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Evaluation of the field-in-field technique with lung blocks for breast tangential radiotherapy

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ABSTRACT

Several studies have reported the advantages of the field-in-field (FIF) technique in breast radiotherapy, including dose reduction in the lungs by using lung field blocks. We evaluated the FIF technique with lung blocks for breast tangential radiotherapy. Sixteen patients underwent free breathing (FB) computed tomography (CT), followed by two CT procedures performed during breath hold after light inhalation (IN) and light exhalation (EX). Three radiotherapy plans were created using the FIF technique based on the FB-CT images: one without lung blocks (LB0) and two with lung blocks whose monitor units (MUs) were 5 (LB5) and 10 (LB10), respectively. These plans were copied to the IN-CT and EX-CT images. V20Gy, V30Gy, and V40Gy of the ipsilateral lung and V100%, V95%, and the mean dose (Dmean) to the planning target volume (PTV) were analyzed. The extent of changes in these parameters on the IN-plan and EX-plan compared with the FB-plan was evaluated. V20Gy, V30Gy, and V40Gy were significantly smaller for FB-LB5 and FB-LB10 than for FB-LB0; similar results were obtained for the IN-plan and EX-plan. V100%, V95%, and Dmean were also significant smaller for FB-LB5 and FB-LB10 than for FB-LB0. The extent of changes in V20Gy, V30Gy, and V40Gy on the IN-plan and EX-plan compared with the FB-plan was not statistically significant. Lung blocks were useful for dose reduction in the lung and a simultaneous PTV decrease. This technique should not be applied in the general population.

Key Words: breast cancer, breast-conserving surgery, breast radiotherapy, field-in-field technique, lung blocks

INTRODUCTION

Most patients with early breast cancer undergo breast-conserving treatment consisting of wide excision and post-operative whole-breast radiotherapy. This form of postoperative radiotherapy reduces the risk of local recurrence and results in long-term survival similar to that obtained with mastectomy.[1-3] Thus, postoperative breast therapy is a standard treatment. In recent years, the field-in-field (FIF) technique has become a widely performed method of administering tangential whole-breast radiotherapy. Compared to irradiation with physical wedges (PWs), the use of the FIF technique permits reductions in the size of the high-dose region and the homogeneity index.[4-16] The impact of respiratory motion is smaller with the use of the FIF technique than with the use of PWs.[17]

The methods used for the FIF technique differed in previous reports. Several authors reported the advantages of lung-blocked subfields, which help to reduce the dose received by the lungs.[18-19] However, the use of multileaf collimators (MLCs) to block the lungs also results in blockade of some parts of the planning target volume (PTV). This could decrease the doses delivered to the PTV. Moreover, it is unclear how the impact of lung blocks is affected by respiratory motion. We evaluated the utility of lung blocks and the impact of respiratory motion in breast tangential radiotherapy using the FIF technique.

MATERIALS AND METHODS

This planning study included 16 patients with early-stage breast cancer, including 9 patients with right-sided cancer and 7 patients with left-sided breast cancer. Institutional review board approval was waived because this study was a simulation study and a part of routine clinical practice. The median patient age was 54 years (range, 45–69). All patients had undergone breast-conserving surgery.

Computed tomography (CT) images were obtained using a scanner with 16 detector arrays (LightSpeed Xtra; GE Healthcare, Waukesha, WI, USA) while patients were in the supine position on a breast board with both arms positioned above their heads. Scanning was performed in 2.5-mm slices from the clavicle to the mid-abdomen during free breathing (FB). After acquisition of the FB-CT data set, 2 additional CT scans were obtained during a held breath after light inhalation (IN) and light exhalation (EX). All CT images were transferred to a computer with Eclipse External Beam Planning 8.6 software (Varian Medical Systems Palo Alto, CA, USA). The IN-CT and EX-CT images were individually fused with the FB-CT images. The remaining whole breast was contoured as the clinical target volume. The PTV was constructed by adding 5-mm margins and removing 5-mm of the build-up region from the skin surface of the breast. Each patient's plan was normalized to a reference point at the interface of the breast and pectoralis major muscle at the level of the nipple. A 6-MV energy photon beam was used. The prescribed dose was 50 Gy in 25 fractions. The dose calculation algorithm used was the analytic anisotropic algorithm.

The method used to create the FIF plan was reported previously.[20] Two opposed tangential fields were created without PWs, and the gantry angles were optimized on FB-CT. The medial field was copied as the first subfield. On the beam's eye view, the MLCs were set to block the dose level at 1–2% lower than the maximum dose (Fig. 1). Then, dose calculation was performed. The beam weight of this subfield was increased until the dose cloud disappeared. Second, the lateral main field was copied as the second subfield. The MLCs were set to block the dose level at 2–3% lower than the dose blocked at the first subfield. Dose calculation was performed again, and the beam weight of this subfield was increased until the dose cloud disappeared. Finally, the medial main field was copied again as the third subfield. The MLCs were set to block the dose level at 2–3% lower than the dose blocked at the second subfield. After recalculation of the dose, the beam weight of this subfield was increased until the dose cloud disappeared. The MLCs were not allowed to block within 1 cm of the reference point. In this study, the lateral main field was copied again as the fourth subfield, which blocked the lung area (Fig. 2). Three radiotherapy plans with lung block subfield monitor unit (MU) values of 0, 5, and 10 (FB-LB0, FB-LB5, and FB-LB10, respectively) were created. After copying these fields on the IN-CT and EX-CT images for each patient, dose calculation was performed by inputting the same number of MU values as used for the FB-plan (IN-LB0, IN-LB5, IN-LB10, EX-LB0, EX-LB5, and EX-LB10).
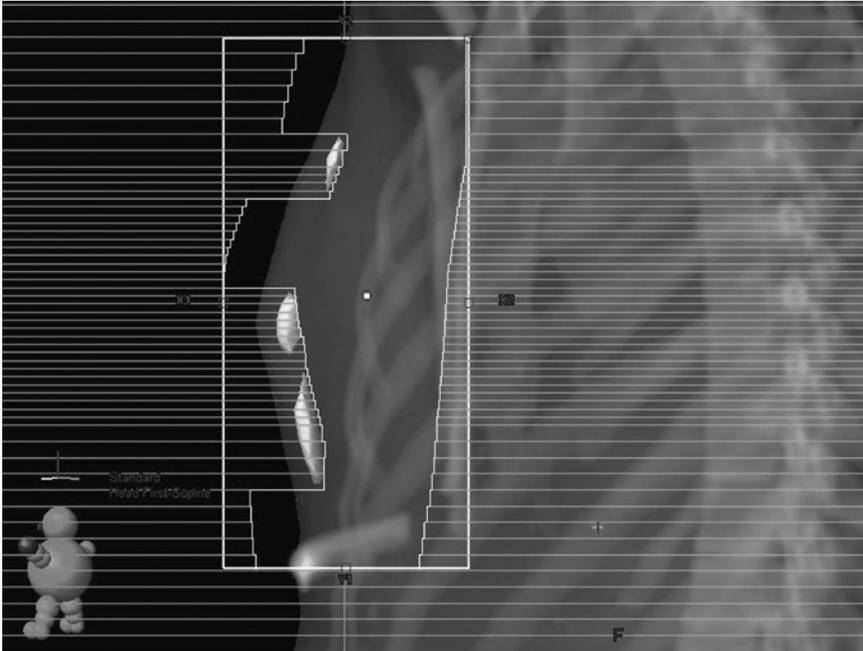
Fig. 1 Beam's eye view of the typical subfield
Multileaf collimators were manipulated to shield the areas of the breast receiving any dose on beam's eye view. The blocked isodose cloud is presented in white.
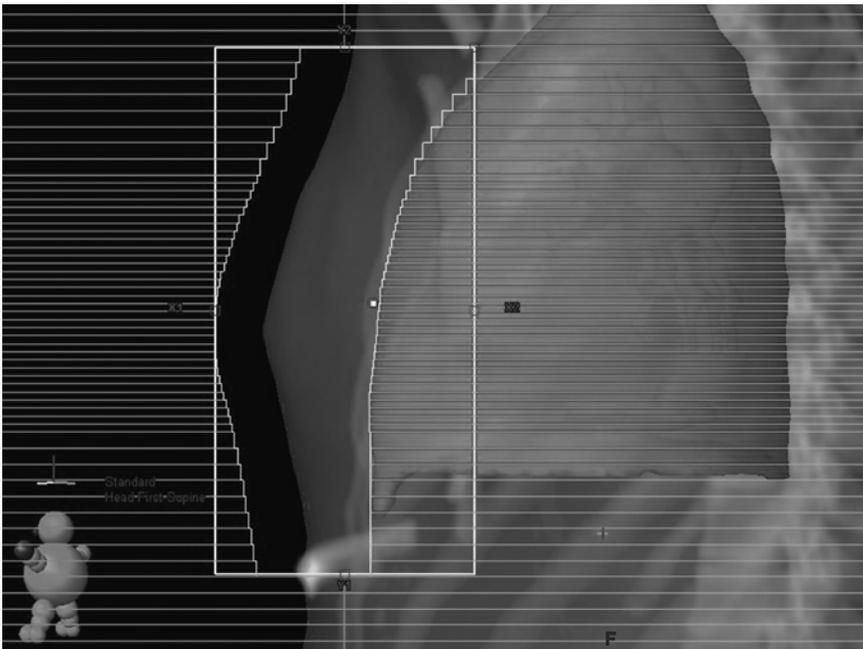
Fig. 2 Beam's eye view of the lung-blocked subfield
Multileaf collimators were manipulated to shield the lung parenchyma on beam's eye view. The ipsilateral lung is presented in dark blue.

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A dose volume histogram was calculated for each patient. The volumes of the ipsilateral lung receiving 20, 30, and 40 Gy (V20Gy, V30Gy, and V40Gy, respectively) were calculated. The volumes of the PTV receiving 100 and 95% of the prescription dose (V100% and V95%, respectively) and the mean dose (Dmean) to the PTV were also calculated. The amounts of change in the IN-plan and EX-plan from the FB-plan were evaluated. Dosimetric parameters were compared using the Wilcoxon signed-rank test. A *p*-value less than 0.05 was considered to indicate a statistically significant difference.

RESULTS

The V20Gy, V30Gy, and V40Gy values of the ipsilateral lung are shown in Table 1. These parameters were significantly decreased by the addition of lung blocks in each respiratory phase. The V100%, V95%, and Dmean values of the PTV are presented in Table 2. These parameters were also significantly decreased by the addition of lung blocks in each respiratory phase. The dose parameters of the PTV in the IN-plan were larger compared to those in the FB-plan. This finding is attributable to the movement of the PTV toward the anterior direction, which is included in the radiation field in the inspiration phase. The extent of the increase was significantly larger in the LB5-plan than in the LB0-plan (Table 3). Moreover, the extent of the increase in the LB10-plan was significantly larger than that in the LB0-plan (Table 3).

Table 1 Average dose parameters of the ipsilateral lung during each breathing phase.

| | FB[a] | | IN[b] | | | EX[c] | | |
	LB0[d]	LB5[d]	LB10[d]	LB0[d]	LB5[d]	LB10[d]	LB0[d]	LB5[d]	LB10[d]
V20Gy[e] (%)	15.1	15.0[f]	14.9[f]	19.4	19.3[f]	19.2[f]	14.8	14.7[f]	14.6[f]
V30Gy[e] (%)	12.9	12.7[f]	12.6[f]	17.0	16.9[f]	16.7[f]	12.5	12.4[f]	12.2[f]
V40Gy[e] (%)	9.4	8.8[f]	8.2[f]	12.8	12.3[f]	11.7[f]	9.0	8.5[f]	7.9[f]

[a] FB = free breathing; [b] IN = light inhalation; [c] EX = light exhalation; [d] LB0, LB5, and LB10 = radiotherapy plan with lung-blocked subfield monitor unit values of 0, 5, and 10, respectively; [e] V20Gy, V30Gy, and V40Gy = volumes of the ipsilateral lung receiving at least 20, 30 and 40 Gy
[f] significantly smaller than that in the LB0-plan in each breathing phase

Table 2 Average dose parameters of the PTV[a] during each breathing phase.

| | FB[b] | | IN[c] | | | EX[d] | | |
	LB0[e]	LB5[e]	LB10[e]	LB0[e]	LB5[e]	LB10[e]	LB0[e]	LB5[e]	LB10[e]
V100%[f] (%)	62.7	57.2[h]	52.3[h]	64.9	62.5[h]	59.0[h]	62.3	56.6[h]	52.0[h]
V95%[f] (%)	93.2	90.7[h]	87.1[h]	95.8	95.2[h]	94.3[h]	92.8	90.3[h]	86.5[h]
Dmean[g] (Gy)	50.3	50.1[h]	50.0[h]	50.5	50.3[h]	50.2[h]	50.3	50.1[h]	49.8[h]

[a] PTV = planning target volume; [b] FB = free breathing; [c] IN = light inhalation; [d] EX = light exhalation; [e] LB0, LB5, and LB10 = radiotherapy plan with lung-blocked subfield monitor unit values of 0, 5, and 10, respectively; [f] V100% and V95% = percentage of the PTV receiving at least 100 and 95% of the prescription dose, respectively; [g] Dmean = mean dose of the PTV
[h] significantly smaller than that in the LB0-plan in each breathing phase

From another perspective, the extent of the decrease of the dose parameters of the PTV in the LB5-plan and LB10-plan from those in the LB0-plan was significantly smaller in the IN-plan than in the FB-plan (Table 4, 5).

Table 3 Extent of increase of the dose parameters of the PTV[a] from FB[b]-plan to IN[c]-plan.

	LB0[d]	LB5[d]	LB10[d]
V100%[e] (%)	2.1	5.2[g]	6.7[g]
V95%[e] (%)	2.7	4.5[g]	7.2[g]
Dmean[f] (Gy)	0.12	0.23[g]	0.27[g]

[a] PTV = planning target volume; [b] FB = free breathing; [c] IN = light inhalation; [d] LB0, LB5, and LB10 = radiotherapy plan with lung-blocked subfield monitor unit values of 0, 5, and 10, respectively; [e] V100% and V95% = percentage of the PTV receiving at least 100 and 95% of the prescription dose, respectively; [f] Dmean = mean dose of the PTV
[g] significantly larger than that in the LB0-plan

Table 4 Extent of decrease of the dose parameters of the PTV[a] from LB0[b]-plan to LB5[b]-plan.

	FB[c]	IN[d]
V100%[e] (%)	−5.5	−2.3[g]
V95%[e] (%)	−2.4	−0.3[g]
Dmean[f] (Gy)	−0.62	−0.15[g]

[a] PTV = planning target volume; [b] LB0 and LB5 = radiotherapy plan with lung-blocked subfield monitor unit values of 0 and 5, respectively; [c] FB = free breathing; [d] IN = light inhalation; [e] V100% and V95% = percentage of the PTV receiving at least 100 and 95% of the prescription dose, respectively; [f] Dmean = mean dose of the PTV
[g] significantly larger than that in the FB-plan

Table 5 Extent of decrease of the dose parameters of the PTV[a] from LB0[b]-plan to LB10[b]-plan.

	FB[c]	IN[d]
V100%[e] (%)	−10.5	−5.9[g]
V95%[e] (%)	−6.1	−0.5[g]
Dmean[f] (Gy)	−1.57	−0.29[g]

[a] PTV = planning target volume; [b] LB0 and LB10 = radiotherapy plan with lung-blocked subfield monitor unit values of 0 and 5, respectively; [c] FB = free breathing; [d] IN = light inhalation; [e] V100% and V95% = percentage of the PTV receiving at least 100 and 95% of the prescription dose, respectively; [f] Dmean = mean dose of the PTV
[g] significantly larger than that in the FB-plan

DISCUSSION

In breast tangential radiotherapy, the use of the FIF technique can improve the dose distribution compared with the use of PWs.[4-16] The FIF technique is used widely in breast tangential radiotherapy. The methods used for the FIF technique differed in published reports. Several studies reported the use of lung-blocked subfields. Yang reported that lung doses could be reduced in FIF with lung blocks.[18] However, the dose to the PTV was decreased by the addition of lung blocks. Kestine also reported the usefulness of lung blocks.[19] Cao reported a method of using lung blocks in the FIF technique.[21] However, the study did not compare the results with those of a method lacking lung blocks. Although Vicini also reported a method using lung blocks, the lung doses were not evaluated.[22]

In our study, lung blocks were useful for reducing the dose delivered to the lungs, but a simultaneous decrease in the PTV was observed. However, the amount by which the PTV doses increase in the IN-plan compared to that in the FB-plan was significantly larger in the LB5-plan and LB10-plan than in the LB0-plan. The PTV dose may have been partially supplemented in the inspiratory phase. In the typical subfield, the PTV moves toward the MLCs that are blocking the high-dose region in the inspiratory phase, resulting in an increase of the blocked area in the PTV. On the contrary, the PTV moves away from the region blocked by the MLCs in the lung-blocked subfield. Thereby, a leaf margin is provided around the PTV unintentionally.

In practice, the doses received by the lungs are unexpectedly large owing to the deformation of the breast after surgery in addition to deformation of the thoracic cavity. The FIF technique with lung blocks is useful only for these patients. This technique should not be applied in the general population.

ACKNOWLEDGEMENTS

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