 6, respectively.

The dosimetric comparison, based on the parameters determined in the Materials and Mmethods section, between the right and left breast lumpectomy and mastectomy patients is displayed in table 2.

As indicated in table 2, dosimetric parameters mentioned below did not result in

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any significant difference between the right breast mastectomy and lumpectomy patients. There were also no significant difference in the cases of maximum, mean, and minimum doses, D_2, D_{98}, V>107%, V<95%, and total MUs (p>0.05). In addition, no significant differences were observed between the mentioned parameters in the left breast.

In terms of CI, the mean ± standard deviation (SD) values for right breast were 0.93±0.005 and 0.9±0.01 (p<0.038) and for left breast were 0.935±0.007 and 0.85±0.014 (p<0.037) for the mastectomy and lumpectomy patients, respectively. Therefore, statistically significant differences were observed between the two groups (table 2).

The difference in HI mean values between the two groups was statistically significant. The mean ± SD values for the right breast lumpectomy and mastectomy patients were 12.92±0.56 and 14.9±0.6 (p<0.047) and those for left breast lumpectomy and mastectomy patients were 11.65±0.21 and 13.85±0.07 (p < 0.029), respectively (table 2). The results revealed that the CI and HI parameters were better in lumpectomy than mastectomy breasts (table 2).

The mean and standard deviation of maximum doses of typical contralateral OARs and irradiated volumes of ipsilateral OARs among two studied groups (mastectomy and lumpectomy) are shown in figure 7. As the figure indicates, no significant differences were observed between the mean of maximum doses and irradiated volumes of OARs in mastectomy and lumpectomy patients.

Table 1. Demographic characteristics of the patients and data on breast and PTV volumes

Characteristics	Lumpectomy (n=12)	Mastectomy (n=12)
Age (years)	46.2± 12.3	47.8± 12
Weight (kg)	71.9± 11.7	74.1± 9.2
Height (cm)	165.7± 9.3	164.5± 8.1
Breast volume (cm^3)	1185± 420	493.5± 104.2
PTV volume (cm^3)	737.23± 20.5	372.4± 78.3
BMI ($kg.cm^{-2}$)	25.8± 5.1	25± 4.8

The values are presented as mean ± standard deviation (SD).

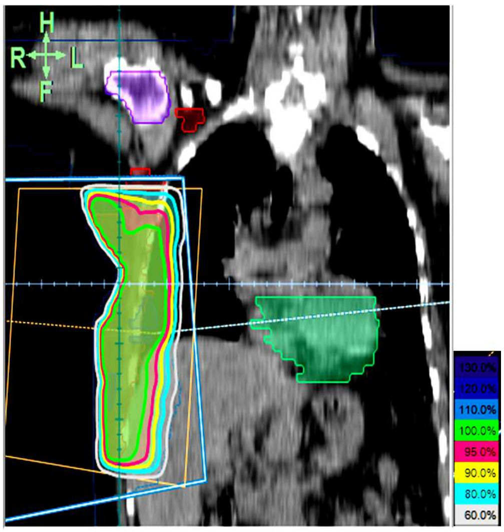

Figure 1. Isodose distributions in coronal images for right breast mastectomy patients without high-dose regions.

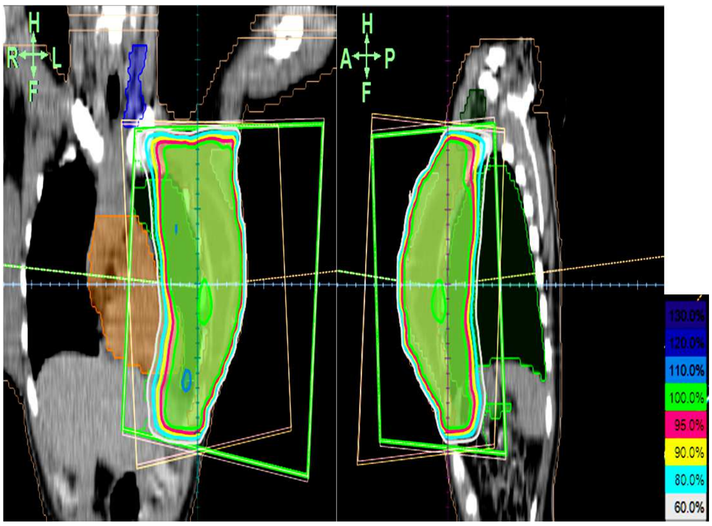

Figure 2. Isodose distributions in coronal (left) and sagittal (right) images for left breast lumpectomy patients without high-dose regions.

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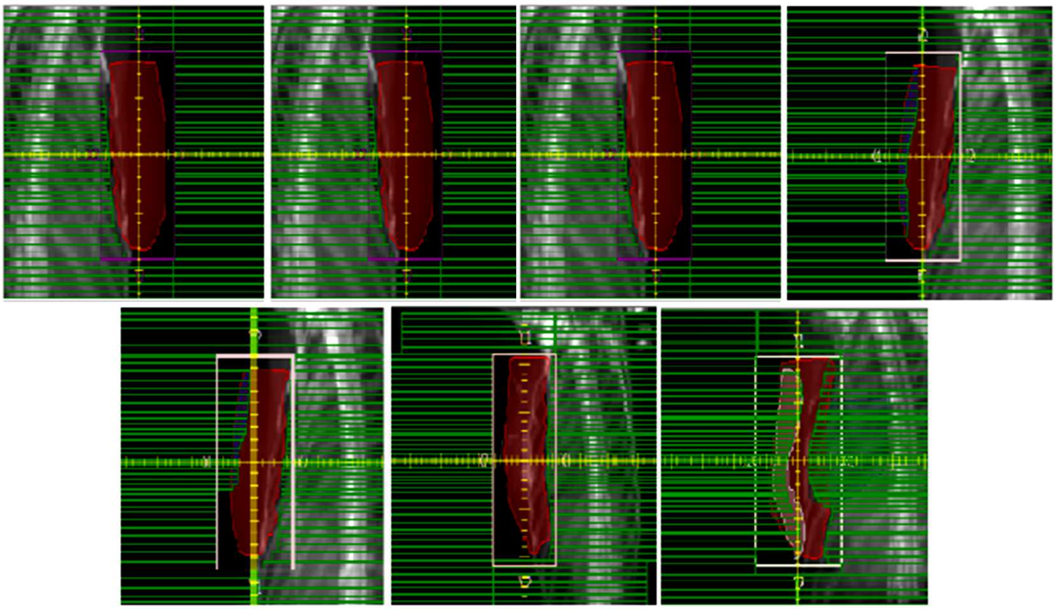

Figure 3. Two main fields and five subfields for disappearing hot points in patients with lumpectomy.

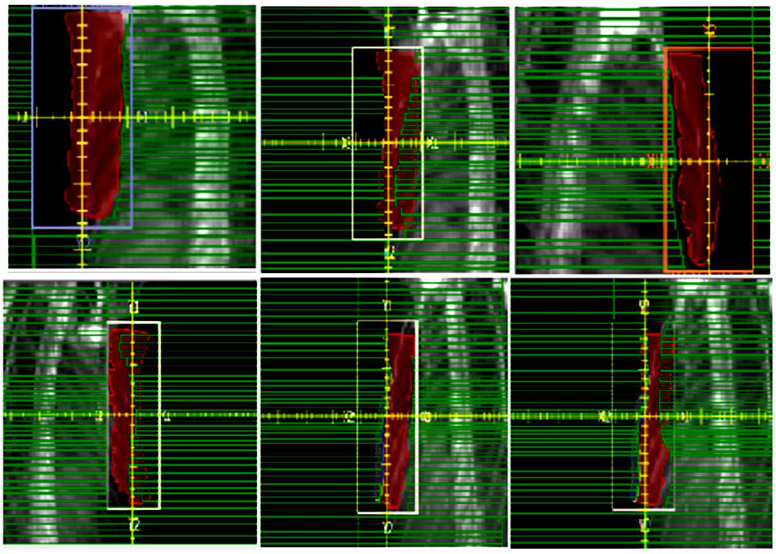

Figure 4. Two main fields and four subfields for disappearing hot points in patients with mastectomy.

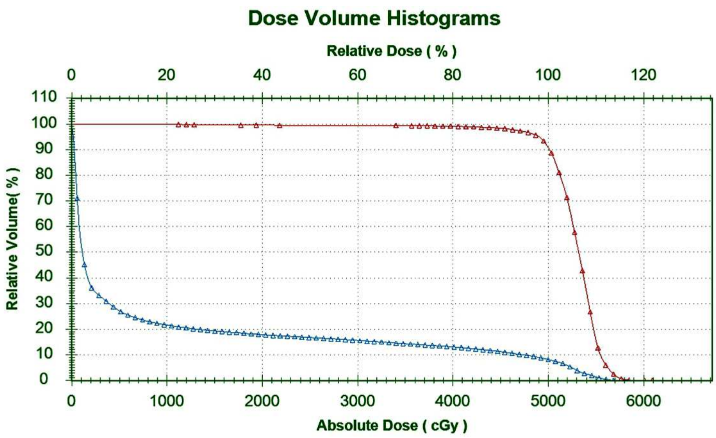

Figure 5. Dose-volume histogram (DVH) of right breast mastectomy patient. Red line shows DVH of gross tumor volume, and blue line indicates DVH of right lung.

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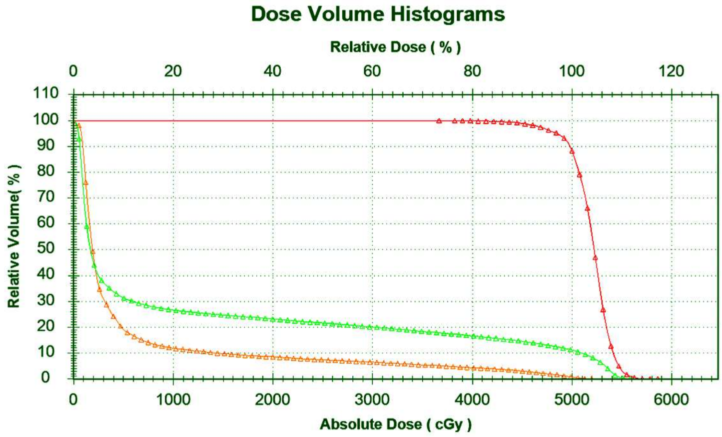

Figure 6. Dose-volume histogram (DVH) of left breast lumpectomy patients. Red line shows DVH of gross tumor volume, and green line displays DVH of left lung. Brown line indicates DVH of heart.

Table 2. Dosimetric comparison of the parameters between patients with right and left breast lumpectomy and mastectomy.

Parameters	Right breast				Left breast		
	Lumpectomy	Mastectomy	*p* value		Lumpectomy	Mastectomy	*P* value
D_{Mean}	5245.3±4.95	5238.9± 67.43	0.908		5220.84±34.41	5101.62±184.94	0.464
D_{Max}	5957.37±145.92	6052.59±41.91	0.419		5837.76±59.36	5777.77±12.08	0.324
D_{Min}	1750±14.14	1939.03±15.51	0.07		3639.06±1.32	3675.00±7.07	0.072
D_2	105.05±1.06	106.05±0.35	0.50		105.4±1.27	106.6±0.42	0.5
D_{98}	91.81±0.82	93.45±3.88	0.588		93.75±1.48	92.75±0.35	0.583
V>107%	0.00±0.00	0.00±0.00	-		0.00±0.00	0.00±0.00	-
V<95%	5.24±0.32	6.84±1.64	0.335		3.96±1.32	11.77±0.84	0.124
CI	0.93±0.005	0.9±0.01	0.038		0.935±0.007	0.85±0.014	0.037
HI	12.92±0.56	14.9±0.6	0.047		11.65±0.21	13.85±0.07	0.029
MU_{Total}	243±2.82	246.5±0.7	0.258		229.5±12.02	235±25.45	0.666

The values are presented as mean ± standard deviation (SD).

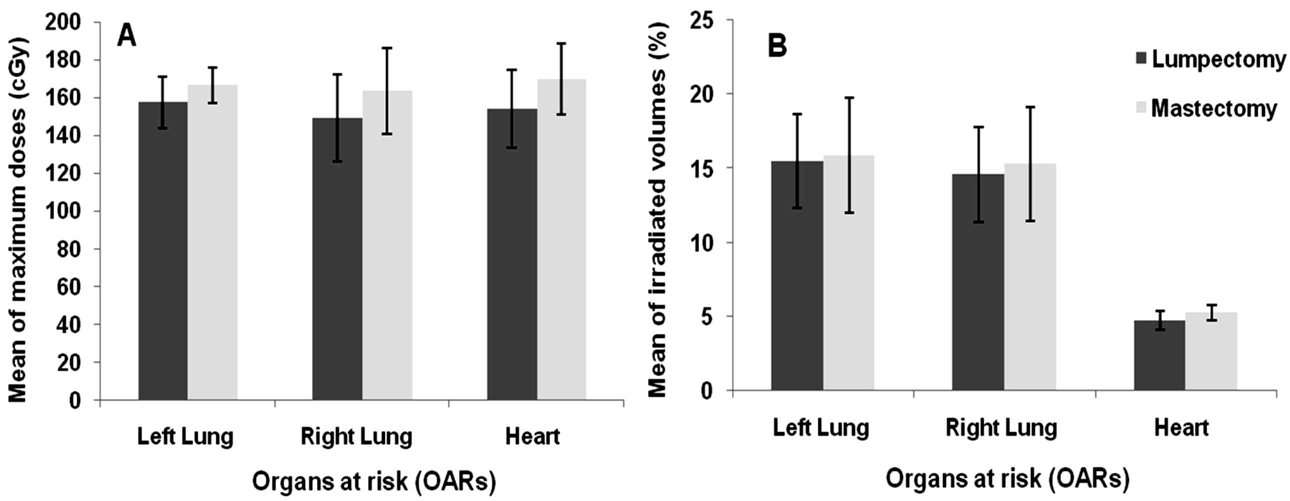

Figure 7. Mean and standard deviation of maximum doses of contralateral OARs and irradiated volumes of ipsilateral OARs in two studied groups (mastectomy and lumpectomy). (A) maximum doses of contralateral OARs. (B) Irradiated volumes of ipsilateral OARs.

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DISCUSSION

Studies have indicated dosimetric superiority of FIF radiotherapy technique in breast cancer radiotherapy [1, 7, 11, 15, 16]. Investigations have also been reported that the FIF technique gives more homogenous dose distribution in target volume compared to the 3D-CRT technique [26-28]. In a study by Baycan *et al.* [1], FIF was compared with 3D-CRT for breast and OARs. They found that HI and CI are better in smaller breasts (V_{breast}<500 cc), which was in contrast to our finding that showed CI and HI were better in larger breasts (lumpectomy). The result of our study also showed that CI and HI were worse for smaller breasts with small PTV sizes. In a previous study, Ayata *et al.* [29] compared the dose distributions in the conventional tangential technique and IMRT plans. They concluded that the HI of treatment plans does not vary with breast size. Herrick *et al.* [30], classified patients with breast sizes of small, medium, and large into three groups of breast volumes: <975 cc, 976-1600 cc, and >1600 cc, respectively. They draw the conclusion that dose homogeneity is better in small and medium breasts, which is in line with the results obtained in our study. The reason for such controversies among various studies can be attributed to the use of different TPS dose calculation algorithms, classifications of patients based on breast sizes, as well as the number of selected subfields, and the type of studies.

Emami's study [31] on the tolerance of normal tissue to therapeutic radiation revealed that symptomatic radiation pneumonities (RP) is one of the most common toxicities in radiotherapy of patients with breast cancer. In addition, breast radiotherapy could result in cardiac symptoms such as clinical pericarditis and death from a myocard infarctus due to previous radiotherapy. Therefore, in breast radiotherapy, reduction in radiation doses of OARs is of great importance.

Based on the results from this study, the number of subfields in lumpectomied breasts was higher than mastectomy plans. In addition, increasing the number of subfields is necessary for decrease of the hot spots in the target volume. The mean number of subfields in our study, despites the surgery type, was the same as the method used in Tanaka and co-workers' study [14]. Their results showed that ASM gives better dose distribution in Japanese patients regardless of their breast size. They suggested that MSM may be a useful method for women with larger breasts, but not Japanese women who have small breast size. Our study also showed that using alternative number of subfields (not only even or odd pairs of subfields) resulted in better dose distribution in the target volume, and larger breast sizes need more subfields for disappearing hot spots and areas in target volume. Moreover, this method of planning requires relatively short planning time and yields higher efficiency.

In conclusion, the use of the FIF radiotherapy technique for breast treatment leads to better dose distribution in the target volume. In addition, our findings indicated that this technique provides better dose homogeneity and conformity in patients with lumpectomied breasts. The present study also showed that ASM is a useful method for arranging subfields in breast cancer FIF radiotherapy.

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Conflicts of interest: *Declared none.*

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