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Factors Involved in the Choice Between Thoracic and Abdominal Deep Inspiration Breath Holds During Left Breast Cancer Radiotherapy

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Purpose: Deep inspiration breath hold (DIBH) is used with adjuvant radiation therapy after left breast cancer surgery to reduce radiation dose to the heart. In this study we determined whether thoracic DIBH (T-DIBH) or abdominal DIBH (A-DIBH) should be selected based on patient background.
Methods: Three-dimensional conformal radiation therapy plans were created under the same conditions using free breathing (FB), T-DIBH, and A-DIBH CT scans of patients who had previously undergone treatment at our hospital.
Results: A-DIBH decreased the left lung dose compared to FB. In comparing T-DIBH and A-DIBH, the heart maximum and left lung doses were significantly lower in A-DIBH. The differences in the heart mean dose (Dmean) between FB, and T-DIBH and A-DIBH were correlated with the cardiothoracic ratio, heart volume, and left lung volume. The difference in the heart Dmean and the left lung dose of T-DIBH and A-DIBH correlated with the forced vital capacity (FVC).
Conclusions: A-DIBH is preferable over T-DIBH with respect to the heart and left lung doses; however, with respect to the heart Dmean, T-DIBH was more effective in reducing the dose in some cases, and the FVC was a relevant factor in this study.

Key words: breast cancer, deep inspiration breath hold, three-dimensional conformal radiation therapy, thoracic deep inspiration breath hold, abdominal deep inspiration breath hold

INTRODUCTION

Radiation therapy has been established in several randomized controlled trials as a means of reducing local recurrence rates and long-term mortality among patients with early-stage breast cancer [1, 2]. Three-dimensional conformal radiation therapy (3D-CRT) is generally performed in the supine position from two opposing directions tangential to the chest wall; however, in patients with left-sided breast cancer the heart and ipsilateral lungs are included in the irradiation field. It has been reported that the mean dose to the heart is proportional to the risk of ischemic heart disease, and that the coronary event rate increases linearly at a rate of 7.4% per 1 Gy with no minimum dose threshold [3]. There have been several attempts to reduce the dose to the heart, including prone irradiation [4], proton therapy [5], and intensity-modulated radiation therapy [IMRT] [6, 7], but a deep inspiration breath-hold (DIBH) is the most commonly used method.

The DIBH method is a technique to lower the heart dose by keeping the heart anatomically separated from the irradiation field by maintaining the heart in an aspirated state during planning computed tomography (CT) and irradiation. In 2001 Sixel first reported that DIBH is beneficial in reducing the radiation dose to the heart [8]. Since then, many reports have recognized DIBH as an effective method to reduce the heart radiation dose [9, 10]. Although numerous reports have since been published, few have separately examined thoracic DIBH (T-DIBH) and abdominal DIBH (A-DIBH). T-DIBH is a breathing technique that focuses on rib movement. During inspiration, the external intercostal muscles and multiple inspiratory support muscles are contracted to move the ribs ventrally and expand the rib cage in a horizontal direction. In contrast, A-DIBH is a breathing technique that contracts the diaphragm and expands the rib cage in a cephalocaudal direction [11, 12].

Furthermore, the heart is located on the diaphragm during A-DIBH, which results in a large caudal shift of the heart. These differences in thoracic and cardiac motion suggest that each breathing technique produces different heart doses. Fig. 1 shows an example of a CT image. Compared to free breathing (FB), the rib cage widens outward and the distance between the heart and chest wall opens during T-DIBH. In contrast, the outward movement of the thorax is smaller during A-DIBH than T-DIBH, but the distance between the heart and chest wall is wider because the diaphragm moves more caudally and the heart moves caudally with the diaphragm. Thus, the planning target volume (PTV) and organs at risk (OAR) differ during T-DIBH

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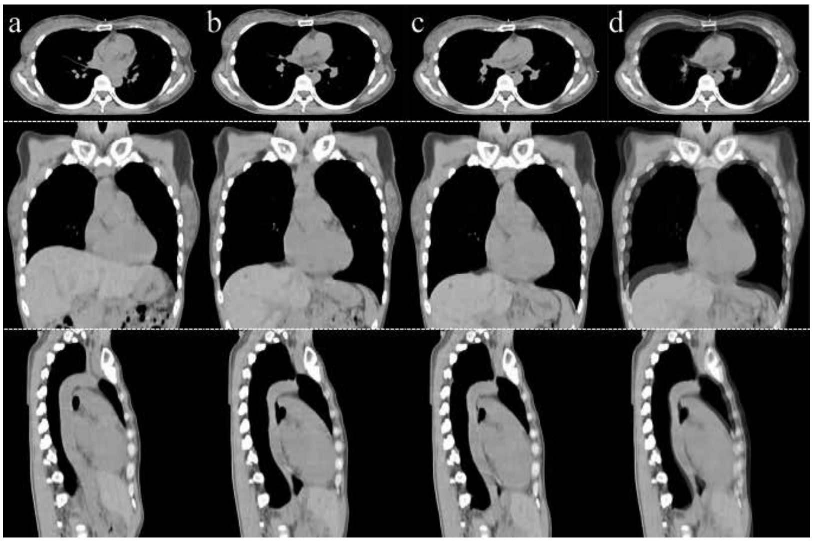

Fig. 1 Comparison of computed tomography images for each breathing method. Top row: body axis cross-section, middle row: coronal cross-section, bottom row: sagittal cross-section. Free breathing (a), thoracic deep inspiration breath hold (T-DIBH) (b), abdominal deep inspiration breath hold (A-DIBH) (c), and composite image of T-DIBH and A-DIBH (d).

and A-DIBH.

Zaho *et al.* [13] compared T-DIBH and A-DIBH, and showed that the use of A-DIBH in treatment planning significantly reduced heart dose and dose to the left lung compared to T-DIBH. Hirata [14] reported no difference in heart dose, suggesting the possibility that selecting a breathing technique with high left lung activity may reduce the heart dose; however, there is no definitive report and CT imaging at each DIBH is needed for comparison to determine the more useful breathing technique for irradiation. Therefore, we evaluated each of the DIBH techniques to determine whether T-DIBH or A-DIBH would contribute to a reduction in heart dose. However, the increase in the number of CT scans leads to an increase in medical radiation exposure and requires the cooperation of the patient at each DIBH, which leads to an increase in patient burden. To prevent the above, it is necessary to be able to select T-DIBH or A-DIBH before simulation CT. We investigated which factors were associated with the selection.

Materials and methods

At our institution, simulation CT scans of FB, A-DIBH, and T-DIBH have been obtained since 2017 in patients irradiated after left breast-conserving surgery. The plan with the lowest heart dose among the three techniques has been used for irradiation. We replanned and examined patients with left breast cancer who underwent a simulation CT scan from January-December 2020. The study was approved by our institution Clinical Research Review Committee.

CT simulation

The patient was imaged with CT (Somatom Definition AS; Siemens Healthcare, Forchheim, Germany) in the supine position with the arms raised and a support device in place.

Prior to imaging, the radiological technologist trained the patient in the A-DIBH and T-DIBH techniques on the day of imaging. This training was done only on the day of imaging and no prior breathing practice was performed. Then, 3-mm slices were imaged for each breathing technique, first for FB, and then for each DIBH.

Contouring & Planning

All cases were prepared by one physician from contouring to planning. Contouring was based on the Radiation Therapy Oncology Group (RTOG) guidelines. The heart and left lung were visualized as OAR. In this study, the clinical target volume (CTV) contours were manually created on FB CT images. In addition, the CTV was cut 5 mm to the skin contour. The CTV was transformed into A-DIBH and T-DIBH CT images using MIM Maestro software (MIM Software, Cleveland, OH, USA), and manual corrections were made to minimize variability in delineation. A PTV was then created by enlarging the CTV by 5 mm from each of the 4 sides. Treatment plans for A-DIBH and T-DIBH were created using two tangential beams with a radiation treatment planning system ([RTPS] Eclipse version 13.7; Varian Medical Systems, Palo Alto, CA, USA).

Six MV X-rays were used. The gantry angle was set so that the midline of the chest was not crossed, but for patients with a PTV to the midline, priority was given to the PTV. The cephalic edge of the irradiation field was set to be the same as the upper edge of the PTV, and in cases in which the humeral head was included in the irradiation field, the beam on one side was set to be the lower edge of the humeral head. The caudal end of the irradiation field was defined as the caudal end of the marker attached to the underside of the breast. The outer side of the irradiation field was opened 1-2 cm from the body surface. Inside the irradiation field, the collimator was angled to coincide with the midline of the breast. An anisotropic analytic algorithm was used for dose calculation. The prescribed dose for PTV was calculated using a total dose

Table 1 Background factors of subject patients

	median	minimum	maximum	n
BMI(kg/m2)	22.0	16.7	35.4	30
stature(cm)	157.4	145.0	167.2	30
weight(kg)	53.9	41.6	86.6	30
age	53.5	41	74	30
FVC(L)	2.92	1.54	4.18	25
FEV1(L)	2.32	1.30	3.08	25
FEV1/FVC, %.	78.3	67.6	96.6	25
CRT(%)	45.8	38.6	57.8	30

Abbreviations: BMI, body mass index; FVC, forced vital capacity; FEV1, forced expiratory volume in one second; FEV1/FVC, %, forced expiratory volume in 1 second as a percentage; CRT, cardiothoracic ratio

of 40.05 Gy and 2.67 Gy per fraction for a total of 15 fractions, as adopted at our institution [15]. The CTV was set to a dose to 98% volume (D98%) of the CTV with 93% of the prescribed dose. To prevent high-dose administration, a subfield was created so that the maximum PTV dose was 105% of the prescribed dose.

Evaluation factor

The hearts and the left lung for OAR dosimetry was evaluated for maximum dose (Dmax), mean dose (Dmean), 20 Gy irradiation volume (V20), 10 Gy irradiation volume (V10), and 5 Gy irradiation volume (V5).

Body mass index (BMI), stature, weight, age, forced vital capacity (FVC), forced expiratory volume in one second (FEV1), forced expiratory volume in 1 second as a percentage (FEV1/FVC, %), cardiothoracic ratio (CTR), heart volume, and left lung volume were used as assessment factors for OAR dose comparison.

Respiratory function tests and thoracic radiography were from routine examinations performed before partial mastectomy. In the respiratory function test, vital capacity (VC) was omitted in our hospital to simplify the routine examination, so FVC was used as a substitute.

Statistics

Statistical evaluation was performed using EZR® (Saitama Medical Center, Jichi Medical University, Saitama, Japan), which is a graphical user interface for R® (The R foundation for Statistical Computing, Vienna, Austria). More precisely, EZR® is a modified version of R® commander designed to add statistical functions frequently used in biostatistics [16].

The Wilcoxon rank-sum test was used for OAR dose comparisons for FB, A-DIBH, and T-DIBH. Correlations with each factor were calculated using the Spearman correlation coefficient. The correlations were divided into A-DIBH- and T-DIBH-lower groups, and after applying the Mann-Whitney U test, a receiver operating characteristic (ROC) curve was generated and the optimal cut-off values were calculated.

RESULTS

Patient background

Thirty patients who underwent planned CT between January and December 2020 served as the study subjects. Table 1 shows the patient details. The patients ranged in age from 41–74 years, with a mean age of 55.5 years and a median of 53.5 years. Some patients referred from other hospitals did not have respiratory function tests performed, thus the FVC, FEV1, and FEV1/FVC % were evaluated in 25 patients.

Volume comparison of PTV and OAR

Table 2 shows the PTV and volumes of the heart and left lung. The heart volume was significantly lower in A-DIBH than FB and T-DIBH. Left lung volume was significantly increased in T-DIBH and A-DIBH over FB, with no significant difference between T-DIBH and A-DIBH.

Dose comparison of PTV and OAR

Table 3 shows the dose comparisons for the PTV, heart, and left lung. The Dmean and dose to 95% volume (D95%) of the PTV was slightly higher for T-DIBH and A-DIBH than FB, and the difference was statistically significant. In contrast, the dose to 2% volume (D2%) was not significant.

Heart doses were significantly lower for T-DIBH and A-DIBH than FB at the Dmean, Dmax, V20, V10, and V5. Dmax was significantly lower during A-DIBH than T-DIBH.

The left lung dose was not significantly different between FB and T-DIBH. In contrast, the Dmean, V20, and V10 were significantly lower for A-DIBH than FB. The Dmean, V20, V10, and V5 were significantly lower for A-DIBH than T-DIBH.

Correlation between OAR dose and evaluation factor

Spearman's correlations of OAR dose differences between FB and T-DIBH, between FB and A-DIBH, and between T-DIBH and A-DIBH with the evaluation factors as variables are shown in Table 4. The correlations in Table 4 are shown in Fig. 2. Differences in heart Dmean between FB and T-DIBH and between FB and A-DIBH were positively correlated with CTR and heart volume, while left lung volume was negatively correlated. The larger CTR and heart volume, and the smaller left lung volume indicated a greater effect of DIBH. The difference in heart Dmean between T-DIBH and A-DIBH was positively correlated with FVC and FEV1. In addition, FVC was positively correlated with the difference in left lung V20 and V10. These results indicated that the greater the FVC, the more A-DIBH reduced the heart Dmean and left lung V20 and V10 compared to T-DIBH.

Two-group comparison of heart Dmean

The heart Dmean was divided into two groups (T-DIBH low-dose and A-DIBH low-dose groups). The

Table 2 Comparison of PTV and organ at risk volumes in FB, T-DIBH, and A-DIBH

	FB			T-DIBH			A-DIBH			p value		
	median	minimum	maximum	median	minimum	maximum	median	minimum	maximum	FB vs T	FB vs A	T vs A
PTV volume(ml)	537.1	259.2	895.0	539.4	258.6	905.1	536.2	260.9	898.9	0.262	0.349	1
Hearts volume(ml)	501.7	260.1	655.9	509.7	361.5	674.0	482.0	315.3	612.9	0.119	< 0.05	< 0.001
L-Lung volume(ml)	1144.0	864.5	1510.0	1793.3	1210.6	2470.4	1802.1	1358.7	2279.4	< 0.001	< 0.001	0.371

Abbreviations: FB, free breathing; T-DIBH and T, thoracic deep inspiration breath-hold; A-DIBH and A, abdominal deep inspiration breath-hold; PTV, planning target volume; L-Lung, left lung; OAR, organ at risk

Table 3 Dose comparison in FB, T-DIBH, and A-DIBH

		FB			T-DIBH			A-DIBH			p value		
		median	minimum	maximum	median	minimum	maximum	median	minimum	maximum	FB vs T	FB vs A	T vs A
PTV	Dmean(Gy)	37.89	36.72	38.74	38.19	37.27	39.02	38.12	36.89	39.13	< 0.001	< 0.001	0.824
	D95%(Gy)	26.88	23.32	31.13	29.98	23.48	34.04	30.29	23.50	34.60	< 0.001	< 0.001	0.114
	D2%(Gy)	41.62	41.16	41.80	41.60	41.30	41.71	41.60	41.34	41.72	0.727	0.276	0.156
Hearts	Dmax(Gy)	36.86	5.18	40.26	33.35	2.93	40.23	20.59	3.54	39.73	< 0.001	< 0.001	< 0.05
	Dmeam(Gy)	1.28	0.44	4.74	0.76	0.29	2.40	0.74	0.27	3.56	< 0.001	< 0.001	0.808
	V20(%)	0.61	< 0.01	9.39	0.04	< 0.01	3.38	< 0.01	< 0.01	6.57	< 0.001	< 0.001	0.164
	V10(%)	1.10	< 0.01	11.12	0.14	< 0.01	4.45	0.03	< 0.01	7.91	< 0.001	< 0.001	0.171
	V5(%)	2.22	< 0.01	14.19	0.51	< 0.01	6.42	0.24	< 0.01	10.17	< 0.001	< 0.001	0.237
L-Lung	Dmeam(Gy)	4.57	2.28	6.81	4.65	2.34	7.37	4.21	2.30	6.73	0.685	< 0.05	< 0.01
	V20(%)	8.71	2.55	15.42	8.77	2.99	16.34	7.70	2.68	14.18	0.792	< 0.01	< 0.001
	V10(%)	11.57	4.32	18.03	11.22	4.76	19.68	10.06	4.42	17.33	0.903	< 0.01	< 0.01
	V5(%)	17.98	8.69	25.11	18.92	9.63	26.76	16.63	9.75	24.48	0.213	0.465	< 0.01

Abbreviations: FB, free breathing; T-DIBH and T, thoracic deep inspiration breath-hold; A-DIBH and A, abdominal deep inspiration breath-hold; Dmean, mean dose; D95%, dose to 95% volume; D2%, dose to 2% volume; Dmax, maximum dose; V20, 20 Gy irradiation volume; V10, 10 Gy irradiation volume; V5, 5 Gy irradiation volume

Table 4 Correlation between organ at risk dose differences and background factors among FB, T-DIBH, and A-DIBH

	FB − T		FB − A		T − A	
Heart Dmean	**p value**	**R**	**p value**	**R**	**p value**	**R**
BMI	0.0786	0.326	0.0631	0.344	0.963	0.0089
stature	0.165	-0.26	0.245	-0.219	0.108	0.299
weight	0.417	0.154	0.385	0.164	0.747	0.0615
age	0.625	0.0929	0.808	0.0463	0.241	-0.221
FVC	0.226	-0.251	0.52	-0.135	< 0.05	0.507
FEV1	0.095	-0.341	0.253	-0.237	< 0.05	0.414
FEV1/FVC, %.	0.169	-0.278	0.139	-0.298	0.334	-0.197
CTR	< 0.001	0.655	< 0.01	0.525	0.101	-0.306
Hearts volume	< 0.05	0.39	< 0.05	0.42	0.167	0.259
L-Lung volume	< 0.001	-0.581	< 0.001	-0.604	0.63	-0.0914
Heart Dmax	**p value**	**R**	**p value**	**R**	**p value**	**R**
BMI	0.52	0.122	0.594	0.101	0.444	-0.145
stature	0.22	-0.231	0.648	-0.0868	0.371	0.169
weight	0.97	0.00713	0.926	-0.0178	0.301	-0.195
age	0.504	0.127	0.869	-0.0314	0.944	-0.0134
FVC	0.556	-0.123	0.916	0.0223	0.571	0.118
FEV1	0.376	-0.185	0.921	0.0208	0.566	0.12
FEV1/FVC, %.	0.979	-0.00581	0.538	0.126	0.928	0.0188
CTR	0.308	-0.193	0.29	-0.2	0.449	-0.144
Hearts volume	0.0621	-0.345	0.0763	-0.329	0.907	-0.0225
L-Lung volume	0.652	0.0857	0.866	0.0323	0.698	0.0736
L-Lung V20	**p value**	**R**	**p value**	**R**	**p value**	**R**
BMI	0.745	-0.0619	0.927	-0.0174	0.712	0.0703
stature	0.471	-0.137	0.934	-0.0158	0.141	0.275
weight	0.539	-0.117	0.503	-0.127	0.581	0.105
age	0.508	0.126	0.358	0.174	0.988	-0.0029
FVC	0.0906	-0.346	0.527	-0.132	< 0.05	0.403
FEV1	0.143	-0.301	0.458	-0.155	0.155	0.293
FEV1/FVC, %.	0.531	0.128	0.63	0.0988	0.597	-0.108
CTR	0.87	0.0312	0.793	-0.0501	0.302	-0.195
Hearts volume	0.408	-0.156	0.912	-0.0211	0.231	0.225
L-Lung volume	0.985	0.00378	0.698	-0.0736	0.907	-0.0225
L-Lung V10	**p value**	**R**	**p value**	**R**	**p value**	**R**
BMI	0.526	-0.121	0.545	-0.115	0.747	0.0614
stature	0.69	-0.0759	0.794	0.0499	0.128	0.284
weight	0.473	-0.136	0.32	-0.188	0.599	0.1
age	0.602	0.0993	0.351	0.176	0.932	0.0163
FVC	0.168	-0.285	0.644	-0.0969	< 0.05	0.418
FEV1	0.206	-0.262	0.57	-0.119	0.119	0.32
FEV1/FVC, %.	0.609	0.105	0.649	0.0933	0.635	-0.0974
CTR	0.89	-0.0265	0.512	-0.124	0.247	-0.218
Hearts volume	0.336	-0.181	0.751	-0.0603	0.224	0.228
L-Lung volume	0.764	0.0572	0.942	0.014	0.944	-0.0136
L-Lung V5	**p value**	**R**	**p value**	**R**	**p value**	**R**
BMI	0.167	-0.259	0.107	-0.301	0.979	-0.00512
stature	0.922	0.0187	0.491	0.131	0.15	0.269
weight	0.349	-0.177	0.125	-0.286	0.871	0.031
age	0.932	0.0163	0.287	0.201	0.631	0.0915
FVC	0.312	-0.21	0.649	-0.0954	0.084	0.353
FEV1	0.515	-0.137	0.724	-0.0743	0.161	0.289
FEV1/FVC, %.	0.216	0.251	0.334	0.197	0.965	-0.00923
CTR	0.61	-0.097	0.348	-0.177	0.168	-0.258
Hearts volume	0.132	-0.281	0.443	-0.145	0.339	0.18
L-Lung volume	0.145	0.273	0.248	0.217	0.999	0.000222

Abbreviations: FB, free breathing; T-DIBH and T, thoracic deep inspiration breath-hold; A-DIBH and A, abdominal deep inspiration breath-hold

Table 5 Comparison of FEV1 and FVC in T-DIBH lower groups and A-DIBH lower groups for heart mean dose

		FEV1			
	minimum	median	maximum	n	p value
T-DIBH lower group(L)	1.46	1.97	2.8	13	0.063
A-DIBH lower group(L)	1.3	2.5	3.08	17	
		FVC			
	minimum	median	maximum	n	p value
T-DIBH lower group(L)	1.54	2.49	3.04	13	0.00962
A-DIBH loewr group(L)	1.76	3.12	4.18	17	

Abbreviations: T-DIBH, thoracic deep inspiration breath-hold; A-DIBH, abdominal deep inspiration breath-hold; FEV1, forced expiratory volume in one second; FVC, forced vital capacity

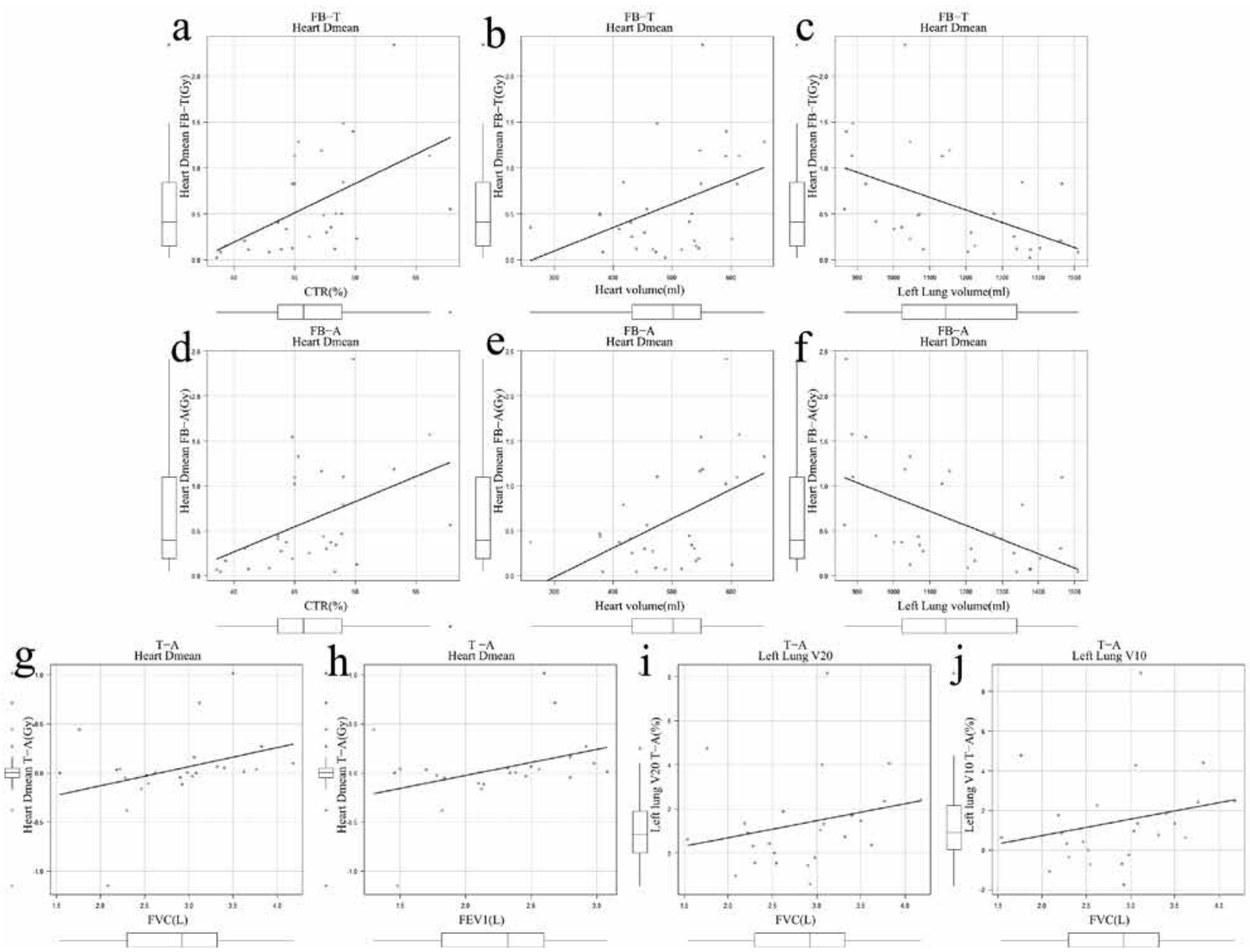

Fig. 2 Correlation between difference in heart mean dose (Dmean) and cardiothoracic ratio (CTR), heart volume, left lung volume between free breathing (FB), and thoracic deep inspiration breath holds (T) (a.b.c.), Correlation between heart Dmean difference and CTR, heart volume, left lung volume between FB and abdominal deep inspiration breath holds (A) (d.e.f.), Correlation between difference of heart Dmean and forced expiratory volume in one second (FEV1), forced vital capacity (FVC) between T and A (g.h.), correlation between left lung 20 Gy irradiation volume (V20) and FVC between T and A (i.), correlation between left lung 10 Gy irradiation volume (V10) and FVC between T and A (j.).

results of the Mann-Whitney U-test for FEV1 and FVC are shown in Table 5. Because there was a significant difference between the two groups with respect to FVC, the ROC curves are shown in Fig. 3. The area under the curve was 0.807, and the optimal cut-off value using the Youden index was an FVC of 3.06 L (sensitivity, 0.667; specificity, 1.000).

DISCUSSION

PTV dose assessment

The PTV Dmean and D95% for T-DIBH and A-DIBH differed significantly from FB. The median Dmean difference was 0.3 Gy for T-DIBH and 0.2 Gy for A-DIBH, which is not clinically significant. Other reports have also shown a median increase in PTV Dmean of 0.1 Gy-0.3 Gy in DIBH, although not significant [17, 18].

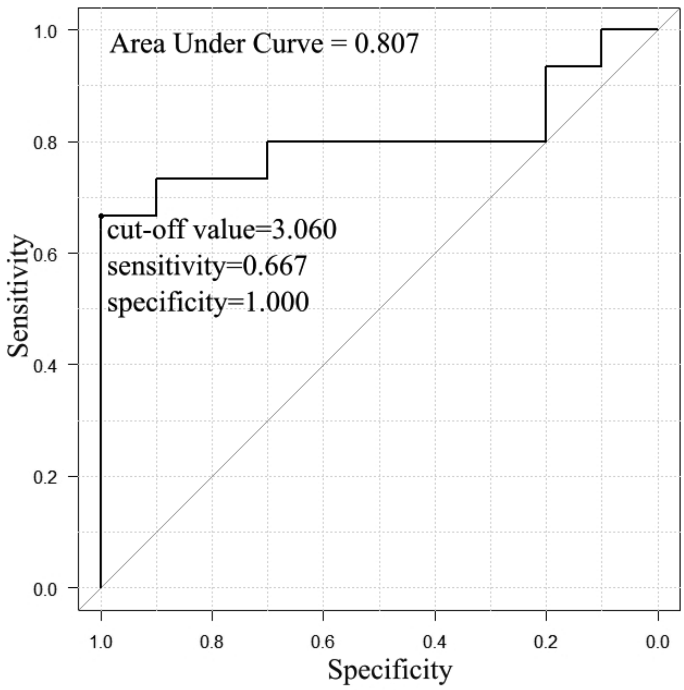

Fig. 3 Receiver operating characteristic curve of heart mean dose (Dmean) and forced vital capacity (FVC) between thoracic deep inspiration breath holds (T-DIBH) lower group and abdominal deep inspiration breath holds (A-DIBH) lower group.

Efficacy of A-DIBH for left lung dose reduction

Although there was no significant difference in left lung dose between FB and T-DIBH in the present study, there was a significant decrease in lung dose in A-DIBH at Dmean and V20 and V10 when comparing FB and A-DIBH. The comparison between T-DIBH and A-DIBH showed significant reductions in Dmean, V20, V10, and V5 during A-DIBH. This result may be due to the fact that lung volume increases in both T-DIBH and A-DIBH, but in different directions (horizontally for T-DIBH and cephalocaudally for A-DIBH). Using 3D-CRT, a comparison of FB and DIBH showed that DIBH contributes to lower left lung doses in some reports [19–21], although there is no consistent consensus in the reports regarding left lung doses. In a previous study comparing T-DIBH and A-DIBH, Zaho *et al.* [13] showed that A-DIBH significantly reduced V20 and V10 compared to T-DIBH, and Hirata *et al.* [14] found no significant difference in left lung dose between FB, T-DIBH, and A-DIBH, which is inconsistent and requires additional data.

Dependence of left lung dose on DIBH

The difference in left lung dose between T-DIBH and A-DIBH was dependent on FVC and FEV1. A-DIBH was shown to be more useful in protecting the left lung than T-DIBH in patients with better FVC and FEV1 (Fig. 2).

Efficacy of DIBH for heart dose reduction

Numerous studies have reported that DIBH is useful in reducing the heart Dmean [9, 10], with a reported reduction in the heart Dmean of 0.4 Gy–4.4 Gy with DIBH and a 29–67% reduction. In the present study, the T-DIBH group had a reduction of 0.59 Gy with a reduction rate of 41%, and the A-DIBH group had a reduction of 0.62 Gy with a reduction rate of 42%, which is comparable to previous studies [22–25].

In the current study, A-DIBH showed a significant reduction in heart dose compared to T-DIBH with respect to Dmax, but no significant differences were demonstrated in other heart dose parameters.

In a previous study comparing T-DIBH and A-DIBH, Zaho *et al.* [13] reported that A-DIBH was significantly better for heart Dmean, Dmax, V5, V10, and V20, while Hirata *et al.* [14] reported no significant difference in heart dose.

Heart mean dose and evaluation factor

The factors associated with a reduced heart Dmean compared to FB were CTR, heart volume, and left lung volume in T-DIBH and A-DIBH (Table 4). The larger the heart and smaller the left lung, the more effective the reduction of the heart Dmean by DIBH (Fig. 2). With respect to CTR, simple chest radiographs are useful for identifying cases in which DIBH is recommended more than other cases because many cases are pre-scanned for medical check-ups and preoperative screening.

Comparison of heart mean dose between T-DIBH and A-DIBH

No significant difference in the heart mean dose was detected between T-DIBH and A-DIBH; however, some cases with large differences were observed in actual planning. The difference in heart mean dose between T-DIBH and A-DIBH was positively correlated with FVC and FEV1, and T-DIBH may contribute to reduced heart mean dose in cases of poor pulmonary function (Fig. 2). There was a significant difference in heart mean dose in relation to FVC when comparing the low-dose group with T-DIBH and the low-dose group with A-DIBH. As shown in Fig. 3, the ROC curves for FVC and the above two groups indicate that the optimal cut-off value was an FVC of 3.06 L. In patients at high risk during cardiac irradiation, T-DIBH should also be considered if the FVC is < 3.06 L.

Limitations

One limitation of this study was the small number of cases. The number of cases in this study was small because contouring and planning were performed by one physician to eliminate differences among planners. It is necessary to continue to collect additional cases to make this a larger population study. Another limitation of this study was the small number of DIBH training hours. In this study there were several cases in which there was no difference or a small difference in thoracic and diaphragmatic movements between T-DIBH and A-DIBH. Because DIBH training was only conducted on the day of simulation, it is possible that the difference between T-DIBH and A-DIBH was not distinguished, thus advanced training needs to be introduced.

CONCLUSIONS

In summary, the 3D-CRT plan for postoperative irradiation of left breast cancer patients showed comparable reductions in the heart Dmean for both A-DIBH and T-DIBH. A-DIBH reduced the maximum heart dose more than T-DIBH. Furthermore, A-DIBH also showed dose reduction in the left lung, and therefore A-DIBH should be selected as the basic treatment.

The effect of cardiac mean dose reduction depends on heart volume, left lung volume, and CTR for T-DIBH and A-DIBH, and the effect can be predicted by chest radiography.

In some patients with low respiratory function, T-DIBH reduced cardiac dose more than A-DIBH, and the choice depended on the FVC. T-DIBH should also be considered in patients at high risk during heart irradiation and low FVC, with an FVC < 3.06 L as one of the indicators.

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