ORIGINAL ARTICLE

Comparison of Lung and Contralateral Scattered Breast Dose between Field-in-Field and Wedge Techniques in Patients with Early Breast Cancer

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Abstract

Purpose: This study aims to evaluate the dosimetric result of the Field-In-Field (FIF) plans compared with Tangential Wedged Beams (TWB) plans for whole breast radiotherapy of patients.

Materials and Methods: In this survey, we entered fifty patients with breast-conserving surgery and postoperative whole-breast radiotherapy. FIF and a TWB plan were made for each patient to compare dosimetric outcomes.

Results: The Homogeneity Index (HI) and Conformity Index (CI) were specified for the evaluation of Planning Target Volume (PTV). The mean dose of the ipsilateral lung and contra-lateral breast for the evaluation of organs at risk dose were used. The FIF plans had significantly lower HI ($p < 0.01$) and CI ($p < 0.01$) than those of the TWB plans. It means in the dosimetric comparisons of the PTV, the FIF plans were better than the TWB plans. The V10lung (31.152vs. 32.72%, $p < 0.01$), V20lung (25.6064vs. 26.6%, $p < 0.01$) V30lung (17.4% vs. 18.4%, $p < 0.01$) were lower with the FIF plans compared with those of the TWB plans, with statistical significance. The FIF plans had a lower mean dose for the lung than those of TWB plans (1225.48 vs. 1670.32 cGy) but no statistical significance (p=0.06). The mean dose in the contra-lateral of the breast in FIF plans was lower than in TWB plans (61.666 vs. 163.45 cGy), with statistical significance ($p < 0.01$).

Conclusion: The FIF plans increased the dose homogeneity, and conformity of the target volume for the whole-breast irradiation compared with the TWB plans. Moreover, the doses of organs at risk (ipsilateral lung and contralateral breast) were reduced with FIF plans.

Keywords: Breast Cancer; Radiotherapy; Radiation Dose; Field In Field Technique.

DOI:

1. Introduction

Several clinical trials showed the effects of Radiation Therapy (RT) after Breast-Conserving Surgery (BCS) [1, 2]. Therefore, the standard treatment for early-stage breast cancer and locally advanced treatment is after BCS [3]. The 15-year survival rate for early-stage breast cancer is outlined at 80% [4]. Minimizing the organ at risk doses in breast cancer radiotherapy is important. Because prolonged side effects such as secondary cancers and skin complications may occur [5]. Typically, two tangential fields with wedges were used in breast planning, but the hot spots could not be eliminated in this technique. By introducing the new FIF technique, hot spots were closed in the tangential fields with Multi-Leaf Collimators (MLC). Therefore, the dose is modulated and assessment factors such as homogeneity and conformity will be improved. For the conventional Tangential Wedged Beams (TWB) technique for whole breast irradiation, it is challenging to achieve homogenous dose distribution because of breast contour irregularities. New radiotherapy techniques were utilized to attain better dose distribution and lower doses to normal tissues. The Field-In-Field (FIF) technique, also called the forward-planned Intensity-Modulated Radiation Therapy (IMRT) technique, which uses the MLC, is relatively simple and a less time-consuming method than the inverse-planned IMRT technique [6]. This study was performed to assess the dosimetric outcome of the FIF plans compared to TWB plans and to confirm the advantages of the FIF plans.

2. Materials and Methods

Fifty patients with breast cancer, treated in our department between July 2019 and July 2021, were included in this analysis. All patients had experienced BCS and were treated with postoperative RT, in which 50 Gy in 25 fractions and 10 Gy in 5 fractions were delivered to the whole breast at the isocenter using 6 MV photon beams (Vitan Beam-SN3011). Exclusion criteria in this study include patients diagnosed with chronic pulmonary and heart diseases and also mastectomy; locally advanced patients will be excluded. Simulation patients underwent CT simulations. Patients were fixed on the Breast board (Omni Board, Macro Medics, and UATB-BPR), and skin wires were placed on the medial and lateral borders.

The medial border was placed at the midline of the chest, and the lateral border was determined by physical examination.

Superior and inferior borders were usually set at the inferior edge of the medial head of the clavicle and 2 cm below the breast fold [7]. CT scans were gained with 5 mm thick slices using Neosoft (Neosoft Medical Solutions, Hun Nun Industrial Area, Shenyang, China), and the acquired image sets were transferred to the Eclipse radiation therapy treatment planning system (Varian Medical Systems, USA).

2.1. Treatment Planning Protocol

The Clinical Target Volume (CTV) was defined as the whole breast tissue [8]. The Planning Target Volume (PTV) was the CTV with an extension of 0.5 to 1 cm margins [9]. Each patient had two plans, the TWB plan and the FIF plan. Conventional TWB plans were generated with appropriate wedge angles for reaching proper dose distribution. To generate FIF plans, two open tangential beams were made. The gantry angle, collimator angle, and primary field size of FIF were the same as those of TWB. However, for the FIF technique, physical wedges were not used. The first assessment was performed with no beam modifiers. Then, hot-dose regions were shielded by additional subfields.

Figure 1 displayed a beam's-eye view of wedge and FIF techniques. Hot dose areas were defined as areas receiving more than 107% of the prescribed dose. Two or three subfields were generated for the tangential field. Both techniques had two fields that covered the whole PTV.

2.2. Indices Used for Dosimetric Comparison

Homogeneity Index (HI) and the Conformity Index (CI) were described and used for the evaluation of the dosimetric outcome of the PTV. The HI was used to evaluate the dose homogeneity within the PTV, and it was defined as the following formula (Equation 1):

$$HI = \frac{D_{max}}{prescription} \quad (1)$$

D_{max} is the maximum dose in the PTV and Dpresciption is the prescribed dose for the PTV [3]. The CI was used to evaluate dose conformity and is defined as the ratio of the volume enclosed by the prescription isodose to the PTV [10]. For Organs At Risk (OARs), Dose-Volume Histograms (DVHs) were generated from the treatment planning system. The V10, V20, or V30 delineates the percentage of the volume of OAR receiving radiation doses of 10 Gy, 20 Gy, or 30 Gy, respectively.

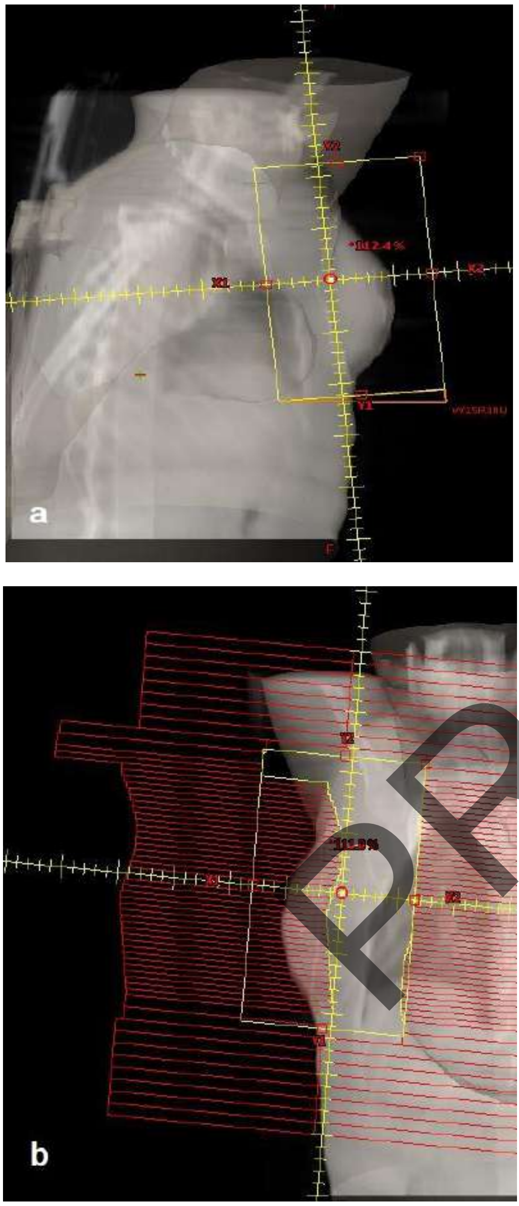

Figure 1. BEV (Beam's-eye view) with DRRs (digitally reconstructed radiography) for the wedged fields (a) and the FIF (b)

2.3. Statistical Analysis

All statistical analyses were carried out with the SPSS version 20 software. Paired t-test was used for the differentiation of the two techniques. A p-value of less than 0.05 indicates a statistically significant difference between the two data sets.

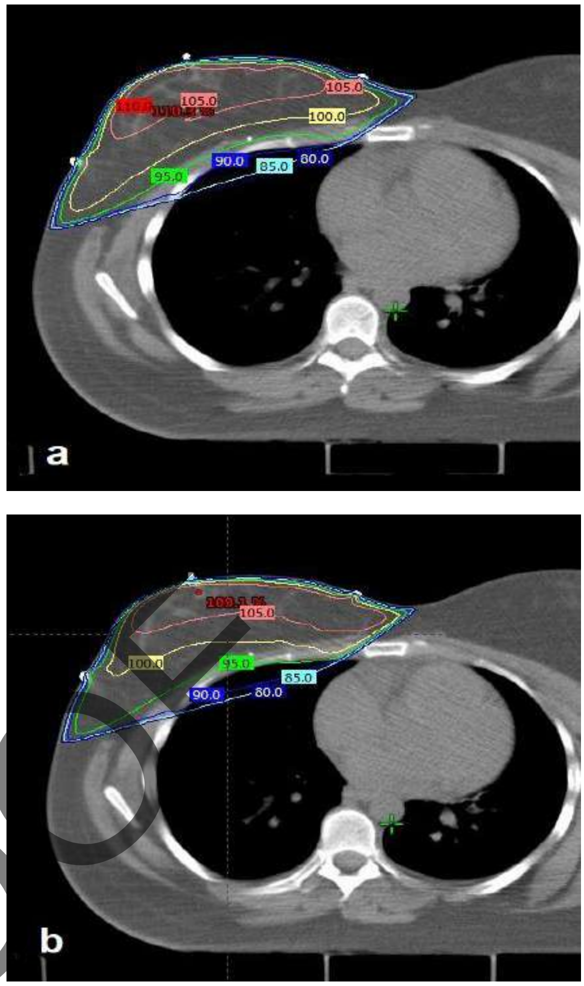

Figure 2. Central CT slice with dose distribution (calculated at the treatment planning system Eclipse) for the FIF technique (a) and the wedge technique (b)

3. Results

The dosimetric parameters of the two techniques are shown in Table 1.

The HI for FIF plans and TWB plans were 1.076 and 1.084, respectively. There was a statistically significant difference in HI between the two plans with a $p < 0.01$. The FIF plans had a lower HI than the TWB plans, which means that the FIF plans displayed better dose homogeneity within the PTV.

Although the difference in HI was statistically significant, the ideal value is 1, increasing as the plan becomes less homogeneous [10]. The CI of the FIF plans was lower than that of the TWB plans, and the differences were statistically significant (1.2174 vs. 1.351, $p < 0.01$). If the conformity index is between 1 and 2, the treatment is by the protocol; if it is between 2-2.5 and 0.9-1 it is considered that there is a minor deviation of the protocol; if it is greater than 2.5, and less than 0.9 it is considered as a severe deviation from the protocol [10, 11]. The dosimetric parameters of the OARs are shown in Table 2. The mean dose of the ipsilateral lung (Dmean lung) was not significantly different between the FIF plans and TWB plans (1225.48 cGy vs. 1670.32 cGy, p=0.06). However, the V10 lung of the FIF plans was 31.152, and that of the TWB plans was 32.72, showing that the FIF plan reduced the V10lung with statistical significance ($p < 0.01$). The V20 lung of the FIF plans was 25.6064 and that of TWB plans was 26.6, p= 1.17E-5 with statistical significance. The V30 lung was lower with the FIF plans (17.4 vs. 18.4, $p < 0.01$). The DVH of a patient with left-sided breast cancer is shown in Figure 3.

Table 1. Dosimetric comparison between FIF and TWB plans

Parameters	FIF plans (Mean± SD)	TWB plans (Mean± SD)	P-value
Homogeneity Index (HI)	1.07±0.01	1.08±0.01	p < 0.01
Conformity Index (CI)	1.21±0.29	1.35±0.32	p < 0.01

FIF: Field-In-Field, TWB: Tangential Wedged Beams

Table 2. Dosimetric parameters of the organs at risk for each treatment plan

Parameters	FIF plans	TWB plans	p-value
D_{mean} lung (cGy)	1225.48	1670.32	0.06
V10lung	31.15	32.72	p < 0.01
V20lung	25.60	26.6	p < 0.01
V30lung	17.4	18.4	p < 0.01
D_{mean} Breast (cGy)	61.66	163.45	p < 0.01

FIF: Field-In-Field, TWB: Tangential Wedged Beams

4. Discussion

Breast-conserving surgery and postoperative radiotherapy are the gold treatments for early-stage breast

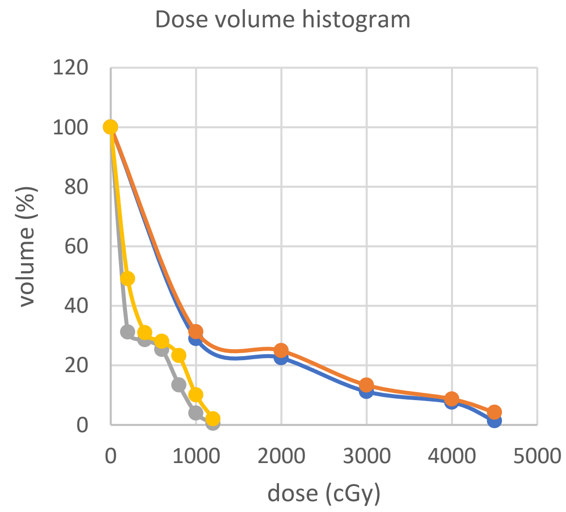

Figure 3. An example of Dose-Volume Histograms (DVH) of contralateral of breast and ipsilateral lung; comparison of TWB plan and FIF plan. Solid blue line: ipsilateral lung, FIF plan, solid red line: ipsilateral lung, TWB plan, Gray solid line: contra lateral breast, FIF plan, solid yellow line: contralateral breast TWB plan

cancer. The dose distribution in the PTV improved with the evolution of radiotherapy planning systems and new breast radiation techniques There are two IMRT techniques, forward-planned and inverse-planned IMRT. The FIF technique is named forward-planned IMRT, which consumes less time.

Several investigators compared the FIF plans and TWB plans for whole breast radiotherapy. In an article with 20 patients, Sasaoka *et al.* concluded that the FIF technique reduced the maximum dose and improved dose distribution. Their maximum dose was 111.2±3.4% for TWB plans and 105.8±1.4% for FIF plans (p=0.005) [12]. In our study, the maximum doses for the FIF technique and TWB plans were 110.7±0.7% and 112.3±1.6%, respectively. Kim *et al.* showed the FIF plans had significantly lower HI (p=0.002) (1.03 versus 1.05) and CI (p=0.000) (0.36 versus 0.24) than those of the TWB plans, which means that the FIF plans were better than the TWB plans in the dosimetric comparisons of the PTV [3]. In a study by Petrova *et al.*, the HI values were 1.08 ± 0.01 and 1.09 ± 0.01 for FIF and technique with two tangential fields ($p < 0.001$). The CI values were 1.38 ± 0.02 and 1.43 ± 0.3 for FIF and technique with two tangential fields (p = 0.001) [10], which correspond with the results of this study. In our study, FIF plans had significantly lower HI and CI than the TWB plans. We had less homogeneous and less conformal dose distribution in patients with TWB plans. We found that the FIF plan was more advantageous for this patient. Furthermore, our study compared the dosimetric parameters of OARs and showed that the FIF plan reduced the V10, V20, and V30 of the ipsilateral lung. Clinically symptomatic radiation pneumonitis occurs in 1~10% of patients irradiated for breast cancer [13]. In a meta-analysis, the mean lung dose, V5, V10 (≥34%), V20 (≥25%), and V30 (≥18%) of the lungs were identified as significant risk factors for radiation pneumonitis [14]. In our study, the Dmean of the ipsilateral lung, V10 lung, V20 lung, and V30 lung of TWB plans were much lower than the constraints for radiation pneumonitis, but FIF plans even lowered these values so that the risk of radiation pneumonitis could be minimized. In another study, the contralateral scattered breast dose was measured in a custom-designed anthropomorphic breast phantom in which 108 Thermoluminescent Dosimeters (TLDs) were volumetrically placed every 1–2 cm. Borghero *et al.* showed that for FIF the mean doses to the medial and lateral quadrants of the contralateral breast were 112 cGy (Range 65–226 cGy) and 40 cGy (range 18–91 cGy), respectively [15]. In our study, the mean dose of the contralateral breast for FIF plans was 61.66 cGy. Compared with the TWB plan, the dose homogeneity and conformity within the breast improved with the FIF plan. Moreover, the FIF decreased the dose-induced toxicities in the lung and heart. Another advantage of FIF was a convenience for technologists in terms of replacing wedges and also relative reduction of monitor units [2, 16]. This study also has limitations. The first limitation is the lack of research studies related to the topic of the article in our country, Iran. The results of the present study can be generalized to Kerman Radiotherapy Center. This study was conducted on early-stage breast cancer patients and cannot be generalized to all. It is suggested that this study be performed on locally advanced patients as well. The third limitation is the lack of high energy in the machine. It has been shown in many studies that the use of combined energies of 6 and 18 results in better homogeneity of dose distribution while maintaining good coverage. It is also suggested that this study be done in the future with different planning and the use of more subfields.

5. Conclusion

This study assessed the FIF technique for breast cancer patients both dosimetrically and clinically. We demonstrated that the FIF technique is a simple and time-saving method, easily applicable to breast irradiation. The dose distribution within the target volume was more homogenous and also the doses for healthy tissue were less in the FIF plan compared to the tangential wedge plan. Another benefit of the FIF plan was the disappearance of the scatter dose, which was more prominent in the wedge plan, resulting in fewer contralateral breast doses, possibly causing a reduction in secondary malignancy in the contralateral breast. The FIF plan reduces the dose to the contralateral breast and OARs without losing plan quality in our clinic, the FIF plan has become routine. Furthermore, other conventional and new techniques should be analyzed for profit and damage.

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References

1- Elisabetta Rapiti *et al.*, "Breast-conserving surgery has equivalent effect as mastectomy on stage I breast cancer prognosis only when followed by radiotherapy." *Radiotherapy and Oncology,* Vol. 69 (No. 3), pp. 277-84, (2003).

2- Todd Yoder, An Ting Hsia, Zhigang Xu, Alexander Stessin, and Samuel Ryu, "Usefulness of EZFluence software for radiotherapy planning of breast cancer treatment." *Medical Dosimetry,* Vol. 44 (No. 4), pp. 339-43, (2019).

3- Suzy Kim and Yunseok Choi, "Dosimetric advantages of the field-in-field plan compared with the tangential wedged beams plan for whole-breast irradiation." *Progress in Medical Physics,* Vol. 25 (No. 4), pp. 199-204, (2014).

4- Early Breast Cancer Trialists' Collaborative Group, "Darby S, McGale P, Correa C, Taylor C, Arriagada R, et al. Effect of radiotherapy after breast-conserving surgery on 10-year recurrence and 15-year breast cancer death: meta-analysis of individual patient data for 10,801 women in 17 randomised trials." *Lancet,* Vol. 378 (No. 9804), pp. 1707-16, (2011).

5- Hilal SARAÇ CANBOLAT, Niyazi Volkan DEMIRCAN, Serap ÇATLI DINÇ, Ertuğrul ŞENTÜRK, and BORA Hüseyin, "Dosimetric Investigation of FIF, VMAT, IMRT, H-VMAT, and H-IMRT Planning Techniques in Breast Cancer Radiotherapy." *TURKISH JOURNAL OF ONCOLOGY,* Vol. 1 (No. 1), (2023).

6- Zakiya Salem Al-Rahbi *et al.*, "Dosimetric comparison of intensity modulated radiotherapy isocentric field plans and field in field (FIF) forward plans in the treatment of breast cancer." *Journal of Medical Physics/Association of Medical Physicists of India,* Vol. 38 (No. 1), p. 22, (2013).

7- Vishnu R Nambiar, Dinesh Makuny, and Beena Kunheri, "Breast Radiation Therapy Techniques." in *Management of Early Stage Breast Cancer*: *Springer*, (2021), pp. 203-15.

8- Kuo Men *et al.*, "Fully automatic and robust segmentation of the clinical target volume for radiotherapy of breast cancer using big data and deep learning." *Physica Medica,* Vol. 50pp. 13-19, (2018).

9- Coen W Hurkmans, Jacques H Borger, Bradley R Pieters, Nicola S Russell, Edwin PM Jansen, and Ben J Mijnheer, "Variability in target volume delineation on CT scans of the breast." *International Journal of Radiation Oncology* Biology* Physics,* Vol. 50 (No. 5), pp. 1366-72, (2001).

10- Deva Petrova, Snezana Smickovska, and Emilija Lazarevska, "Conformity index and homogeneity index of the postoperative whole breast radiotherapy." *Open access Macedonian journal of medical sciences,* Vol. 5 (No. 6), p. 736, (2017).

11- Loic Feuvret, Georges Noël, Jean-Jacques Mazeron, and Pierre Bey, "Conformity index: a review." *International Journal of Radiation Oncology* Biology* Physics,* Vol. 64 (No. 2), pp. 333-42, (2006).

12- Masahiro Sasaoka and Tomoyuki Futami, "Dosimetric evaluation of whole breast radiotherapy using field-in-field technique in early-stage breast cancer." *International journal of clinical oncology,* Vol. 16 (No. 3), pp. 250-56, (2011).

13- Paiman Ghafoori, Lawrence B Marks, MD Zeljko Vujaskovic, and Christopher R Kelsey, "Radiation-induced lung injury: assessment, management, and prevention." *Oncology,* Vol. 22 (No. 1), p. 37, (2008).

14- Xiao-Jing Zhang *et al.*, "Prediction of radiation pneumonitis in lung cancer patients: a systematic review." *Journal of cancer research and clinical oncology,* Vol. 138 (No. 12), pp. 2103-16, (2012).

15- Yerko O Borghero *et al.*, "Multileaf field-in-field forward-planned intensity-modulated dose compensation for whole-breast irradiation is associated with reduced contralateral breast dose: a phantom model comparison." *Radiotherapy and Oncology,* Vol. 82 (No. 3), pp. 324-28, (2007).

16- Tülay Ercan *et al.*, "Dosimetric comparison of field in field intensity-modulated radiotherapy technique with conformal radiotherapy techniques in breast cancer." *Japanese journal of radiology,* Vol. 28pp. 283-89, (2010).