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Deep Inspiration Breath Hold Techniques with Homemade LPT System for Left Breast Cancer Comparison between 3DCRT and IMRT

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Abstract: Background and Purpose: Radiation treatment to the left breast is associated with increased cardiac morbidity and mortality. The deep inspiration breath-hold technique (DIBH) can decrease radiation dose delivered to the heart and lung. IMRT-DIBH becomes more suitable for treating complex target volumes as it is able to generate more complicated dose distributions and dose gradients with narrower margins than those allowed using traditional methods. As a consequence, IMRT can provide a dosimetric benefit in terms of increased tumor control through escalated dose and reduced normal tissue complications through OARs sparing compared to 3DCRT-DIBH. The purpose of this study is to present a comparison between the dosimetric aspects of 3DCRT-DIBH and IMRT-DIBH in the left-sided breast radiotherapy. **Materials and Methods**: CT studies of 10 patients with early stage left breast cancer who underwent breast conservative surgery were planned using 3DCRT-DIBH compared with DIBH-IMRT data-set that was the international article completed by Amy J Hayden: Journal of Medical Imaging and Radiation Oncology. PTV, lungs, heart and contralateral breast (CB) were outlined. The dose prescribed was 50 Gray in 25 fractions to the left breast PTV. Dose volume histogram parameters (DVPs) for both plans were compared and analyzed statistically using Wilcoxon Signed-Ranks test. **Results**: Both 3DCRT-DIBH and IMRT-DIBH achieved adequate and comparable target coverage. On the other hand, tangential IMRT-DIBH showed insignificant higher PTV maximum dose with significant less dose homogeneity compared to 3DCRT. This is with greater sparing of the heart and contralateral breast in IMRT-DIBH plans. 3DCRT-DIBH technique seems better in sparing critical organs parameters like lung V20 and Mean lung Dose. **Conclusion**: IMRT –DIBH for breast cancer treatment is feasible. In comparison to 3DCRT-DIBH, IMRT-DIBH can show incidentally the maximum dose to the target volume, and dose to the OAR. However, 3DCRT technique is superior in terms of low dose volume, integral dose, and treatment time. With the use of deep inspiration breath-hold technique in IMRT, it can further improve the target coverage and reduction of doses to the heart, heart V30, LAD and contralateral breast.

Key words: Breast cancer radiotherapy, Deep inspiration breath hold, Planning Tumor Volume, Cardiac toxicity, IMRT, 3DCRT, Organs at Risk and mastectomy.

1. Introduction

Breast cancer is the most common cancer in women both in the developed and less developed world. It is estimated that worldwide over 508,000 women died in 2011 due to breast cancer (Global Health Estimates,

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WHO 2013). Although breast cancer is thought to be a disease of the developed world, almost 50% of breast cancer cases and 58% of deaths occur in less developed countries (GLOBOCAN 2008). In Bangladesh, the rate of breast cancer occurrence is estimated to be 22.5 per 100,000 females of all ages, compared to 124.8 per 100,000 females worldwide. For Bangladeshi women aged between 15-44 years, breast cancer has the highest rate of occurrence – 19.3 per 100,000, compared to any other type of cancer; cervical cancer comes in second for this age group at 12.4 per 100,000 (https://dnanonymous.wordpress.com/2013/01/20/breast-cancer-in-bangladesh).

Breast cancer can be treated using a multimodality approach of surgery, chemotherapy, radiotherapy and targeted therapy. The treatment options vary as per the stage of the tumor. The most adopted treatment method for breast cancer patients is breast conservation surgery (BCS), or mastectomy followed by adjuvant radiotherapy. Adjuvant radiotherapy improves local control and improves overall survival [1]. The adjuvant radiotherapy of the left chest wall is commonly delivered by three dimensional conformal radiotherapy (3DCRT) with field-in-field technique which have shown that increased cardiac morbidity and mortality in patients treated with radiotherapy for left-sided breast cancer compared to right-sided, due to the higher cardiac dose for the left-sided patients [2]. Cardiotoxicity is most frequently reported as decreased myocardial function or coronary artery disease (also reported as ischemic heart disease or decreased cardiac perfusion). However, less common toxicities can include myocardial infarction, congestive heart failure, pericarditis, arrhythmias, angina, or valve dysfunction [3]. However, many studies have demonstrated increased cardiac mortality and morbidity after breast radiotherapy [4]. Although many of the studies included in the this review involved old treatment techniques, which probably delivered a higher dose to the heart than seen in modern radiotherapy clinics, the issue of cardiac morbidity and mortality after breast cancer treatment is still relevant [5]. Dose–response curves for cardiac mortality derived from two randomized trials of surgery with or without radiotherapy for early breast cancer show a strong correlation with the dose delivered and a lesser dependency on the volume of the heart irradiated, assuming homogeneous radio-sensitivity within the irradiated heart volume [6]. On the other hand, the volume of the left ventricle within the treatment fields is an important predictor for the development of short-term myocardial perfusion defects after treatment although the long-term clinical significance of such defects remains to be determined [7]. Additionally, there may be detrimental effects from low doses of radiotherapy to larger volumes of the heart [8]. For example, a study of survivors of the atomic bombings of Hiroshima and Nagasaki who had received single whole body doses in the range of 0 to 4 Gy found a 17% increased risk of death from heart disease persisting for up to 52 years after exposure [9]. Therefore, dose-volume reduction of irradiation to the heart has become a common treatment goal in order to avoid increased risk of cardiovascular morbidity and mortality.

A promising method for minimizing the volume of the heart included in the treatment field involves increasing the distance between the target and heart through deep inspiration. In the deep inspiration breath hold (DIBH) technique, the goal is to achieve the maximum separation between the target area and heart, with irradiation therefore taking place only at or near maximum inspiration. This allows high doses of radiation to be delivered to the chest wall and to the breast tissue while reducing the high dose area of the heart [10]. In the absence of evidence for a threshold dose below which there is no excess risk of cardiac morbidity and mortality it seems appropriate to endeavour to minimize both the dose delivered to the heart and the volume of heart irradiated as well as the dose delivered to the LAD by using DIBH [11]. This cardiac complication can decrease by reducing dose to the heart, which can be achieved by using deep inspiration breath-hold technique (DIBH) and intensity modulated radiotherapy (IMRT) [12]. The DIBH technique has been recommended to reduce radiation to the heart by displacing the breast and chest wall away from the heart during treatment [13-16]. Different methods, such as the use of real-time position management systems [17], active breathing control [18], and magnetic sensors [19] have been used to monitor or control respiratory motion. However, these methods have not been routinely implemented by many breast cancer treatment centers. The failure to adopt DIBH into routine practice is due to concern about increases in the required resources and workloads. We explored whether the DIBH technique using LPT during left-sided breast irradiation was effective for minimizing the amount of radiation to the heart and lung compared to free breathing (FB). We also performed dosimetric evaluations to assess the extent of dose reduction to the heart, left anterior descending coronary artery (LAD), and ipsilateral lung [20-24].

2. Material and Methods

2.1 Homemade of Respiration-monitoring Device

In Bangladesh, RPM system is not available to use in deep inspiration breath hold technique. We have constructed the respiration-monitoring device (Figure 1) to use in DIBH by using LPT like as RPM system. Our system is composed primarily of glass fiber, PMMA, and with the use of a linear position transducer (code: AD/15/026) to monitor the changes in the patient's chest area caused by breathing.

Glass-fiber: A type of fiber-reinforced plastic which model number is jiutai made by China. The glass fiber may be randomly arranged, flattened into a sheet (called a chopped strand mat), or woven into a fabric.

PMMA: Polymethyl methacrylate® (PMMA) belongs to a family of synthetic polymers. It is better known as acrylic which brand name is Akrylon® used in this device. PMMA is a tough, highly transparent material with excellent resistance to ultraviolet radiation and weathering.

LPT: The LPT stands for linear position transducer which is essentially a spring-loaded potentiometer in which a pressure is applied to the transducer shown displacement of chest wall on the display which is digital volt-meter connected to the multi-pelage.

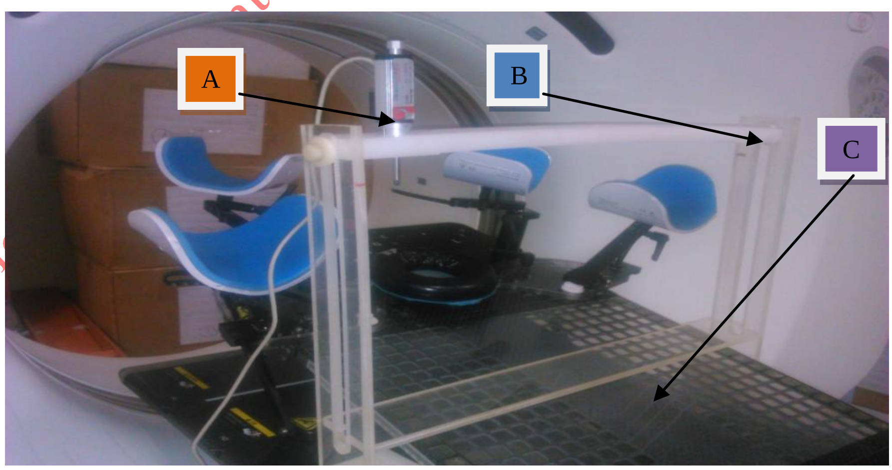


Fig. 1 Respiration-monitoring device. There are two Holes A and B used for holding the linear position transducer. When the hole A is used to hold the LPT with respect to PMMA, then the patient is scanned to the CT-simulator getting wanted image for left breast and B is used for getting image of right breast. During respiration, pointer C of the device made by glass fiber moves to the PMMA to get the value of LPT .This device, therefore, serves as an external device to monitor respiration. This system is not used for gating irradiation but for facilitating precise irradiation of a target by assuring a stable breath hold.

2.2 Respiratory Control Using LPT system

All patients were advised that the treatment was to be administered during respiratory standstill and were informed about the importance of reproducing the tumor position at the outpatient clinic by the treating physician. Next, each patient was trained how to hold her breath in the supine position with the left arm above the head in a customized arm support using a breast board to ensure that the sternum was in a horizontal position.

Figure 1 shows the procedure implemented for respiratory control using the LPT. Patients were instructed to hold their breath at the end of inspiration and asked to practice breath holding by repeating the instructions “breathe in, out, and stop”. The LPT is fixed to right side on the PMMA to get left side image to minimize the image artifact. Figure 1 shows **A** and **B** that are two holes minimized the image artifact. When we scanned the left side of breast, the LPT was fixed in the right side hole A and LPT was fixed in the left side hole **B** to scan the right breast. During normal breath the LPT was placed on the moveable pointer **C** fixed on the chest wall, we got zero voltage on display. While being taken breath, the voltage was increased within increasing the chest wall. The voltage was constant after deep breath hold. The LPT was used to generate a voltage signal from the changing circumference in the upper chest region as the patient breathes. This device detects a linear range of motion shown the measured voltage on the LED display (Figure 2) is adjusted for a deep inspiration maneuver and accounts only for the difference between the deep inspiration and normal breathing level.

Fig. 2 The measured voltage on the LED display.

2.3 Patient Selection

From July 2015 to October 2015, ten patients with early-stage breast cancer were retrospectively and randomly selected for this study, which was approved by our hospital review board. The remaining 10 patients underwent computed tomography (CT) simulation scans with both FB and DIBH without intravenous contrast. These scans were retrospectively re-planned using standardized criteria for the purpose of this study.

2.4 CT Simulation and Immobilization

Patients were screened for the ability to hold deep inspiration for greater than 20 s. All patients were positioned supine on a carbon fibre breast board with a fixed base accompanied by an adjustable tilt to ensure the sternum was in a horizontal position with the ipsilateral arm above the head. A body cast fabricated to immobilize the patient’s shoulder was used to ensure daily set-up accuracy. All patients were scanned with multi-detector 16slice a helical CT scan in the treatment position on a flat tabletop. Images were obtained as two different sets in a series, taken during free breathing (FB) and DIBH with 3-mm intervals. According to International Commission on Radiological Protection publication number 87, mean absorbed dose to breast was approximately 21 mGy for each thorax CT scan .Accuracy of the technique and the patients' ability to maintain DIBH were also verified with CT images. Images were transferred via network to a Varian Eclipse treatment planning workstation. CT images taken during DIBH were registered to FB images, according to DICOM coordinates. The LPT system was used to analyze and monitor the patients' deep inspiration. This system uses a Respiration-monitoring device by using LPT situated on the frame of RMD on the CT couch. Several practice sessions are performed before the DIBH CT scan is acquired to ensure that the patient can maintain a reproducible and constant deep inspiration breath hold for the duration of the scan and for treatment. The patient is instructed to 'breathe in and hold their breath' for approximately 20 s and then instructed to 'breathe normally'. The breath-hold is then analyzed on the LPT monitor with the upper and lower gate thresholds Adjusted. Once the patient is comfortable with this procedure the DIBH scan is acquired sequentially in 5 mm slices. The increase in slice thickness decreases the CT acquisition time, decreasing the breath hold time.

2.5 Eclipse Treatment Planning System

Eclipse treatment planning system (v8.6) was designed and developed by Varian Medical Systems and was used in the phantom study. With an intuitive Windows-based interface, Eclipse is designed to increase productivity for clinicians using simplified data settings and easy drag and drop functionality. Using leading edge automated tools, Eclipse opens the door for clinicians to create, import and optimize plans across numerous multiple linear accelerators. In a Varian environment, Eclipse integrates the ARIA oncology information system making workflow smooth, integrated and seamless. As Varian takes radiation treatment to the next level, Eclipse is designed to advance along with it.

2.6 Protocol

The following protocols have been used for verifying doses:

1 EMAMI and QUANTEC.
2 Swedish breast cancer group.
3 NCCN Guidelines version 2.2011.

2.7 Methods

In Bangladesh, none of the radiotherapy departments are using deep inspiration breaths hold technique facility for treating breast cancer based on IMRT-DIBH. For comparing with the 3DCRT, the data of IMRT-DIBH for left breast cancer has been collected from several relevant articles. These articles were searched in Pub-Med and other journals from July 2015 to January 2016. One of the studies is based on IMRT-DIBH was similar to 3DCRT-DIBH whose relevant parameters were adopted for comparison between 3D-Conformal Radiotherapy and Intensity Modulated Radiotherapy plans. The name of the article was "Deep inspiration breath hold technique reduces heart dose from radiotherapy for left-sided breast cancer" carried out by Amy J Hayden [14]. The practical work for this study was carried out by the following parameter which is given below:

1) Delineation of target volumes and organs at risk
2) Treatment planning.
3) Statistical analysis.

2.7.1 Delineation of target volumes and organs at risk

After CT scan, Digital Imaging and Communication in Medicine (DICOM) images were transferred to Eclipse treatment planning system (V8.6). The contours that were generated were the Gross Tumor Volume (GTV), Clinical Tumor Volume (CTV), and Planning Target Volume (PTV), ipsilateral lung, contralateral breast, heart, spinal cord, trachea and LAD coronary artery. The target delineation was performed based Radiation Therapy Oncology Group (RTOG) guidelines. Structures were delineated in both the DIBH and FB CT sets by one radiation oncologist. The margin from CTV to PTV was 5 mm, except for superficial areas where PTV was never closer than 5 mm to the skin. The margins were the same for DIBH and FB. Due to the chosen 2 mm gating window the movement of the chest wall during the DIBH plateau was the same, or smaller, as compared to FB. Hence the margin to compensate for CTV motion did not have to be increased with the DIBH technique.

2.7.2 Treatment planning

For each patient, Both FB and DIBH CT scans were contoured by one oncologist and were carried out by one medical physicist to ensure plan uniformity. If the patient is capable of holding the breath for more than 15 seconds, DIBH based 3DCRT is a standard technique for left sided chest wall/ breast patients. The prescribed dose was 50 Gy in 25 fractions. 3DCRT planning was performed using two opposing 6 or 10 MV tangential conformal fields. For anterior field the gantry was rotated laterally by 10 degrees in order to avoid the spinal cord and the esophagus. Field-in-field technique with multi leaf collimators were used to produced adequate dose coverage (95% of the prescribed dose) for target volume while minimize the global hot spot less than 110%.The beam angles and field weights were chosen to optimize coverage of the PTV, while minimizing exposure to the left lung, heart and right breast. This study has followed QUANTEC and RTOG protocol which is given below (Table 1).

Table 1 Normal Tissue Tolerance for Standard Fractionation.

Organ	Endpoint	Rate (%)	Dose-volume parameter	D_{mean}(Gy)
Heart	Pericarditis Cardiac Mortality	< 15% < 1%	V30 < 46% V25 < 10%	< 26Gy
Lung	Pneumonitis	20 %	V20 ≤ 30%	20Gy

2.7.3 Statistical analysis

Dose-volume histograms (DVHs) were calculated and compared for the FB as well as DIBH plans. Doses to CTV, PTV and organs at risk were assessed. Volume size, mean and maximum doses were obtained from the DVH statistics. The relative volume V x , irradiated to a minimum dose x (in Gy or %), e.g. V 30 for the heart, V 20 for the lung and V 95% for PTV, were registered from the DVH graph. The maximum heart distance (MHD) and central lung distance (CLD) were measured in beams eye view. The breathing amplitudes during the CT session were retrieved from the LPT system. Paired Wilcoxon test was used for statistical analysis of the differences with Matlab. Data were considered statistically significant for p- value of ≤ 0.05.

3. Results

3.1 Dosimetric Comparison between 3DCRT-DIBH and IMRT-DIBH Plans

As shown in table 2. CT-simulation scans demonstrated significantly larger total lung volume and irradiated heart volume when compared with scans performed in 3DCRT-DIBH and IMRT-DIBH. IMRT-DIBH also resulted in a significant reduction in the heart V30, mean heart dose, mean contralateral breast dose.

Table 2 also shows that; Mean heart dose is 4.49Gy for 3DCTR-DIBH compared to 3.96Gy for IMRT-DIBH. IMRT-DIBH plans showed a significant reduction of 11.8% compared to

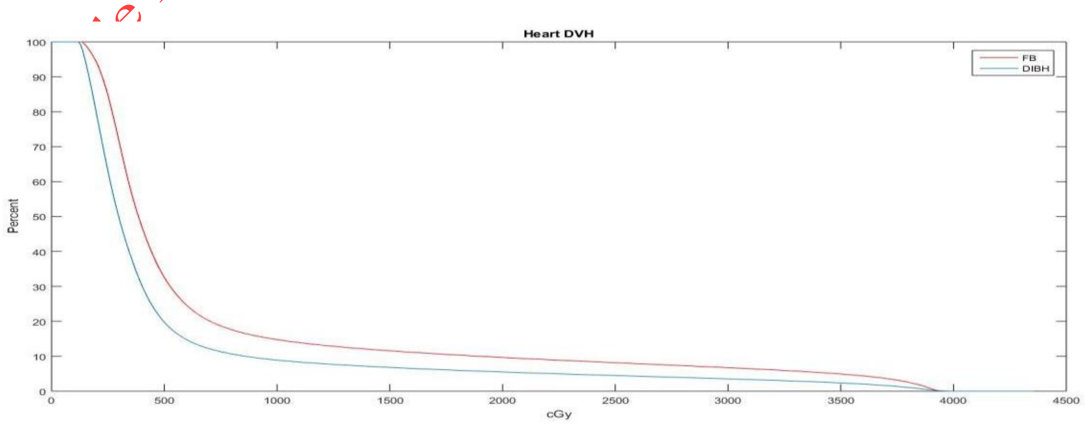
3DCRT-DIBH plans. Mean LAD dose is 20.39Gy for 3DCTR-DIBH compared to 21.94Gy for IMRT-DIBH. 3DCRT-DIBH plans showed a significant reduction of 7.5% compared to IMRT-DIBH plans. Heart V25 is 6.41% for 3DCRT-DIBH compared to 3.76% for IMRT-DIBH. IMRT-DIBH plans showed a significant reduction of 41.3% compared to 3DCRT-DIBH plans. Heart V30 4.74% for 3DCRT-DIBH compared to 2.45% for IMRT plans. IMRT-DIBH plans showed a significant reduction of 48.3% compared to 3DCRT-DIBH plans. So IMRT-DIBH plans achieved significant heart sparing compared to 3DCRT-DIBH plans without LAD dose. A significant reduction of irradiated volume ($p < 0.001$) was found when 3D-CRT and IMRT techniques were compared.

Table 2 Dosimetric comparison between 3DCRT-DIBH and IMRT-DIBH plans for left- sided adjuvant breast radiotherapy.

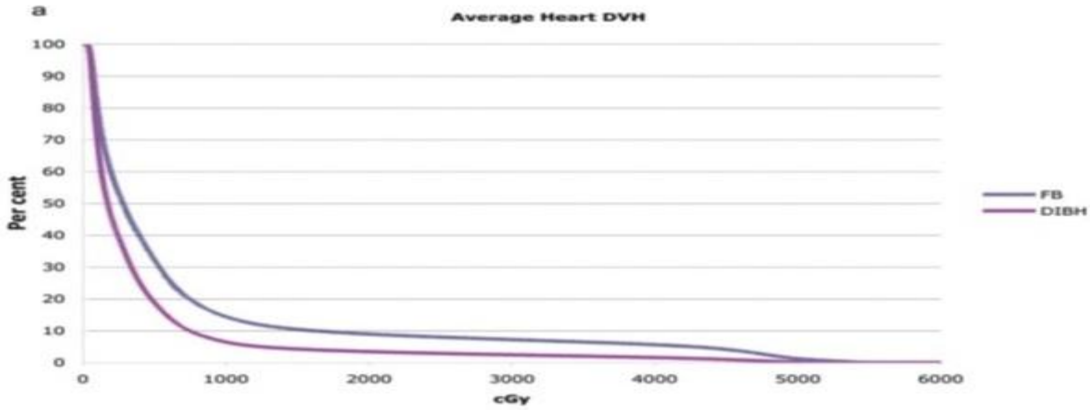
Parameter	3DCRT-DIBH mean	IMRT-DIBH mean	P-value for 3DCRT	P-value for IMRT
Irradiated heart Volume (cc)	6.30	2.1	P < 0.001	P < 0.001
Mean heart dose(Gy)	4.49	3.96	P = 0.009	P < 0.001
Heart V30 (%)	4.74	2.45	P = 0.006	P < 0.001
Heart V25 (%)	6.41	3.16	P = 0.004	P < 0.001
Mean LAD dose (Gy)	20.39	21.94	P < 0.001	P < 0.001
Total lung volume(cc)	1271.7	2051	P < 0.001	P < 0.001
Mean lung dose (Gy)	8.18	12.77	P < 0.001	P = 0.058
Lung V20 (%)	20.26	22.1	P < 0.001	P = 0.136
Mean contralateral breast dose (Gy)	3.0	0.6	P = 0.014	P = 0.475

Table 2 shows that left lung mean dose is 8.18Gy for 3DCRT-DIBH plans compared to 12.77Gy for IMRT-DIBH plans. 3DCRT-DIBH plans show a significant reduction of 36% compared to IMRT-DIBH plans. Left lung V20 is 20.26% for 3DCRT-DIBH compared to 22.1% for IMRT-DIBH. 3DCRT-DIBH plans showed a significant reduction of 8.3% compared IMRT-DIBH plans. So 3DCRT-DIBH plans achieved significant lung sparing compared to IMRT-DIBH plans. For the mean lung dose a significant reduction was found in breath-hold technique with both 3DCRT-DIBH than IMRT-DIBH.

Significantly larger lung volumes were found in breath-hold than in free-breathing ($p < 0.001$); mean lung volume in breath-hold was 1271.7(cc) for 3DCRT and 2051(cc) for IMRT. The average dose volume histogram (DVH) comparing IMRT-DIBH against 3DCRT-DIBH the heart, LAD PRV and left lung is shown in Figure 3. However, no difference was noted in the comparative DVH for the left lung.



(A)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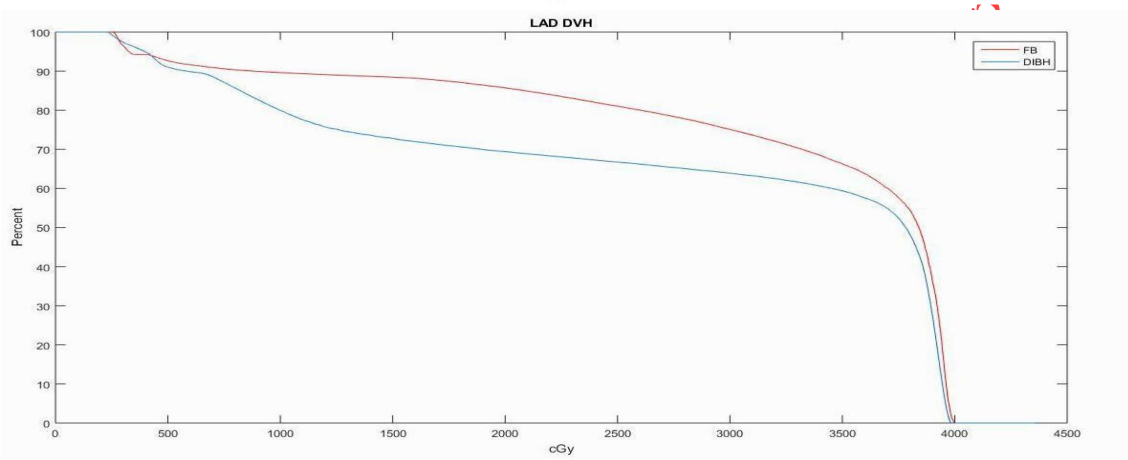
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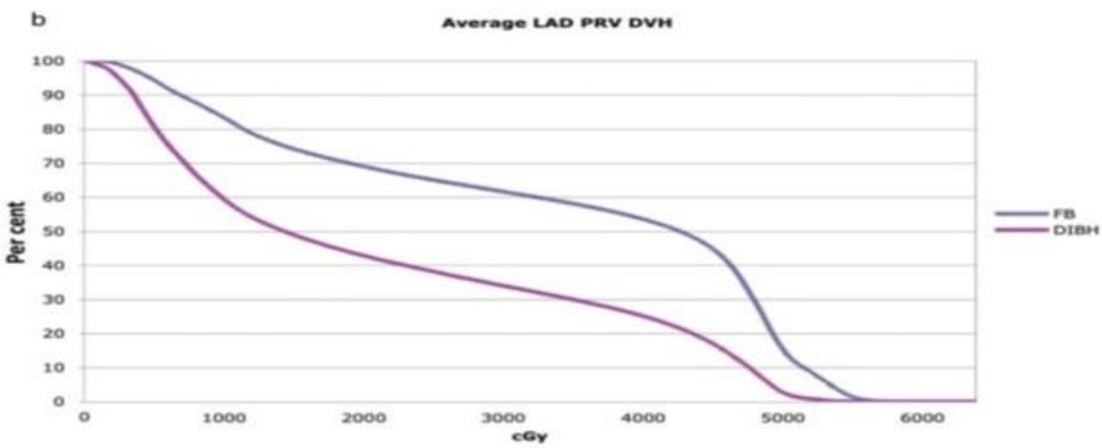
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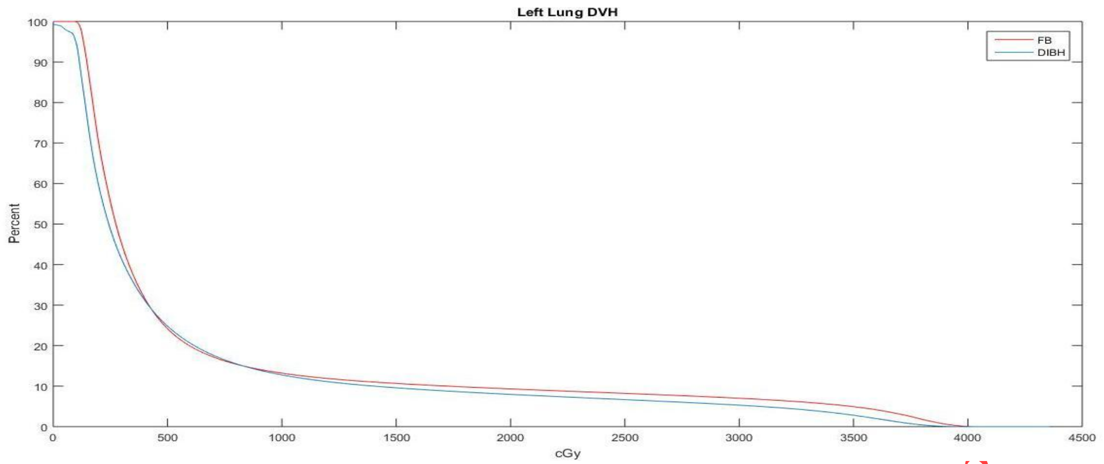

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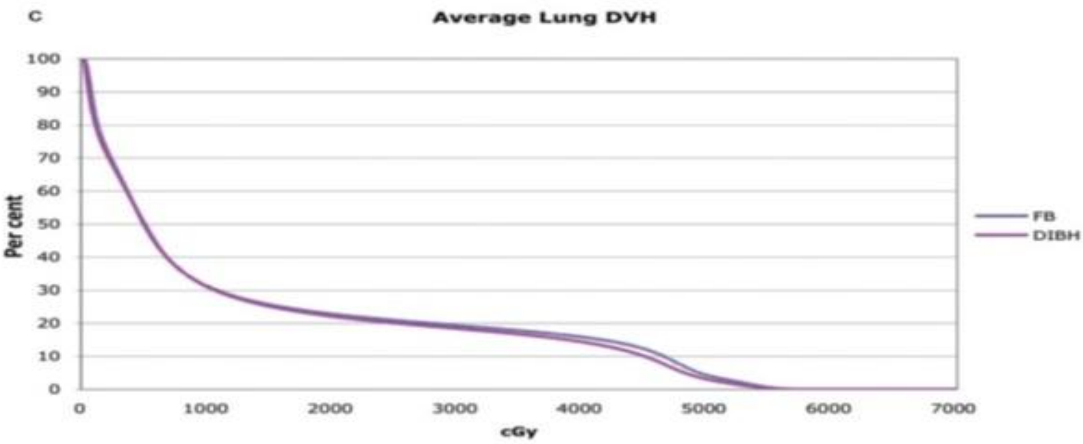
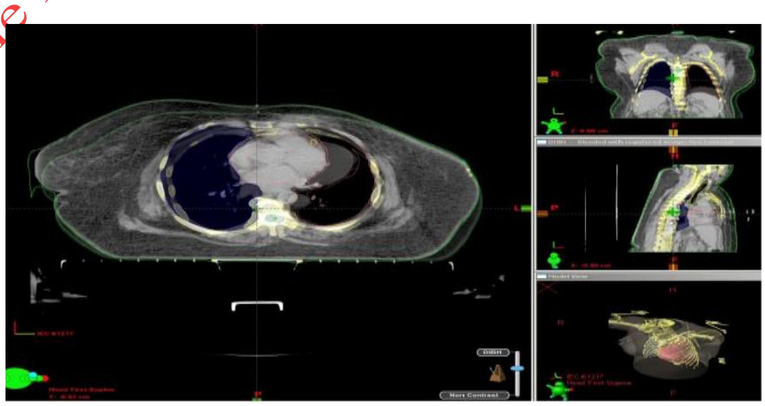


(F)

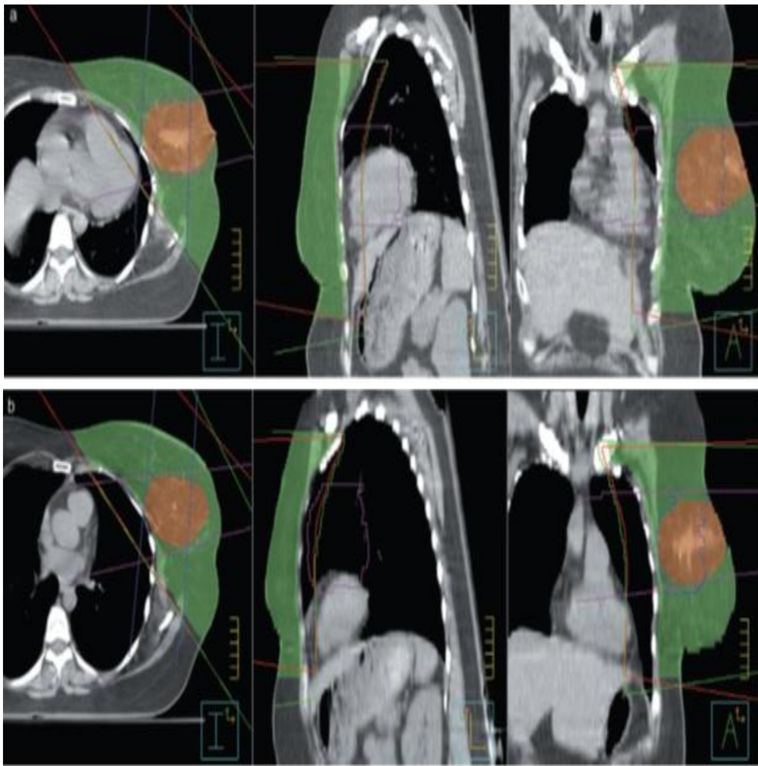
Fig. 3 A: The heart DVH comparing FB against DIBH for 3DCRT; B: The heart DVH comparing FB against DIBH for IMRT (ref.11); C: The LAD DVH comparing FB against DIBH for 3DCRT; D: The LAD DVH comparing FB against DIBH for IMRT (ref.11); E: The Lung DVH comparing FB against DIBH for 3DCRT; F: The Lung DVH comparing FB against DIBH for IMRT (ref.11).

Regarding CB mean dose; it was 3.0Gy for 3DCRT-DIBH compared to 0.6Gy for IMRT-DIBH. IMRT-DIBH plans showed a significant reduction of 80% compared to 3DCRT-DIBH plans. There was no significant difference mean dose to the contralateral breast with comparing IMRT-DIBH and 3DCRT-DIBH.

Figure 4 demonstrates the displacement of the PTVs away from the heart between FB and DIBH scans in one patient compared with both IMRT and 3DCRT.



(A)



(B)

(C)

Fig. 4 A: The displacement of the PTVs away from the heart between FB and DIBH scans for 3DCRT; B: The displacement of the PTVs away from the heart FB scans for IMRT (ref.11); C: The displacement of the PTVs away from the heart DIBH scans for IMRT (ref.11).

3.2 Workload Requirements and Patient and Staff Acceptance

The implementation of the DIBH technique required minimal additional resources and only a moderate increase in workload. We assessed the overall treatment time for each patient. The mean durations of FB and DIBH were about 5 minutes 10 seconds and 10 minutes 30 seconds, respectively. All planning staff became familiar with the DIBH planning and LPT system education processes. Staff responsible for operating breast cancer treatment machines became proficient with patient setup and treatment delivery using LPT system about 6 weeks.

4. Discussion

Many studies [25-33] have shown benefits of DIBH in left breast patients using both 3DCRT and IMRT, especially in minimizing the cardiac complications. This study was undertaken to appraise the benefit of DIBH-3DCRT compared to DIBH- IMRT for locally advanced left sided chest wall breast patients. Early studies indicated that DIBH could reduce the volume of the heart within tangential fields. Discussion of the results for 3DCRT-DIBH compared with IMRT-DIBH has been given below:

Rahbin et al [3] have shown that, DIBH-IMRT reduces the maximum dose to the heart, as well as the fraction of the heart volume receiving 30Gy but it increased the mean dose as compared to DIBH-3DCRT plans. The DIBH-3D-CRT and DIBH-IMRT plans achieved similar sparing of critical organs. Similar results are observed in this study. In the current study, the data shows that tangential beam IMRT-DIBH for left breast cancer patients offers the potential to significantly reduce dose-volume parameters of the mean heart dose, heart V30Gy and contralateral breast respectively compared to tangential beam 3-DCRT-DIBH with comparable target dose coverage. On other hand DIBH-IMAT increased the mean lung dose, lung V20Gy and mean LAD dose compared to DIBH-3DCRT. Approximately on average DIBH-3DCRT reduced the mean heart dose and mean LAD dose compared to FB-3DCRT.

Ha Yoon Lee et al [13] explored whether the deep inspiration breath hold (DIBH) technique using Abches during left-sided breast irradiation was effective for minimizing the amount of radiation to the heart and lung compared to free breathing (FB). A total of 25 patients with left-sided breast cancer underwent two computed tomography scans each with the DIBH using Abches and using FB after breast-conserving surgery. The scans were retrospectively re-planned using standardized criteria for the purpose of this study. The DIBH plans for each patient were compared with FB plans using dosimetric parameters. All patients were successfully treated with the DIBH technique using Abches. Significant differences were found between the DIBH and FB plans for mean heart dose (2.52 vs. 4.53 Gy), heart V30 (16.48 vs. 45.13 cm3), V20 (21.35 vs. 54.55 cm3), mean left anterior descending coronary artery (LAD) dose (16.01 vs. 26.26 Gy, all $p < 0.001$), and maximal dose to 0.2 cm^3 of the LAD (41.65 vs. 47.27 Gy, $p = 0.017$). The mean left lung dose (7.53 vs. 8.03 Gy, $p = 0.073$) and lung V20 (14.63% vs. 15.72%, $p = 0.060$) of DIBH using Abches were not different significantly compared with FB. The current study was similar with Article of Ha Yoon Lee but significantly improved LAD dose, mean lung dose and V20 compared with Ha Yoon lee's thesis. The project work has been used with a custom made respiration-monitoring device using LPT system which was cost minimize then Abches system.

Mansouri et al [15] have shown, DIBH-IMRT reduces the ipsilateral lung dose-volume (V20Gy) and heart dose-volume (V30Gy) respectively compared to DIBH-3DCRT for left sided whole breast patients. The similar results from this study show that 3DCRT significantly reduce the mean heart dose, the mean lung dose and LAD absorbed dose. The treatment delivery time of IMRT is often much longer than that 3DCRT treatment. One concern with DIBH-IMRT is that the added time to DIBH will make the beam delivery time too long. The most important advantage of DIBH -3DCRT is treatment delivery time better than DIBH-IMRT.

Mirjam E. Mast et al [34] have shown a comparison between 3D-Conformal (3D-CRT) and Intensity Modulated Radiotherapy (IMRT) treatment plans based on free-breathing (FB) and breath-hold (BH). They investigated whether IMRT enables an additional decrease of cardiac dose in radiotherapy plans with and without BH. Mast et al. described that twenty patients referred for whole breast irradiation were included. The whole breast, heart and LAD-region were contoured. Four treatment plans were generated: FB_3D-CRT; FB_IMRT; BH_3D-CRT; BH_IMRT. Several doses were obtained from Dose Volume Histograms and compared. Results were compared statistically using the Wilcoxin Signed Rank Test. For heart and LAD-region, a significant dose reduction was found in BH ($p < 0.01$). For both BH and FB, a significant dose reduction was found using IMRT ($p < 0.01$). By using IMRT an average reduction of 5% was noted in the LAD-region for the volume receiving 20 Gy. In 5 cases, the LAD-region remained situated in the vicinity of the radiation portals even in BH. Nevertheless, with IMRT the LAD dose was reduced in these cases. IMRT results in a significant additional decrease of dose in the heart and LAD-region in both DIBH and FB.

In this current study was carried out to evaluate the difference in dose distribution of tangential beam IMRT-DIBH compared to tangential beam 3DCRT-DIBH of whole breast in early breast cancer patients underwent breast conservative surgery. Regarding to lung sparing; in the current study 3DCRT-DIBH resulted in better lung sparing compared with IMRT-DIBH. This is in accordance with the results of Ha Yoon Lee et al [13]. The mean lung dose was significantly reduced with tangential 3DCRT-DIBH compared to IMRT-DIBH. The results of the current study were supported by Ha Yoon Lee et al [13]. The current study was found that the left lung mean dose and V20Gy with 3DCRT-DIBH were lower than IMRT-DIBH and also lower than that of the current study (8.18Gy compared to 12.77Gy and in current study) but the current study was not match with the results of Mast et al [34].

Regarding to heart sparing; current study showed that DIBH- IMRT resulted in better heart sparing; V20Gy and V30Gy were significantly lower with DIBH-IMRT than with DIBH- 3DCRT. This is in accordance with the results of Mast et al [34]; they found that the volume of heart receiving large doses was significantly decreased with the tangential IMRT-DIBH compared to 3DCRT-DIBH. The results of the current study were also supported by Gamal Elhusseiny et al [35] who showed that heart V30Gy was lower with IMRT than with 3DCRT (17% and 21% respectively). Although Gamal Elhusseiny et al did not show IMRT-DIBH compared to 3DCRT-DIBH, they showed the results of IMRT compared to 3DCRT but reduction is still significant and results were within tolerance dose of the heart.

As regard to CB dose; current study revealed significant reduction of CB mean dose with IMRT-DIBH compared with 3DCRT-DIBH. This is in accordance with Gamal Elhusseiny et al [35]; the mean dose to the CB was significantly reduced with the tangential IMRT plans (3.5 Gy compared to 5.0 Gy with 3DCRT).

5. Conclusions

The objective of this study was to compare the dosimetric characteristics of IMRT-DIBH and 3DCRT-DIBH techniques to the left-side breast radiotherapy in the early stage of the breast cancer. In the current study, the data shows that tangential beam IMRT-DIBH for left breast cancer patients offers the potential to significantly reduce dose-volume parameters of the ipsilateral lung, heart and contralateral breast compared to tangential beam 3-DCRT-DIBH with comparable target dose coverage. However, 3DCRT technique was superior in terms of low dose volume of normal tissue, integral dose, and treatment time. Consequences of these low doses would have to be weighed against the benefits of reducing high doses on individual patient selection basis. We have developed and implemented a low-cost, automated deep inspiration breath hold technique using a new external motion sensor (a linear position transducer) for the treatment of left-side breast cancer for 3DCRT. Linear position transducer (LPT) has been used for tracking the organ position in the thoracic region during a breath hold. It was demonstrated that the sensor has a rapid response and produces accurate and reproducible signals. Our DIBH technique improves the accuracy of treatment for moving tumors. The technique is useful for patients with good lung function, no significant cough, and low anxiety. Although the present work uses an LPT as a sensor, in future studies we can use other sensor that is IR sensor for better accuracy [36-41].

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