Original Article

Immobilization techniques influence on treatment plan results in postmastectomy radiotherapy

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ABSTRACT

Purpose: To compare different immobilization devices used for chest wall and nodal irradiation in breast cancer dosimetrically.

Materials and Methods: All patients with left-sided breast cancer received chest wall and lymphatic irradiation. Treatment plans were created for radiotherapy in single arm (SA) lift board, double arm (DA) lift board, and wing board (WB) positions. Dose–volum e histograms (DVH) were used for evaluation based on planning target volume (PTV) coverage and organs at risk (OARs). One-way analysis of variance (ANOVA) test was performed to identify the dose–volume differences among different immobilization techniques.

Results: Clinically acceptable plans were generated with all immobilization boards. Significantly lower doses in the body except target volumes were found in the SA lift board group compared to other groups ($P < 0.05$). No relevant differences were observed among the plans according to the other dose parameters of target volumes and OARs.

Conclusion: SA board is an immobilization device that can be used safely for three-dimensional conformal radiotherapy in young left-sided breast cancer with an unfavorable anatomy as it significantly reduces low-dose exposure.

KEY WORDS: Breast Cancer, helical tomotherapy, immobilization, low-dose exposure

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INTRODUCTION

Breast cancer is the most common cancer in women and the second cause of cancer-related death in women. Despite the development of early diagnosis methods and advances in treatment, it is still an important cause of mortality and morbidity.[1] Breast cancer, as a systemic disease, requires a multidisciplinary approach consisting of surgery, chemotherapy, and radiotherapy (RT).

Depending on the stage of breast cancer, RT reduces the risk of locoregional recurrence, increases survival, and provides symptom palliation. Post breast-conserving surgery (BCS), RT is considered an absolute component of the treatment in early-stage breast cancer. It is also known that adjuvant RT reduces the risk of local recurrence in more advanced cases and increases survival in cases with axilla metastasis.[2] Internal mammary (IM) and supraclavicular (SC) irradiation for breast cancer reduces breast cancer mortality and improves disease-free survival and distant disease-free survival.[3] Before the three-dimensional conformal RT (3D-CRT) technique, field shaping was carried out in square and rectangular forms with the help of the primary collimators of the RT devices, and with the advancement of technology, it was started to be carried out with the devices containing multi-leaf collimators, which are computer-controlled field-shaping secondary collimators.[4] Intensity-modulated RT (IMRT) is a more advanced 3D-CRT technique in which beams of varying intensities are used to precisely irradiate a tumor. IMRT is based on treating the patient with angles (or continuous arc) in different directions of inhomogeneous flux maps to deliver high dose to target volume and acceptable low dose to surrounding healthy tissues.[5]

In helical tomotherapy (HT), the dose is given in a spiral fashion with the use of a dual external quality control that irradiates the target volume with multiple beamlets. This contributes to more

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precise dosing compared to traditional IMRT techniques applied in traditional linac s.[6] The HT plans provide an excellent coverage of the planning target volume (PTV) and improved dose conformity and homogeneity in target volumes with a decreased dose to organs at r isk (OARs). At the same time, HT delivers lower doses to larger volumes of the tumor surrounding tissues. This may result in an increased risk of secondary cancer.[7]

RT is applied with complex techniques in the breast. The large concave structure of the target volumes, differences in their depth, and the nearby moving organs such as the lung and heart create difficulties in treatment planning. Thus, achieving a sharp dose gradient between target and OARs and dose uniformity at the target is difficult. In standard tangential fields, dose differences up to 20% occur in the dose homogeneity in the medial, lateral, superior, and inferior regions.[8] Inadequate dose areas can be seen at the target in regional lymph nodes, especially in the IM nodes. Radiation-induced damage is related to the volume of the organ tissue exposed to radiation and the radiation dose. Therefore, normal tissues should be protected from radiation as much as possible in RT applications.[9]

A good immobilization should be made to ensure the patient's position in order that it is reproducible every day and thr oughout irradiation.[10] Meanwhile, patient comfort should also be considered. The patient's age, general health status, and treatment technique are the factors affecting the patient's comfort.

During the simulation process and treatment, patient-specific fixation devices such as mask, vacuum bed, single arm (SA) board, double arm (DA) board, and wing board (WB) are used to immobilize the patient in the appropriate position and to prevent movement. During treatment, the patient's position on the inclined plane, head position, and gantry angles are the same as in the simulator.[11]

To our knowledge, there is no accepted immobilization device that demonstrates the dosimetric advantage in treatment plans for the irradiation of breast cancer patients with lymphatic involvement. Therefore, we decided to compare dosimetric alterations related to target volumes and OARs using different immobilization devices as part of postoperative breast cancer RT. We tried to emphasize the lower dose exposure differences in healthy tissues, which is a great disadvantage of IMRT in regard to the risk of the development of secondary cancer.

MATERIALS AND METHODS

Three computed tomography (CT) scans of each of five patients with left-sided locally advanced breast cancer who had undergone modified radical mastectomy were prospectively chosen for this study. Before treatment, each patient was scanned in supine position with an axial slice of thickness of 3 mm, and the patient breathed freely during simulation and treatment. For treatment, the patients were positioned using boards. The three different immobilization devices used were SA lift on breast board, DA lift on breast board and DA lift on WB. Prior to delivery, megavoltage CT (MVCT) images were performed using the imaging device from the HT (Accuray®, USA).

Delineation of target and OARs

All the patients received HT treatments involving the chest wall (CW) and IM, SC, and axillary nodes. Contouring of different nodes was done according to the guidelines for target volume delineation in breast cancer of the Radiation Therapy Oncology Group (RTOG).[12] All the patients received HT treatments involving CW and IM, SC, and axillary nodes. This PTV was created with a margin of 0.3 cm on the breast PTV to assure coverage of the treatment area. CTV was restricted to 5 mm under the skin surface to exclude the build-up region from the CTV for skin sparing.

Design of the treatment plans and delivery

For the purpose of this study, a set of three alternative plans for each patient were generated by using three different immobilization methods. The same physician approved all plans for treatment. The parameters affecting dose conformity and treatment times for tomotherapy are the field width, pitch, and modulation factor.[13] We used a field width of 5.02 cm, a pitch value of 0.287, and a mean modulation factor of 2.5. Directional or partial blocking was applied to the virtual structures, thus closing the beamlets if the blocked structure was proximal to the target to limit the beamlet entrance direction. For treating the PTV, specific objectives were established to treat 100% of the PTV with an ideal of 50 Gy, but at least 47.5 and 45 Gy in the MI node s. After the calculation was completed, the optimization process was started by entering numbers in the parameters "importance, penalty, maximum and minimum dose penalty, and dose–volume histograms (DVH) dose and DVH percentages" to the target volume and critical organs in order to obtain the desired dose–volume curves. Our criterion in this study was that the maximum dose in the target volume or body should not exceed 110% of the prescribed dose, while providing as much protection to critical organs as possible after 1000 optimizations for each planning. All plans were optimized using version 5.1.4 of the Tomotherapy Hi-Art Treatment Planning System (TPS) (Tomotherapy Inc, Madison, WI, USA) and evaluated for optimal target coverage, conformality, homogeneity, and dose limits of OARs.

Plan comparison and statistical analyses

After examining the normal distribution of variables, parametric interval data were analyzed using one-way analysis of variance (ANOVA) test. Levene test was used to assess the homogeneity of the variances. When an overall significance was observed, pairwise post hoc tests were performed using Tukey's test. Conditions below 5% of Type-1 error level are

considered significant. Statistical analyses were performed using Statistical Package for the Social Sciences (SPSS) version 13 software.

Evaluation tools

The evaluation of the plans was based upon a DVH analysis. The following parameters extracted from DVH were reported:

1. V_{55}, D_{min}, D_{max}, and D_{mean} for PTV: V_{55} was defined as the percent volume receiving 55 Gy of PTV; D_{min} was the minimal dose to the PTV, while D_{max} was the maximal dose to the PTV. D_{mean} was the mean dose at the PTV.
2. The ipsilateral lung V_5, V_{20}, and D_{mean}: V_5 and V_{20} were defined as the percent volume receiving 5 and 20 Gy, respectively, at the ipsilateral lung; D_{mean} was the mean dose to ipsilateral lung.
3. The contralateral lung V_5, $V_{20,}$ and D_{mean}: V_5 was defined as the percent volume receiving 5 Gy at the contralateral lung, and D_{mean} was the mean dose delivered to the contralateral lung.
4. The heart V_5, V_{10}, $V_{20,}$ V_{25}, D_{mean}: The heart V_5, V_{10}, V_{20}, and V_{25} were defined as the percent volume receiving 5, 10, 20, and 25 Gy, respectively, at the heart, and D_{mean} was the mean dose to the heart.
5. Whole lung V_5, $V_{20,}$ and D_{mean}: V_5 and V_{20} were defined as the percent volume receiving 5 and 20 Gy, respectively, at the whole lung. D_{mean} was the mean dose to the whole lung.
6. The contralateral breast V_3, V_5, V_{10}, $D_{max,}$ and D_{mean}: V_3, V_5, and V_{10} were defined as the percent volume receiving 3, 5, and 10 Gy, respectively, at the contralateral breast, D_{max} was the maximal dose to and D_{mean} the mean dose delivered to the contralateral lung.
7. The spinal cord D_{max} was determined by the maximal dose in the whole length spinal cord.
8. The esophagus D_{mean} was defined as the mean dose to the esophagus.
9. BODY-PTV V_3, V_5, V_{10} V_{20} $V_{30:}$ V_3, V_5, V_{10} V_{20} V_{30} were defined as the percent volume receiving 3, 5, and 10 Gy at the volume of the body outside the PTV.

RESULTS

Organs at risk

Table 1 shows the dosimetric parameters for OARs obtained from 15 treatment plans for all the patients in the three different immobilization techniques. All HT plans were clinically acceptable respecting the dose–volume of heart, lung, contralateral breast, and spinal cord irradiated. Among the three immobilization methods, there was no significant difference in other OARs' dosimetric d ata. While collecting data on OARs, we observed that the data had very close values in the planning made with SA and DA boards, while WB was associated with considerable low-dose exposure to OARs, although not statistically significant owing to low sample sizes.

Table 1: Comparison of OAR dose-volume metrics as a function of plan modality (χ±SD)

	SA board	DA board	WB	*P*
Ipsilateral Lung				
D_{mean}	14.41±0.51	14.79±1.30	15.00±0.86	0.622
V_5	57.36±3.42	58.31±8.17	60.24±6.24	0.764
V_{10}	43.44±2.81	44.76±5.45	46.29±2.97	0.536
V_{20}	28.19±1.73	29.62±3.17	29.44±2.01	0.597
Contralateral lung				
D_{mean}	5.13±0.96	5.20±0.93	6.38±0.99	0.109
V_5	40.47±5.77	39.50±8.27	48.43±5.67	0.108
V_{10}	16.77±7.99	16.18±6.28	25.20±5.37	0.094
V_{20}	1.31±0.97	1.73±1.55	3.07±3.02	0.388
Total lung				
D_{mean}	9.72±1.04	10.00±1.58	10.54±1.35	0.629
V_5	48.74±4.36	48.92±8.50	54.51±6.13	0.321
V_{10}	30.00±5.48	30.47±6.66	35.51±4.92	0.280
V_{20}	14.62±2.86	15.76±3.91	15.66±3.91	0.859
Heart				
D_{mean}	6.66±2.61	6.30±2.67	8.45±3.00	0.446
V_5	36.59±10.63	34.49±10.86	47.46±8.01	0.127
V_{10}	20.45±12.31	18.40±12.38	28.24±13.75	0.464
V_{20}	6.99±6.69	6.58±6.46	10.72±9.13	0.642
V_{25}	4.53±4.43	4.24±4.32	6.65±6.08	0.715
Contralateral breast				
D_{max}	14.90±1.04	17.38±4.69	17.02±1.39	0.372
D_{mean}	4.23±0.51	4.32±1.11	4.90±1.26	0.538
V_3	72.63±12.31	68.63±22.09	81.98±20.93	0.538
V_5	27.81±8.78	27.23±17.23	36.69±24.31	0.656
V_{10}	1.52±1.03	3.11±4.49	4.48±4.90	0.501
BODY-PTV				
V_3	62.13±4.85	64.78±3.65	70.68±3.43	0.016
V_5	48.61±4.98	53.45±4.41	59.57±3.33	0.006
V_{10}	30.70±2.22	35.95±4.25	39.45±3.07	0.004
V_{20}	18.03±0.92	20.41±1.87	22.18±1.77	0.005
V_{30}	11.16±0.85	12.64±1.30	13.29±1.20	0.032
Esophagus				
D_{mean}	9.55±1.75	11.01±2.67	10.01±2.84	0.643
Spinal cord				
D_{max}	20.44±3.78	23.42±5.23	22.80±4.64	0.572
Treatment time (min)	9.48±1.07	9.40±0.70	8.20±0.77	0.064

DA=double arm, OAR=organ at risk, PTV=planning target volume, SA=single arm, SD=standard deviation, WB=wing board. χ corresponds to the mean dose

Target coverage and doses

The doses of PTV according to five different plans are summarized in Table 2. There was no significant difference among the three techniques in all the dosimetric parameters of PTV. In all cases, 95% of the prescription dose covered at least 100% of each PTV.

No point dose outside PTVs was >105% of the prescribed dose, and no point dose within PTVs was >110% of the prescribed dose. HI is a tool used for dosimetric analysis of treatment plans to describe the uniformity in dose distribution within the target volume. CN is a parameter that quantifies how much the degree of the target volume and the prescription isodose volume coincides exactly.[14] The range of the CN value is between 0 and 1 (ideally 1).

Delivery time and low doses of total body

The dosimetric values in the body were significantly lower in the SA arm compared to the DA and WB arms (all values

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Table 2: Comparison of PTV dose-volume metrics as a function of plan modality (χ±SD)

	SA board	DA board	WB	*P*
PTV				
D_{mean}	50.05±0.07	50.08±0.08	50.14±0.06	0.133
D_{99}	47.60±0.44	47.27±1.18	47.70±0.37	0.648
D_{95}	48.57±0.33	48.78±0.22	48.86±0.06	0.168
D_{5}	51.59±0.29	51.65±0.28	51.90±0.26	0.213
D_{1}	52.48±0.43	52.60±0.41	52.92±0.52	0.330
V_{55}	0.01±0.02	0	0.19±0.35	0.286
CTV				
D_{mean}	50.06±0.09	50.10±0.08	50.17±0.06	0.112
D_{99}	47.65±0.54	47.38±1.31	47.79±0.40	0.747
D_{95}	48.63±0.45	48.78±0.26	48.87±0.07	0.474
D_{5}	51.61±0.29	51.63±0.37	51.94±0.31	0.240
D_{1}	52.56±0.42	52.62±0.41	52.92±0.53	0.445
V_{55}	0.01±0.02	0	0.19±0.35	0.286
SCF				
D_{mean}	50.02±0.25	49.99±0.24	49.91±0.16	0.715
D_{99}	49.16±0.22	49.16±0.21	49.10±0.17	0.841
D_{95}	49.48±0.23	49.28±0.21	49.34±0.20	0.348
D_{5}	50.63±0.34	50.59±0.33	50.49±0.14	0.724
D_{1}	50.96±0.38	50.89±0.34	50.78±0.16	0.647
V_{55}	0	0	0	-
Axilla				
D_{mean}	49.95±0.17	49.99±0.15	49.99±0.06	0.861
D_{99}	49.02±0.14	49.11±0.12	49.07±0.11	0.572
D_{95}	49.25±0.10	49.23±0.22	49.32±0.11	0.626
D_{5}	50.93±0.53	50.73±0.16	50.77±0.07	0.593
D_{1}	51.11±0.18	51.14±0.24	51.16±0.14	0.932
V_{55}	0	0	0	-
MI				
D_{mean}	48.67±0.98	48.78±0.96	48.82±1.07	0.973
D_{99}	46.46±1.20	45.47±1.24	45.38±3.27	0.683
D_{95}	47.11±1.49	46.70±1.15	46.72±1.80	0.889
D_{5}	50.12±0.71	50.37±0.92	50.16±0.52	0.848
D_{1}	50.72±0.97	50.88±0.94	50.63±0.53	0.897
V_{55}	0	0	0	-
CN	0.609±0.06	0.593±0.04	0.617±0.05	0.722
HI-PTV	0.060±0.01	0.057±0.01	0.061±0.01	0.581
HI-CTV	0.060±0.01	0.057±0.01	0.061±0.01	0.597
HI-SCF	0.023±0.01	0.026±0.01	0.023±0.01	0.513
HI-Axilla	0.034±0.01	0.030±0.01	0.029±0.01	0.439
HI-MI	0.062±0.02	0.075±0.01	0.071±0.03	0.637

DA=double arm, PTV=planning target volume, SA=single arm, SD=standard deviation, WB=wing board. χ corresponds to the mean dose

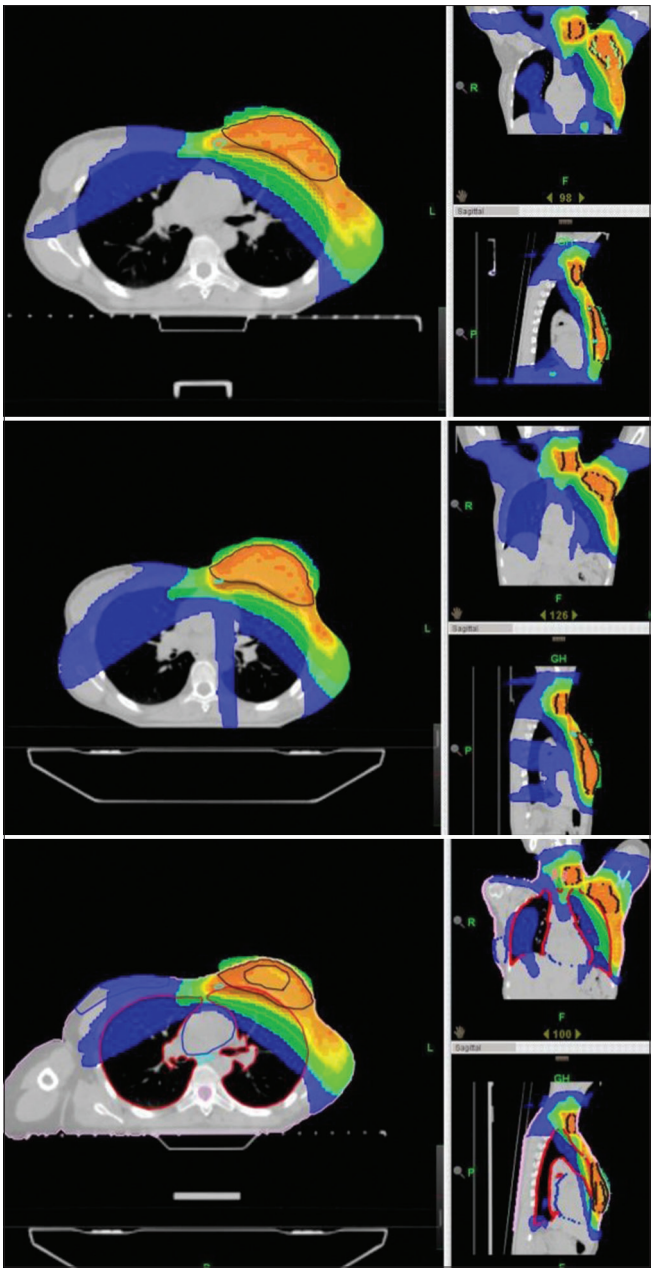


Figure 1: Dose distribution of the same patient in axial, coronal, and sagittal planes. Threshold color was set to at least 5 Gy. (a) WB, (b) DA board, and (c) SA board. DA = double arm, OAR = organ at risk, SA = single arm, WB = wing board

$P < 0.005$) [Table 3]. The dosimetric values in the body were significantly lower in the SA arm [Figure 1]. On the contrary, statistical analysis demonstrated no significant difference in delivery time among the methods.

DISCUSSION

In this prospective study, irradiating CW and lymphatic regions using the SA board resulted in a considerable decrease in the volume of body exposed to low-dose irradiation. This is, to our knowledge, the only dosimetric study comparing different immobilization devices on low-dose exposure. Other studies in the literature reported that raising the two arms is more reliable in terms of treatment accuracy.[15] However, in our daily practice, we predicted that low-dose areas of the patient were better protected by raising one arm on an inclined floor compared to DA raising on a flat surface with WB. We also supposed that the heart and lung volumes extending the treatment area would be larger when lying on a flat surface, and therefore, OAR doses could increase slightly compared to lying on an inclined board.

Nowadays, the importance of immobilization has rapidly increased due to the presence of sharp treatments such as

Table 3: Estimated *P* values for the treatment modalities compared

	BODY-PTV				
	V3	V5	V10	V20	V30
SA board-DA board	0.568	0.217	0.064	0.082	0.142
SA board-WB	0.015	0.004	0.003	0.004	0.029
DA board-WB	0.091	0.103	0.252	0.221	0.640

DA=double arm, PTV=planning target volume, SA=single arm, WB=wing board

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protons as well as IMRT, in which sudden dose drops are seen after reaching the target volume, in order to protect normal tissues.[16] Due to these dose reductions, daily differences in patient position or organ movements during treatment become more important in the IMRT technique than in 3DCRT. If these parameters cannot be controlled, recurrence may be seen at the edges of the field. In addition, too much field entry in IMRT causes the whole body to be exposed to more low-dose radiation. Whether there is a secondary cancer risk associated with this will be clarified at the end of long-term follow-ups. Previous studies have shown that the risk of radiation-induced secondary cancer is higher on using the IMRT technique.[17,18] It has been said that its use causes an increase in the volumes receiving low doses, and that the scattered radiation increases the whole-body dose with the increase in the monitor unit.

Breast cancer patients are routinely irradiated using 3DCRT techniques. According to Ashraf *et al.*,[19] the conformity to the PTV and critical structure sparing was better with 3DCRT than IMRT. Advanced radiation techniques such as IMRT are used owing to better target acquisition, and lower maximum doses are also used in complex cases having complications such as unfavorable anatomy. Haciislamoglu *et al*.[20] evaluated the dose distribution and homogeneity of four different types of IMRT (forward planned IMRT, inverse planned IMRT, HT, and VMAT) in comparison with standard wedged tangential beam 3DCRT of the left breast in patients who had undergone lumpectomy. All evaluated modalities provided adequate coverage of the whole breast. HT resulted in the lowest maximum doses delivered to the ipsilateral organs. Thus, if available, HT seems to be a good alternative. In all of our HT plans, adequate coverage of PTVs and desired limitations of OARs were achieved. To be safe and efficient, the IMRT and HT techniques must be performed with high attention due to rapid dose gradients.[21] Probst *et al*. reported that using both arms up technique decreased the lung and heart volume in the treatment volume an d increased patient's stability during irradiation were provided in HT treatment. Furthermore, the best immobilization method should be provided in order to avoid exposure to higher doses at OARs during longer treatment periods.[22] One recent publication assessed the SA and DA techniques with dosimetric parameters and comfort levels, and the SA position seems to be more comfortable and can reduce dose coverage to the heart.[23] In our study, patients' comfort was not evaluated and the only asserted difference among the immobilization techniques involved BODY-PTV doses.

Although limited clinical data exist utilizing cardiac-sparing techniques, IMRT is one of the techniques for cardiac protection/avoidance, which can decrease the mean dose, maximum dose, V5, V20, and V30 of heart.[24] Schubert *et al*.[25] compared all breast irradiations performed with four different planning techniques including 3BCRT and advanced planning IMRT techniques in 10 patients with left breast cancer. According to their results, advanced planning IMRT technique was found to be superior to 3BCRT technique in terms of heart doses. In the literature reviews of Gagliardi *et al.*,[26] it has been shown that the increase in volume receiving 30 and 25 Gy for the whole heart is the most important factor causing an increase in cardiac mortality. In the present study, the mean heart doses were 6.66, 6.30, and 8.45Gy for SA, DA board, and WB, respectively, with WB providing the poorest outcome. At the same time, the V5, V10, V20, and V25 doses were higher than the SA and DA boards. Increased doses to which the heart is exposed lead to the conclusion that the risk of heart disease also increases. Investigators reported that the mean heart dose correlates with the extent of the heart reposing the CW.[27] In fact, anatomical differences occurring in the positioning of organs with different immobilization methods contribute to the increased heart and lung exposure. Our data demonstrate correlation between the presence of closer heart and lungs in contact with CW wit h WB greatly impacted cardiac and lung doses.

However, there are several limitations in this study. First of all, if these immobilization methods were compared in terms of registration time with MVCT and the day-to-day adjustment parameters during treatment, it would be much more comprehensive if they were added to dosimetric evaluation. Second, the sample size is small and large clinical trials are needed to verify our findings. Third, we did not compare volumes of OARs in the treatment field and patient comfort levels, which is one of the most important factors in keeping the patient stable during treatment with different positions. Strengths are also worth mentioning. This study contributes to the literature because there are not enough studies evaluating the best immobilization methods for breast radiation. Exposure to low-dose bath should be avoided as much as possible, and to solve this clinical problem with maximal benefit, reproducible and consistent immobilization is critical. Moreover, planning by a single physicist, contouring by a single doctor, and homogeneity of the patient population are other advantageous aspects of the study.

As it is known in many HT centers in our country, WB is preferred before breast cancer RT immobilization because of the possibility that patients can be more stable and comfortable. However, we planned this study with the idea that positional change of the patient in our daily practice will cause dose differences in the surrounding target tissues and OARs.

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CONCLUSION

By taking into account all dosimetric parameters, we demonstrated in this study that treatment plans with SA board have more favorable dosimetric advantages than others in left CW and axillary region radiation during HT treatments. The results revealed that SA board is the best device in terms of low radiation dose exposure. Considering the risk of developing secondary cancer, it is recommended to be considered, especially in young breast cancer patients. It is believed that more comprehensive studies may provide statistically significant results of analyses by increasing the number of patients, adding parameters used for setting up controls, and patient comfort during treatment.

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Nil.

Conflicts of interest
There are no conflicts of interest.

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