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Application of Deep Inspiration Breath Hold Technique in Radiotherapy After Breast-Conserving Surgery for Left Breast Cancer and Its Improvement on Cardiac Dose

Yu Luo[1], Lihan Huang[2], Qiao Lan[1], Yurui Wu[1]*, Yin Li[1], Xiaorong Cheng[1], Kunhai Xiong[1], Xiaoyu Wu[1]

[1]Lichuan People's Hospital, Lichuan 445400, Hubei Province, China
[2]Boao Evergrande International Hospital, Qionghai 571437, Hainan Province, China

Corresponding author: Yurui Wu, chengnands@sohu.com

Abstract: *Objective:* To analyze the application of deep inspiration breath hold technique in radiotherapy after breast-conserving surgery for left breast cancer and the improvement of cardiac dose. *Methods:* A total of 45 patients with left breast cancer treated in our hospital after breast-conserving surgery were selected, and the selection time was set from January 2020 to August 2022. All patients received radiotherapy. The right breast, heart, and lung volumes, and dose parameters of the heart, lungs, right breast, and left anterior descending coronary artery were compared under free breathing (FB) and deep inspiration breath hold (DIBH) technical modes. *Results:* The heart volume of the DIBH group was smaller than that of the FB group, and the left and right lung volumes were significantly larger than those of the FB group. In the DIBH group, the heart dose parameters V5, proper lung dose parameters, and left anterior descending coronary artery dose parameters were found lower than that of the FB group, and the differences were statistically significant ($P < 0.05$). *Conclusion:* Compared with FB, the DIBH technique can reduce the heart's size and increase the lung volume when used for radiotherapy after breast-conserving surgery for left breast cancer. It also reduces the dose to the heart, right lung, and left anterior descending coronary artery, thus protecting the heart and lungs.

Keywords: Breast cancer; Breast-conserving surgery; Deep inspiration breath hold; Free breathing; Cardiac dose

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1. Introduction

Breast cancer mainly manifests as breast lumps, nipple discharge, and other symptoms. If the patient fails to receive timely treatment, as the disease progresses, it can metastasize to other organs, thus seriously threatening the patient's life and health [1]. Radiotherapy after breast-conserving surgery is one of the comprehensive treatments commonly used for breast cancer at the current clinical stage. It can control the progression of the patient's disease and prolong the life cycle. However, due to the application of radiotherapy, it can cause damage to normal tissues (such as the heart, lungs, etc.). Toxic reaction damage can quickly increase the risk of adverse events, which is detrimental to the long-term survival of patients, especially for patients with left breast cancer undergoing breast-conserving radiotherapy [2,3]. Free-breathing (FB) mode is commonly used in current radiotherapy applications, but its effect on the dose control of organs at risk is poor [4]. The deep inspiration breath hold (DIBH) technique can expand the patient's lungs, move the diaphragm downward, and move the heart downward to the right rear to increase the distance between the target area of the chest wall and the heart, thereby helping to control the dose to the organs at risk. However, the application effect of DIBH in radiotherapy after breast-conserving surgery for left breast cancer has not yet been fully clarified [5]. Based on this, this study aims to explore the application effect of DIBH in radiotherapy after breast-conserving surgery for left breast cancer.

2. Materials and methods

2.1. General information

This study has been approved by the Medical Ethics Committee of our hospital after professional review. A total of 45 patients with left breast cancer who were treated in our hospital after breast-conserving surgery were selected and the selection time was set from January 2020 to August 2022. All patients were female, aged 25 to 65 years, with an average of 45.30 ± 4.52 years old. Inclusion criteria included patients who met the relevant diagnostic standards in the "Guidelines and Norms for the Diagnosis and Treatment of Breast Cancer of the Chinese Anti-Cancer Association (2019 Edition)" [6], had indications for adjuvant radiotherapy and received radiotherapy treatment, signed the informed consent, preoperative pathological stage at Ia period, and with basically normal cardiopulmonary function, etc. Exclusion criteria included those who cannot skillfully cooperate with DIBH training, poor compliance, and primary severe diseases (liver, kidney, hematopoietic system, etc.).

2.2. Methods

DIBH training was performed on all patients; each breath-holding time was 30 s or more. On the breast holder, the patient laid in a supine position, with both hands raised to hold the rod and completely expose the breast target area. The body surface of the target area was marked and scanned using a CT simulation positioning machine (GE Company, USA, model: Discovery CT590). The scanning range was 5 cm below the breast fold to the mandible, and the parameters were set: tube current 300 mAs, layer spacing 3 mm, tube voltage 120 kV, and layer thickness 3 mm. Imaging in DIBH and FB modes was acquired and uploaded to the workstation (Eclipse 15.5). The target area was outlined, and the organs at risk were the lungs, heart, right breast, and left anterior descending coronary artery. A 6-field intensity-modulated radiotherapy plan was designed in FB and DIBH modes, the parameters were adjusted and optimized while meeting the plan requirements (target dose, coverage, uniformity), and the dose to organs at risk was reduced as much as possible. Finally, the dose normalization value was changed to meet the plan comparison requirements (95% of the prescribed dose surrounds 95% of the target volume), the prescribed dose of 40 Gy, and a total of 15 fractions (2.66 Gy/fraction).

2.3. Observation indicators

The observation indicators included: (1) a comparison of right breast, heart, and lung volumes under two breathing modes, and (2) a comparison of the heart, lungs, right breast, and left anterior descending coronary artery dose parameters under two different breathing modes.

2.4. Statistical method

Data analysis was performed using SPSS 26.0 statistical software. The right breast, heart and lung volume, and dose parameter indicators of the heart, lung, right breast, and left anterior descending coronary artery were measurement data, represented by mean ± standard deviation (SD), and independent samples *t*-test was used to compare groups. $P < 0.05$ means the difference is statistically significant.

3. Results

3.1. Comparison of right breast, heart, and lung volumes under two breathing modes

Analysis of the data in **Table 1** shows that the heart volume of the DIBH group is smaller than that of the FB group, and the left and right lung volumes are significantly larger than that of the FB group ($P < 0.05$). There is no difference in the volume of the right mammary gland between the two groups ($P > 0.05$).

Table 1. Comparison of right breast, heart, and lung volumes under two breathing modes (cm^3)

Group	Number of cases	Heart	Left lung	Right lung	Right breast
FB group	45	534.27 ± 31.46	1,152.54 ± 84.57	1,552.18 ± 103.52	236.15 ± 35.36
DIBH group	45	482.14 ± 40.32	1,752.23 ± 88.34	1,994.21 ± 112.35	232.17 ± 48.39
t		6.838	32.895	19.410	0.445
P		< 0.001	< 0.001	< 0.001	0.657

3.2. Comparison of dose parameters of heart, lung, right breast, and left anterior descending coronary artery under two different breathing modes

Analysis of the data in **Table 2** shows that the heart dose parameters (average dose and V_5), proper lung dose parameters (V_5 and maximum dose), and left anterior descending coronary artery dose parameters (maximum dose and average dose) in the DIBH group were lower than those in the FB group ($P < 0.05$). There was no difference in the dose parameters of the left lung and right breast between the two groups ($P > 0.05$).

Table 2. Comparison of dose parameters of the heart, lungs, right breast, and left anterior descending coronary artery under two different breathing modes (mean ± SD)

Group	Number of cases	Heart		Right lung		Left anterior descending coronary artery	
		V_5 (%)	AD (Gy)	V_5 (%)	MD (Gy)	MD (Gy)	AD (Gy)
FB group	45	3.26 ± 0.33	0.63 ± 0.15	11.29 ± 2.43	2.75 ± 0.47	32.52 ± 5.43	24.63 ± 4.47
DIBH group	45	2.45 ± 0.31	0.46 ± 0.09	5.25 ± 1.08	1.81 ± 0.31	24.61 ± 4.32	16.58 ± 4.85
t-value		12.001	6.519	15.237	11.200	7.648	8.187
P value		< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

Group	Number of cases	Left lung					Right breast	
		V_5 (%)	V_{10} (%)	V_{20} (%)	V_{30} (%)	AD (Gy)	MD (Gy)	AD (Gy)
FB group	45	44.63 ± 5.56	26.47 ± 3.56	13.58 ± 2.45	10.35 ± 1.14	8.24 ± 1.11	3.28 ± 0.65	0.88 ± 0.19
DIBH group	45	44.25 ± 5.74	26.18 ± 3.37	13.13 ± 2.12	10.26 ± 1.21	8.07 ± 1.05	3.46 ± 0.64	0.82 ± 0.15
t-value		0.319	0.397	0.932	0.363	0.746	1.324	1.663
P value		0.750	0.692	0.354	0.717	0.457	0.189	0.100

Abbreviation: AD, average dose; MD, maximum dose; V_5, the volume of heart (%) receiving 5 Gy; V_{10}, the volume of heart (%) receiving 10 Gy; V_{20}, the volume of heart (%) receiving 20 Gy; V_{30}, the volume of heart (%) receiving 30 Gy.

4. Discussion

Breast cancer is a disease in which breast epithelial cells proliferate out of control and become malignant due to the influence of multiple factors such as heredity and changes in hormone levels. Due to the high incidence of breast cancer and the severe harm to patients' physical and mental health, timely clinical diagnosis and treatment are significant [7,8]. Breast-conserving postoperative radiotherapy for breast cancer can control the disease by preserving the shape of the breast, which is beneficial to improving the prognosis of patients. Currently, radiotherapy after breast-conserving surgery for left-sided breast cancer is performed in the FB state to outline the target area (the medial edge is close to the lateral border of the sternum). However, this will result in high doses to the heart and coronary arteries, which can easily damage normal tissue around the breast [9,10].

In radiotherapy after breast-conserving surgery for left-sided breast cancer, the application of the DIBH technique can move the patient's diaphragm downward and heart toward the right, posterior, and downward direction, increase the volume of both lungs, and reduce the size of the heart. In addition, in the application of the DIBH technique, the patient's breathing pattern training can be strengthened to reduce the fluctuation of the chest hence reducing the dose of tissue such as the heart, lungs, left anterior descending coronary artery, etc., thereby protecting the normal tissue around the breast as much as possible [11,12]. At the same time, taking a deep breath and holding a breath can activate the diaphragm and chest muscles, and move the heart away from the breast target area to reduce its exposure dose, thereby protecting the functions of the heart, lungs, and other tissues. Although the volume of the left lung increases, its proportion of the lung volume in the irradiation field will also increase, resulting in a minor change in the left lung irradiation dose [13,14]. The results of this study show that the heart volume of the DIBH group is smaller than that of the FB group, and the left and right lung volumes are more significant than those of the FB group. In the DIBH group, the heart dose parameters, proper lung dose parameters, and coronary artery dose parameters of the left anterior descending branch were lower than those of the FB group, indicating that the DIBH technique can reduce heart volume and increase lung volume in the application of radiotherapy after breast-conserving surgery for left breast cancer. The results found in this study are consistent with the research results of Yu *et al.* [15].

In summary, the DIBH technique can reduce the heart's size, increase the lung's volume, and reduce the dose to the heart, right lung, and left anterior descending coronary artery in the application of radiotherapy after breast-conserving surgery for left breast cancer, thereby protecting the heart and lungs. However, this study has shortcomings such as small sample size and single-center, thus more samples can be included in the clinical practice, and a more in-depth, multi-center study can be conducted to further analyze the application of the DIBH technique in postoperative radiotherapy for patients with left-sided breast cancer after breast-conserving surgery.

Disclosure statement

The authors declare no conflict of interest.

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