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Original Research Article

Deep Inspiration Breath Hold Technique Reduces Liver Dose in Right-Sided Breast Irradiation

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Abstract

Purpose: Deep inspiration breath hold (DIBH) is an effective method for cardiac sparing in individuals with left-sided breast cancer. The current study's objective was to ascertain if DIBH is helpful in lowering liver and other organs at risk from radiation exposure during right breast irradiation (RT).

Materials and Methods: Twenty right-sided breast cancer patients were included in this investigation. With two distinct computed tomography scans of free breathing (FB) and DIBH, three-dimensional conformal RT plans were created for each patient. The contouring of nodes was done in accordance with the recommendations of the Radiation Therapy Oncology Group. Organs at risk and target volume coverage dose-volume histograms were assessed and examined.

Results: In comparison to FB plans, DIBH plans demonstrated a significant reduction in mean liver dose (5.59 ± 2.07 Gy vs. 2.54 ± 1.40 Gy; $p = 0.0003$), V20Gy (148.38 ± 73.05 vs. 64.19 ± 51.07 mL; $p = 0.0003$), and V10Gy (195.34 ± 93.57 vs. 89.81 ± 57.28 m. In DIBH plans, right lung dosages were also dramatically decreased. With the use of the DIBH approach, heart and left lung dosages exhibited a slight but statistically significant improvement.

Conclusion: We demonstrate that the radiation doses to the liver, lungs, and heart are greatly reduced when DIBH is used to treat right-sided breast cancer.

Keywords: Breast cancer, Deep inspiration breath-hold, Liver, Radiotherapy.

Introduction

A crucial component of managing breast cancer is radiotherapy (RT). Overall survival and locoregional control both improve as a result [1]. The key determinant of survival may shift from risks associated with the core disease as survival rates increase to adverse effects of RT [2,3]. Therefore, a number of approaches have been created to reduce the exposure of the nearby normal tissues and, as a result, the potential for both short- and long-term negative effects. One of these is the deep inspiration breath-hold (DIBH) technique, which has been shown to reduce radiation exposure of the cardiac chambers and coronaries in patients with left-sided breast cancer (LBC) [4–7]. Numerous dosimetric studies clearly support the technique in patients with

LBC, and it is hoped that this effect will translate into clinical benefits [4–8]. DIBH is widely accepted as an important tool in selected patients to prevent long-term cardiovascular sequelae of RT.

Despite the improvements in LBC patients, the technique's usefulness in patients with right-sided breast cancer is not fully proven (RBC). Our study's main objective was to evaluate the dosimetric advantages of DIBH to conventional free breathing (FB) methods in terms of liver doses for RBC patients who had undergone mastectomy. Only two recent studies [9,10] have looked at the benefit and applicability of DIBH in patients with RBC, since previous studies have only looked at individuals with LBC.

These studies offer evidence in this area, however they are not without flaws. First off, Essers et al's [9] first investigation did not examine hepatic dosages. As the undamaged right breast was considered to be indicative of breast-conserving surgery for dosimetry purposes, another study that allowed a dosimetric comparison of liver doses between the procedures was carried out on LBC patients [10]. On the other hand, both studies [9,10] followed the European Society for Radiotherapy and Oncology (ESTRO) breast and nodal contouring guidelines, involving larger lung volumes in the treatment field than standard clinical practice [11]. We preferred to use the Radiation Therapy Oncology Group (RTOG) contouring guidelines, which are more widely used in clinical practice [12]. In addition, we aimed to compare heart and ipsilateral lung doses between the techniques.

Methods

30 consecutive female patients with stage II–III RBC who were referred for adjuvant RT after mastectomy and consented to be treated with this method between February 2022 and June 2022 made up the study population. Patients with a body mass index (BMI) less than 25 kg/m^2 (2 patients), those older than 70 years old (4 patients), and those unwilling to participate throughout the DIBH training (4 patients) were eliminated. Patients were immobilised on the breast board while lying supine with their arms over their heads. Patients were given adequate training to hold their breath. All received two planning computed tomography (CT) scans, one in FB and one in DIBH, each with a slice thickness of 3.0 mm. The DIBH and FB scans were taken on the same day without changing patient position between scans. We used the Sentinel system (C-RAD, Uppsala, Sweden), a laser-based optical surface scanning system used during CT acquisition to create a reference surface scan in FB and to track deep inspiration amplitude. Three-dimensional (3D) optical glasses were used to maintain a stable gating level.

Version 13.0 of the Varian Eclipse treatment planning system received CT data (Varian Medical System, Palo Alto, CA). According to the RTOG breast cancer atlas' radiation therapy planning standards, each patient's clinical target volume (CTV) and normal tissues were marked on all CT slices of both CT sets [12]. Patient body, contralateral breast, liver, heart, left lung, and right lung were all contoured as normal structures. CTV was defined as chest wall and regional lymph nodes including supraclavicular, infraclavicular, axillary and internal mammary lymph nodes. Planning target volume (PTV) was created with an additional 5-mm margin on CTV. PTV was retracted 3 mm from the skin surface. The prescribed dose to the target was 50 Gy in 25 fractions. A 3D conformal RT treatment plan was created for each CT dataset employing opposing tangential fields, field-in-field method, and a combination of 6 MV and 15 MV photons. In Eclipse 13.0, calculations for the plans were made. For uniformity, matched CT data sets (FB and DIBH scans) were scheduled by the same dosimetrist for each subject.

Dose-volume histograms were extracted for both datasets and analysed comparatively. Primary endpoints were dosimetric measures: mean dose of the liver, and liver volumes receiving ≥10 Gy (V_{10Gy}) and ≥20 Gy (V_{20Gy}). Additionally, mean dose of the ipsilateral lung, percentage of right lung volume receiving ≥20 Gy and ≥30 Gy, mean dose of heart, volume of heart receiving ≥5 Gy (V_{5Gy}), and left lung V_{5Gy} volume were also compared. The Health Research Ethics Board of Alberta's screening method, the Alberta Research Ethics Community Consensus Initiative (ARECCI), assessed that our study posed a low risk and was commensurate with a quality improvement initiative and did not require further ethics board approval [13].

A mean and standard deviation are used to depict continuous variables. Wilcoxon signed rank tests with two-tailed statistics were used to compare the groups. Statistical Package for the Social Sciences (SPSS) version 17 was used for all statistical calculations (SPSS Inc., Chicago, IL, USA). A statistically significant difference was determined to exist when the p-value was less than 0.05.

Results

Data from 20 patients were examined after exclusion criteria were applied. The patients' average age was 53 years (range, 35 to 64 years). Nine patients were in stage III, while 11 patients (55%) were in stage II. Invasive ductal carcinoma was the pathological diagnosis in 13 individuals (65%) and invasive lobular carcinoma in 7. 77.8 kg was the average body weight, while 30.4 kg/m2 was the average BMI. All patients finished approximately 20 minutes of training to adequately apply the DIBH method. All 20 patients were treated with DIBH. PTV coverage was similar for DIBH and FB: $V_{90\%}$ was 95% for both plans (p = 0.66).

The most important outcome parameter in our study was liver exposure, which was significantly lower with DIBH when compared with FB. While liver mean dose with FB was 5.59 ± 2.07 Gy, it was markedly decreased with DIBH (2.54 ± 1.40 Gy; p = 0.0003). DIBH scans showed significant reduction in liver V_{20Gy} volume, which was 148.38 ± 73.05 mL and 64.19 ± 51.07 mL for FB and DIBH scans, respectively. Liver V_{10Gy} volume was also reduced with application of the DIBH technique (89.81 ± 57.28 vs. 195.34 ± 93.57 mL; p = 0.0003).

DIBH significantly increased the right lung volume compared to FB (2,092.5 ± 407.9 mL and 1,254.2 ± 248.2 mL, respectively; p = 0.0003). With the use of DIBH, the exposure to the right lung was dramatically decreased in terms of mean dosage, V_{20}, and V_{30}. Additionally, DIBH significantly reduced the amount of V_{5Gy} exposure to the contralateral lung (0.52 ± 0.9 vs. 0.22 ± 0.30 mL; p = 0.00001). Application of DIBH could result in a statistically significant reduction in mean dose and V5 volume of the heart, despite the fact that cardiac exposure was already very low in patients with RBC.

Discussion and Conclusion

Numerous studies have been conducted since the initial publication of DIBH [4] to support its usefulness in lowering cardiac and other nearby organ doses in LBC patients. These trials have altered routine radiation treatment for LBC patients, and the DIBH technique is now the go-to method for treating a subset of LBC patients. The effectiveness of DIBH in patients with RBC has not been thoroughly studied because the vast majority of these trials involved patients with LBC and there was little work involving RBC [9,10].

The results of the current investigation showed that patients with RBC can reduce their exposure to the liver's toxic effects by using the DIBH approach. The only other study to exclusively examine DIBH in individuals with RBC did not focus consider liver dosages [9]. Conway et al. [10] looked into liver dosages in LBC patients in another study. The undamaged right breast was considered to be indicative of breast-conserving surgery with an excellent cosmetic outcome for dosimetry reasons [10]. This study showed significant reduction of the liver volume, receiving 25 Gy and more with application of DIBH technique (7.3 and 49.6 mL, respectively). Our study included RBC patients following mastectomy, which causes excessive exposure of liver and lung tissues in comparison with patients following breast-conserving surgery as in the aforementioned study [10]. Although liver radiation exposure was already much lower in the FB group (5.59 ± 2.07 Gy) than dose limits (28 Gy), we believe that every effort should be made to minimise normal tissue exposure without compromising PTV coverage.

Hormati et al. [14] concluded that breast RT, even at doses higher than 40 Gy, had no effect on liver stiffness because they discovered no relevant relationship between breast cancer RT and liver fibrosis, as measured by elastography. However, we must take into account that the methods that are now in use could not be sensitive enough or be chosen in the right way to detect radiation-induced liver damage. Further liver dose reduction may be helpful even though these doses are currently regarded as safe in cases of liver metastasis to be treated with stereotactic body RT or stereotactic RT in addition to breast irradiation among patients who have obtained hepatotoxic chemotherapy regimens, or those with synchronous or metachronous liver tumours. Because our study was dosimetric, nausea and other manifestations of acute toxicity were not objectives or pre-specified endpoints. However, we observed that nausea seemed to be less frequent compared with conventional RT. We are conducting another study which will examine this issue.

Another important result of the current study is ipsilateral lung dose reduction with the DIBH technique. DIBH during radiotherapy significantly reduced average mean dose and mean percentage of volume receiving ≥20 Gy (V_{20Gy}) and ≥30 Gy (V_{30Gy}) compared with FB, in line with previous studies [9,10]. Reducing lung exposure in patients with breast cancer is important to prevent radiation pneumonitis and secondary lung cancer. Although risk of radiation pneumonitis is already low, further reduction of risk may be achieved with normal tissue-sparing radiation techniques.

According to Grantzau et al. [15], the median interval between the diagnosis of secondary lung cancer and the completion of breast cancer therapy is 12 years. Smokers are more at risk for developing secondary lung cancer after receiving breast radiation. The need for improvements in standard tissue-sparing radiation treatments is highlighted by the rising number of long-term survivors following breast cancer therapy, despite the fact that the absolute risk is quite low. In contrast to FB, DIBH reduced the mean cardiac dosage and V_{5Gy} volumes in our study. Our results are concordant with previous studies: Conway et al. found that DIBH could reduce heart exposure in right breast irradiation. In addition, Pedersen et al. [16] found that DIBH could eliminate cardiac volume within RT fields in nearly all patients. However, Essers et al. [9] reported that DIBH did not result in a relevant dose reduction to the heart. The heart-sparing effect of DIBH in patients with LBC is well established and significant absolute dose reduction can be achieved with this technique. Although cardiac exposure in patients with RBC is already low, every effort should be made to obtain maximal cardiac protection, as even small reductions in cardiac exposure could have clinically relevant, long-term benefits.

Implementing DIBH doesn't come at a high expense. A research from India found that DIBH reduces cardiac problems in LBC patients at a reasonable cost [17]. We are aware that this procedure could not be as cost-effective in RBC patients as it is in LBC, but since these are only the first steps, we don't think it's yet appropriate to make a firm judgement about the technique's cost effectiveness in RBC patients. In conclusion, DIBH is a useful method for RBC patients to lessen radiation exposure to the heart, ipsilateral lung, and liver. [18]

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