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Research article

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The effect of a breath-hold technique on conformal and intensity-modulated radiotherapy techniques at right-sided breast cancer radiotherapy including internal mammarian fields

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The study does not require any ethical permissions since it is a dosimetric study.

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Abstract

Background/Aim: Significantly lower heart doses can be achieved by breath-hold technique at left-sided breast cancer radiotherapy (RT). We see high doses at organs at risk such as lung, heart, and contralateral breast during right-sided breast cancer RT planning especially in the presence of RT indication for mammaria interna (MI) lymph nodes. This study compared RT-planning methods that are conformal with intensity-modulated RT (IMRT) with breath holding and free breathing for right-sided breast cancer RT including full axillary and MI lymph node fields.
Methods: Computed tomography (CT) simulations were performed using free-breath (FB) and breath-hold (BH) methods in 10 patients with right-sided breast cancer. A total of 40 RT treatment plans were calculated. Right-sided breast, level 1-2-3 axillary regions, and MI regions served for the target-planning volume. Left-sided breast, heart, as well as right-sided and left lungs were contoured as critical organs according to the atlas of the "Radiation Therapy Oncology Group." We used a Varian Eclipse v.13 for treatment planning. Conformal “FieldinField” RT (FinFRT) and dynamic IMRT (dIMRT) planning were performed separately for each patient over breath-hold and free-breath images. For PTV, 50 Gy was prescribed in 25 fractions and optimized such that the planned target volume (PTV) remained between 95% and 110% of the dose. The mean and maximum doses of the heart, V5 and V20 of the lungs, as well as V95 doses for MI were recorded. Statistical analyses were performed with SPSS version 22, and a paired t-test was used for comparison.
Results: Four treatment plans (FB FinFRT, BH FinFRT, FB dIMRT, BH dIMRT) were made separately for 10 patients. For comparison, common FB FinFRT plans were accepted as the baseline plan. As expected, there were no significant differences in PTV coverage. The mean dose received by 95% of the MI volume was between 42.27 Gy and 42.4 Gy. For the maximum heart dose, the breath hold technique had no significant effect on plans. The lowest average maximum heart dose was seen in the BH FinFRT group. Mean heart doses are between 1.28 Gy – 4.85 Gy. There was no significance between BH FinFRT and FB FinFRT plan (P=0.504), and there was a significant difference for heart mean dose versus dIMRT plans (P=0.001). The mean V20 of the lungs ranged from 11.9 to 17.8. There was a significant decrease in V20 with BH or FB dIMRT plans (P=0.001). There was no difference between BH FinFRT (P=0.138). On the contrary, lung V5 values were significantly higher in dIMRT plans, and the lowest mean V5 value was seen in BH FinFRT plan.
Conclusion: With the BH method, lower doses (but not significantly lower doses) were obtained in critical organ doses. There was a significant decrease with FinFRT plans in terms of heart mean and maximum dose and lung V5 percentages. The dIMRT plans were significant only in lung V20 percentages. When planning RT, we recommend evaluating all treatment techniques individually for right-sided breast cancer patients to obtain lower doses in critical organs.

Keywords: breath-hold, radiotherapy, internal mammarian field, breast cancer

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Introduction

Adjuvant radiotherapy (RT) efficacy has been evaluated in studies with high patient numbers and meta-analyses. There is strong evidence for RT indications. The Breast Cancer Trials Collaborative Group (EBCTCG) published reports of 10- and 20-year locoregional recurrence and breast cancer-related mortality rates. These showed a significant decrease in the recurrence and breast cancer-related mortality rates in patients who received breast-conserving treatment with RT [1]. RT is currently applied after surgery as a standard in breast-conserving treatments. Likewise, significant advantages were also observed with RT in patients with mastectomy and pathological node-positive patients. Nodal RT was mostly applied to the patients that had mastectomy and were node-positive. Recurrence and breast-related death rates were significantly lower with RT regardless of the number of lymph nodes involved or whether they received systemic treatment [2].

There have been many improvements in RT over time due to technological developments. Conventional RT can be used to understand classical conformal RT techniques. However, conformal planning is increasingly common due to rapid progress in planning systems that allow the use of virtual wedges and field-in field (FinF) calculations. Modern RT techniques can produce more homogeneous and conformal dose distributions in PTV using both dIMRT and breath-hold (BH) techniques. Better protection of critical organs can be achieved [3, 4]. However, modern RT techniques is thought to be associated with the risk of second cancer due to the low dose distribution at body and an increase in monitor unit (MU) values. Modern RT techniques are often preferred for patients who have significant benefit in dose distribution rather than being used for each patient [5].

Here, the impact of the BH technique on conformal RT and dIMRT techniques was examined in large-area breast cancer planning. The treatment planning of the patients was studied, and PTV coverage and critical organ doses were recorded.

Materials and methods

Ten patients were randomly selected among the patients who would receive radiotherapy treatment with the diagnosis of right-sided breast cancer. The exclusion criteria were having funnel chests, pathologically enlarged hearts, and any other anatomical variation. Computed tomography (CT) simulation images (SOMATOM Force, Siemens Healthineers) were obtained using free-breath (FB) and BH methods. A special breast board (Civco Medical Instruments Co. Inc. Coralville, Iowa, USA) on which patients placed their right arm overhead was used for immobilization.

A Varian real-time position management (RPM) system was used for the BH method. An RPM localizer box was placed on the skin between the chest and abdomen of the patients. Thus, we could follow the respiratory cycle of the patient on the monitor of the treatment device by following the box with cameras during treatment. During the BH treatments, the technicians directed the patient to take a deep breath for about 10-20 seconds and observe the respiratory movement of the patient from the monitor.

The atlas of the "Radiation Therapy Oncology Group" was used as a guide the contour of the patients. The PTV was determined to include the right-sided breast as well as level 1-2-3 axillary areas. The MI area was created as a separate contour in the PTV and defined as PTVmi. All PTV contours were cut 5 mm from the skin surface. The left breast, heart, as well as right and left lungs were contoured separately within the organ volumes at risk (OAR).

The eclipse planning program (version 13.6, Varian Medical Systems, Palo Alto, CA, USA) was used for treatment planning. Treatment plans were created for the Varian TrueBeam linear accelerator device. Conformal FieldinField RT (FinF RT) and dIMRT were planned separately for FB and BH contours for each patient. There were 40 plans (FB FinFRT, BH FinFRT, FB dIMRT, BH dIMRT) for 10 patients in total. Of these plans, those with a FB FinF RT technique (used broadly at clinics) was accepted as the basal plan. For PTV, 50 Gy was prescribed in 25 fractions and optimized such that the PTV remained between 95% and 110% of the dose.

Statistical analysis

Descriptive statistics used the mean (SD) and maximum doses of the heart. These were defined as OAR, V5, and V20 of the lungs; V95 doses for MI were used to present continuous data with normal distribution. Median values with minimum-maximum values were applied for continuous variables without a normal distribution. Numbers and percentages were used for categorical variables. Data analysis used Chi-Square, Kruskal-Wallis, and Mann-Whitney U tests with SPSS program version 16.0 (SPSS Inc.). A paired-t test was used for comparisons.

Results

No significant differences were seen in PTV dose coverage when all treatment plans were compared with the baseline plan (P=0.442). The average dose received by 95% of the MI volume was 42.27 Gy. It was 42.15 Gy in FinFRT plans and 42.4 Gy in dIMRT plans.

Analyses for OAR are detailed in Tables 1 and 2. Versus the maximum dose of the heart, there was no significant difference in the maximum dose of the heart in BH plans. The lowest mean dose was seen in the BH-FinFRT group. The mean heart dose averages were recorded between 1.28 Gy and 4.85 Gy across all plans. There was no significant difference between BH FinFRT and FB FinFRT plan (P=0.504). Significantly higher doses were observed for a heart mean dose versus dIMRT plans (P=0.001).

The mean V20 of the lungs ranged from 11.9 to 17.8. There was a significant decrease in V20 with BH or FB dIMRT plans (P=0.001). There was no difference between BH FinFRT (P=0.138). On the contrary, V5 of the lungs were observed significantly higher in dIMRT plans. The lowest mean V5 value was seen in the BH FinFRT plan (Table 3).

Table 1: Results of statistical analyses of OAR with RT techniques

	Free-Breath FinF RT	Breath-hold FinF RT		Free-Breath IMRT		Breath-hold IMRT	
	Mean	**Mean**	***P*-value**	**Mean**	***P*-value**	**Mean**	***P*-value**
Mean heart dose (Gy)	1.37	1.28	0.504	4.85	0.001	4.17	0.001
Max heart dose (Gy)	19.42	14.67	0.287	21.25	0.716	24.40	0.320
Lungs V20 (%)	17.88	15.74	0.138	14.29	0.04	11.9	0.001
Lungs V5 (%)	29.66	27.45	0.06	43.67	0.001	42.43	0.001

Table 2: Values of OAR with RT techniques

Plans	FB FinF TFRT			BH FinF TFRT			FB dIMRT			BH dIMRT		
	Mean	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**
Heart Mean (Gy)	1.37	0.78	2.68	1.28	0.94	1.68	4.85	2.43	8.56	4.17	3.15	5.18
Heart Maks (Gy)	19.4	4.7	46.7	14.6	7	31.7	21.2	15.7	40.1	24.4	8.35	28.75
Lung V20 (%)	17.8	11.38	27	15.7	8.8	31	14.29	12.3	18	11.9	9,7	15.5
Lung V5 (%)	29.6	21.3	37	27.45	18.8	41	43.67	34.6	53	42.43	37	46.8

Table 3: The significance between RT techniques

	Treatment Plans											
Organs	**SN FinF TFRT**			**NT FinF TFRT**			**SN dIMRT**			**NT dIMRT**		
	***P*-value**			***P*-value**			***P*-value**			***P*-value**		
	BH FinF RT	**FB dIMRT**	**BH dIMRT**	**FB FinF RT**	**FB dIMRT**	**BH dIMRT**	**FB FinF RT**	**BH FinF RT**	**BH dIMRT**	**FB FinF RT**	**BH FinF RT**	**FB dIMRT**
Heart Mean	0.504	0.001	0.001	0.504	0.001	0.001	0.001	0.001	0.229	0.001	0.001	0.229
Heart Max	0.287	0.716	0.320	0.287	0.026	0.05	0.716	0.26	0.267	0.320	0.05	0.267
Lung V20	0.138	0.04	0.001	0.138	0.512	0.032	0.04	0.512	0.032	0.001	0.032	0.032
Lung V5	0.68	0.001	0.001	0.068	0.001	0.001	0.001	0.001	0.560	0.001	0.001	0.560

Discussion

Late adverse effects have a significant impact quality of life and survival among breast cancer patients due to prolonged survival. Reports have demonstrated cardiac anomalies from myocardial perfusion data years after RT in left-sided breast cancer patients [6]. Nevertheless, early cardiac imaging of patients who received RT with BH technique showed no anomaly regarding perfusion or wall motion [7]. Another study showed a decrease of 3.6% in heart volume receiving 30 Gy in patients whose RT plan were executed with BH technique instead of FB for left-sided breast cancer [8]. A retrospective study reported that RT planning with BH technique for left-sided breast cancer resulted in a mean heart dose of 2.7 Gy instead of 5.2 Gy with the FB technique [9]. Here, RT planning of left-sided breast cancer patients use the BH technique as long as the RT devices are eligible to do so. On the other hand, the BH technique is not an essential requirement in right-sided breast cancer patients given that heart doses are expected to be significantly lower. Here, we analyzed the effect of the BH technique on heart dose in right-sided breast cancer patients who had a high-volume PTV and whose MI fields were irradiated with a dIMRT technique.

OAR doses were not significantly lower with the BH technique, but we found that the planning technique was equally important. The dIMRT technique is associated with a higher mean heart dose as well as increased volume of lung receiving a low dose. The FinFRT technique resulted in a higher mean heart dose than in patients whose irradiation volume comprised only right breast, but this technique for PTVs with all the fields included was significantly lower than in dIMRT techniques.

Current analyses show no significant difference between heart doses between the BH and FB techniques. The evidence that contradicts left-breast planning might result from inadequate exclusion of the heart from the target volume due to high PTV volumes despite using the BH technique. The mean and maximum heart dose as well as lung V5 were significantly lower in the FinFRT technique; only lung V20 was significantly lower with the dIMRT technique.

Several results have been reported in the literature regarding lung doses. Some studies show a significant decrease in lung doses with the BH technique, but there are also studies finding no significant difference [10-12]. dIMRT planning is more convenient in terms of dose homogeneity. These increase low-dose areas in lung and heart with a decrease in high-dose regions [13-16].

Limitations

The retrospective design and small sample size limit this study. The low number of subjects in the treatment plan might impact the significance of some results.

Conclusion

In conclusion, we report a dosimetric study that compares non-standard treatment methods in right-sided breast cancer. Our results might be improved by higher patient numbers in future work. The choice of RT techniques must be tailored with respect to patient-specific dose preferences regarding critical organ doses.

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