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Research Article

Retrospective Observational Study Comparing Organs at Risk Doses in Left Sided Breast Cancer Patients Receiving Adjuvant Radiotherapy in Free Breathing, Voluntary Deep Inspiratory Breath Hold Technique and Institutional Modified Voluntary Deep Inspiratory Breath Hold Technique

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Abstract

Objective: *To analyze the reduction of the dose to the organs at risk between the institutionalmodified voluntary DIBH (mv-DIBH), conventional voluntary DIBH (cv-DIBH), and Free Breathing (FB).*

Methods: *60 Left-sided breast cancer patients received adjuvant Radiotherapy and were retrospectively analyzed. Treatment plans are generated between mv-DIBH, cv-DIBH and Free Breathing (FB) Computed Tomography (CT) scans. The treatment planning was performed with the conformal tangential field using a 6 MV photon field. The treatment schedule was 40Gy in 15 fractions over 3 weeks Hypofractionation schedule along with or without a sequential boost to the tumor bed. The Dose Volume Histogram (DVH) was compared between all three arms. For the comparison, we considered cardiac and Ipsilateral lung doses and volumes. Quantitative statistical analyses of plans dose differences were generated*

Results: *In this study, there was a 40% reduction in heart Dmean in mv-DIBH compared to FB (5.07Gy in FB and 3.08Gy in mv-DIBH) with a p-value <0.0001. the mv-DIBH techniqueshowed a significant reduction in Heart V5Gy, V10Gy, and V30Gy with 47%, 46%, and 49%in comparison with the FB technique. Pulmonary dosimetric parameters such as Ipsilateral Lung Mean dose and V20Gy in the mv-DIBH group showed a significant reduction compared with the FB and cv-DIBH techniques. Total Lung Dmean in the mv-DIBH technique showed an average relative dose reduction of 18% compared to FB groups and 16% with the cv-DIBH technique.*

Conclusion: *Our findings confirm the literature data about the DIBH technique advantage interms of dose reduction of cardiac and pulmonary doses for tangentially treated left-sided breast cancer patients. This was a retrospective study, further prospective study with larger samples is warranted to evaluate the long-term clinical implication of our institutional mv- DIBH technique and its relevant dosimetric results.*

Introduction

Breast cancer is the second most common cancer in the world and most common cancer to affect women globally (1). Worldwide it is the leading cause of cancer mortality in women. In India, it is the most common cancer among females (1). It is a complex disease and it has many clinical, molecular, genetic and morphological features. Radiotherapy is an essential component in the multimodality treatment of breast cancer (2). All the patients who have undergone breast conservative surgery and modified radical mastectomy with risk factors such as T3 lesions and above, node positive disease requires adjuvant radiotherapy (3,4). Breast conservative surgery (BCS)is equivalent treatment outcomes compared with mastectomy with good cosmetic results (5). After BCS adjuvant radiotherapy to the whole breast is mandatory (5). Post mastectomy patients who receive adjuvant Radiation owing to high-risk features have an improved overall survival and better locoregional control (6).

Radiotherapy treatment of left sided breast cancer increases risks of radiation related late toxicities. Postoperative radiotherapy in patients with left-sided breast cancer is characterized by exposure of significant portion of the heart volume to high doses of irradiation (7). Adjuvant radiotherapy increases the risk of cardiac disease (ischemic heart disease) and lung disease pneumonitis .For left sided breast cancer, coronary arteries and left lung tend to be co- irradiated due to their proximity to the target volume(8).Pathophysiology of radiotherapy induced cardiac toxicity involves damage of blood vessels and interstitial fibrosis, leading to coronary artery disease, valvular abnormalities, myocardial dysfunction ,pericardial disease and conductive disturbances (8). Reports shows that an increase of mean dose 1 Gray to the heart results 7.4% relative increase in the risks of major coronary events (9).

The main aim is to avoid irradiating (or) reduce doses of Radiation to organ at risk without compromising coverage of target volume in left sided breast cancer.

Various radiotherapy techniques like prone position radiotherapy, DIBH, Partial breast irradiation (PBI) and Gating, spares the heart and decreases the cardiac doses. Among these techniques, DIBH is one of the better ways of heart sparing (11). DIBH minimizes heart volume and increases the distance between the chest wall and the heart, thereby decreasing the cardiac volume in the radiation field (11,12).

Different Breath hold methods have been used in modern radiotherapy. The major dominant methods are

(i) Conventional Voluntary DIBH **(**cvDIBH**)**

(ii) Spirometry-based Active Breathing co-ordinator **(**ABC**)** system, [Elekta, Stockholm, Sweden].

(iii) Audio or Video–based Real Time Positioning Management **(**RPM**)** System [Varian Medical System, Palo Alto, CA]. Voluntary DIBH **(**vDIBH**)** takes less time and it is simple in comparison to active breathing control DIBH **(**ABC DIBH**)** and RPM mvDIBH **(**15**)**.

The main disadvantage we experience in the day-to-day cvDIBH technique is it's very hard to observe or assure whether patient holding their breath while radiation. With that in mind in our institution, we created a modified setup with the presence of a touch sensor, light, and alarm in place these will help us to confirm the breath hold while treatment.

This study compares dosimetric differences in Heart, LAD, and left Lung doses in Institutional Modified Voluntary DIBH [mvDIBH] with the Free breathing [FB] technique and Conventional Voluntary DIBH [cvDIBH]. Hypothesis of this study to find out "How much difference in OAR doses in patients treated using Institutional mv-DIBH compared with the Free Breathing and cv- DIBH"

Aims and Objectives

Aim:

To assess the dosimetric difference in terms of organs at risk between Free

Breathing **(**FB**)** technique, Conventional Voluntary Deep Inspiratory Breath Hold **(**cvDIBH**)** technique, and Modified Voluntary Deep Inspiratory Breath Hold **(**mvDIBH**)**]

Objectives:

To compare the Lung, Heart, and Left Anterior Descending Artery [LAD] dose of mvDIBH with FB, cvDIBH.

OAR	PARAMETERS TO BE SEEN				
Cardiac Dose	Mean Dose	V5Gy	V10Gy	V30Gy	
LAD Dose	Mean Dose	Maximum Dose		V5Gy	
Ipsilateral Lung	Mean Dose	V5Gy		V10Gy	V20Gy
Combined Lung	Mean Dose	V20Gy			

Materials and Methods

Study Area: This study was conducted in the Department of Radiation Oncology, Ruby General Hospital, Kolkata

Study Population: All female patients, with left-sided breast carcinoma, who got treated between 2020 to 2022 in the Department of Radiation Oncology, Ruby General Hospital for adjuvant radiotherapy either after Modified Radical Mastectomy **(**MRM**)** or Breast Conservation Surgery **(**BCS**)**.

Study Design: A Retrospective observational dosimetric study.

Sample Size: Total of 60 patients dosimetric data in 3 arms with each arm consisting of 20 patients.

Inclusion criteria:

1. Female patients with left-sided breast cancer
2. Biopsy proved Left-sided Breast cancer, non-metastatic.
3. Age > 18 years but <70years.
4. After Breast Conservation Surgery **(**BCS**)** or after Modified Radical Mastectomy **(**MRM**)**, if adjuvant Radiotherapy is indicated.

5. Able to hold breath for greater than 15 seconds.

Exclusion Criteria:

1. Patients who are not able to perform cvDIBH due to medical issues or difficulty in following the command
2. Patients treated with other than Hypofractionation **(**40Gy/15fr/3 weeks**)**
3. Patients with metastatic disease.
4. Patients who require axillary nodal radiation Internal mammary nodal radiation or both
5. Any congenital deformity of the chest wall

Methodology and Statistical methods

Methodology:

Structure of the Institutional Modified Voluntary DIBH:

- The initial setup is made in the SBRT bridge **(**GVLO Body Pro-LOK ONE**)** with an abdominal compression plate used while SBRT treatment. We modified the abdominal compression plate by placing a 4-touch sensor fixed in the bottom of the flat surface of the plate with a circuit connection to each sensor with the 4 LED lights and one alarm all connected to the 9V Battery.

Image 1: SBRT Bridge setup in Vac-Lock Immobilization

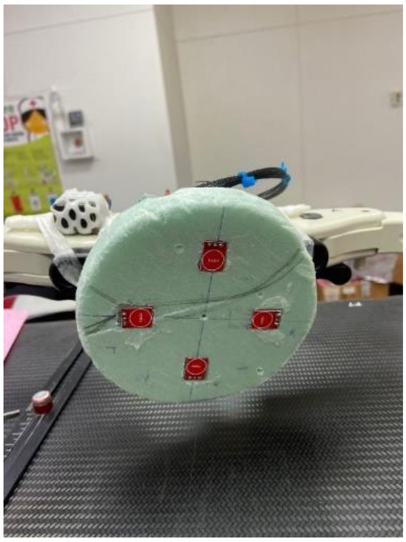


Image 2: Touch Sensor

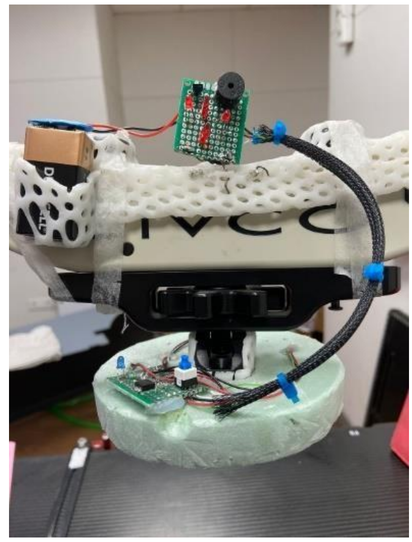


Image 3: LED Light with Alarm

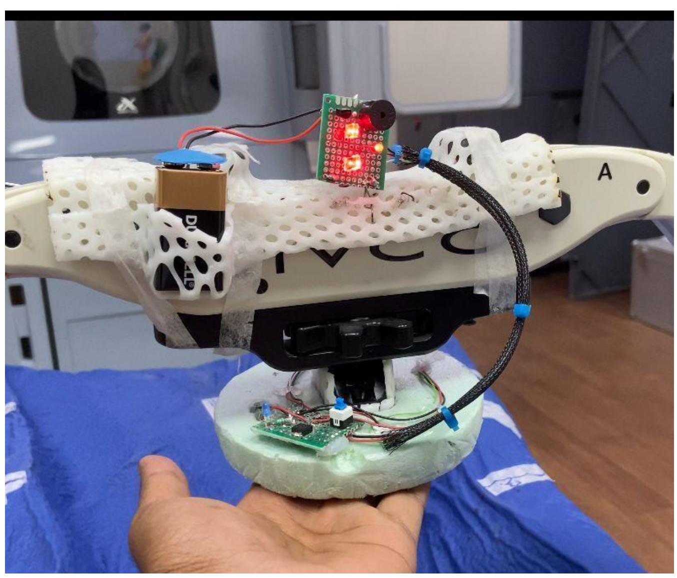


Image 4: Image showing the appearance of light when the touch sensors activated

Image 5: Image showing the full setup with the patient.

- The Bridge was placed at the level of Abdomen four light corresponds to the four sensors and a common alarm was set for audio visual confirmation to achieve the threshold level of breathing. **(**Image 5**)**
- The advantage of using this setup as a monitoring device is it has variable height adjustment **(**21.6 cm to 46.3 cm**)** which can used for set the threshold height of individual patients based on their breath holding capacity and duration.
- When patient's abdomen touches one of the sensors, light and alarm gives signal. Beam on and off is done manually this gives the advantage over conventional voluntary DIBH **(**cv-DIBH**)**.

Patients were selected based on the inclusion criteria. They were explained about the process of mvDIBH technique and its advantages. Patients were trained for voluntary breath hold and advised to do breathe holding practice at home. **(**To hold the breath after taking a comfortable inspiration for at least 15 to 20 seconds**)**. All patients were prescribed hypo-fractionated regimen **(**40Gy in 15 fractions @2.67Gy / fractions, once daily,5 days a week for total of 3 weeks**)** for adjuvant radiotherapy to the left chest wall or left sided breast.

RT Planning: CT simulation Done for all patients in presence of clinician, medical physicist and radiotherapy technologist.

Positioning and Immobilization conventional DIBH:

- All patients were simulated in head first and supine position.
- Patients were positioned on a carbon fiber immobilization breast board, both arms abducted and externally rotated above head by 90 degrees or in a comfortable position for the patient and elbows were kept in flexed position, holding a central pole overhead for FB and cv- DIBH patients.
- Radio opaque lead wires were used to mark anatomical boundaries Radio opaque lead wire was kept over mastectomy scar and BCS scar.
- Patient was made comfortable and relaxed. Then she was given instruction to take a deep breath and to exhale for 1st time and then again to take a deep breath and hold it for at least 15 seconds. For each patient, the time of breath hold was noted in the set-up form.
- The CT isocenters of both free breath (FB) and cvDIBH and mv-DIBH were tattooed with the use of Indian ink after doing the CT simulation.

CT Simulation:

- All the CT simulations were done with kilo-voltage computed tomography(kV-CT)
- CT images were taken in free breath and deep inspiratory phase of respiratory cycle as continuous spiral CT scan with 3 mm slice thickness.
- From the vertex to the umbilicus were taken in CT.

Contouring

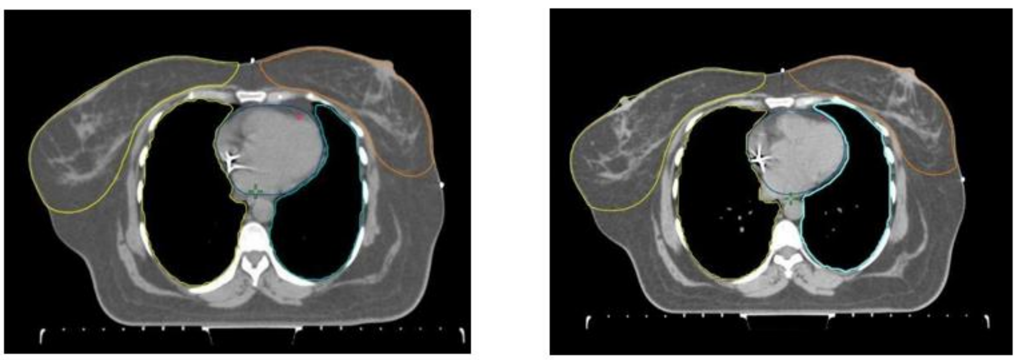
- CT image sets (both FB, cvDIBH, mv-DIBH) were imported in the Eclipse treatment planning system (Version13.1) for contouring and treatment planning.
- The body, clinical target volume (CTV) and organs at risk (OAR)including Heart, Left Anterior Descending artery (LAD), Ipsilateral and contralateral Lung, contralateral breast, esophagus, spinal cord were contoured on each CT slice as per the following guidelines for both the image sets (FB and vDIBH) for each patient.

Target volume

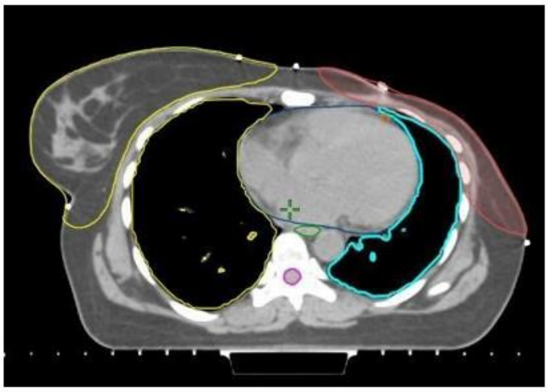
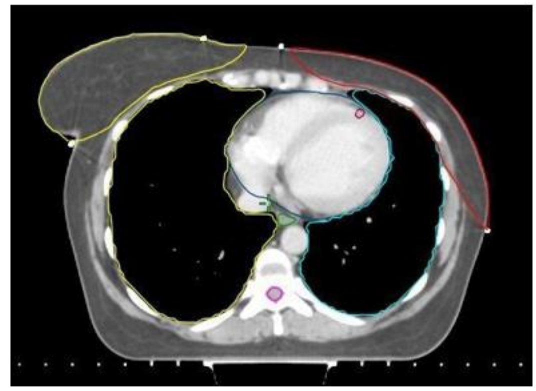
LEFT CHEST WALL or LEFT BREAST:

Contouring of left chest wall or left breast Clinical target volume **(**CTV**)** was done according to RTOG guideline **(**13,14**)**.

Breast:



Borders	
Cranial	Clinical reference + second rib insertion
Caudal	Clinical reference + loss of CT apparent breast
Anterior	Skin
Posterior	Excludes Pectoralis muscles, chest wall muscles, ribs
Lateral	Clinical reference/midaxillary line typically, excludes Latissimus dorsi
Medially	Sternal rib junction

Borders	
Cranial	Caudal border of the clavicle head
Caudal	Clinical reference + loss of CT apparent contra lateral breast
Anterior	Skin
Posterior	Rib–pleural interface **(**includes Pectoralis muscles, chest wall muscles, ribs**)**
Lateral	Clinical reference/mid axillary line typically ,excludes Latissimus dorsi
Medially	Sternal rib junction

Organ at Risk:

Heart: Heart was contoured along with pericardial sac, superiorly from the level of inferior aspect of the pulmonary artery passing the midline and inferiorly till the apex of the heart.

LAD coronary artery: Left anterior descending **(**LAD**)** artery was contoured according to cardiac contouring atlas. Proximal part of the artery was contoured from the end of the left main coronary artery passing anteriorly behind the pulmonary artery. The middle part of artery was contoured descending antero-laterally in the anterior inter ventricular groove. The distal part of the artery was contoured along interventricular groove till the apex of the heart **(**15**)**.

Lungs: Lungs were contoured separately using pulmonary window. Inflated, collapsed, fibrotic, emphysematous lungs were included in the contour whereas hilum, trachea and main bronchus were excluded from the contour.

The contouring was approved by Radiation Oncologist for treatment.

Dose Prescription:

- For all patients, prescribed dose to target volume as 40Gy in 15 fractions **(**2.67Gy daily fraction**)**, 5 days a week for total of 3weeks.
- For BCS patient additional tumor bed boost was given by clinical planning with electron beam, energy selected on the basis of depth of lumpectomy cavity.
- If Supraclavicular irradiation was indicated we prescribed dose of 40Gy in 15 fractions **(**2.67Gy daily fraction**)**,5 days a week for total of 3 weeks clinically. For target volume, 90% isodose was prescribed to cover at least 95 % of target volume.

For OARs specific dose constraints were given as tabulated below Constraints for OARs:

Organ at risk	**Constraint**
Heart	Mean heart dose<3Gy
LAD	No specific constraint given Mean dose and Maximum dose were only documented/reported
Ipsilateral lung	IpsilateralV20<30%

- But dose coverage for target volume was never compromised to achieve the dose constraint for OAR and minor deviation was allowed.

Technique: 3D Conformal Radiotherapy

Energy: Linear accelerator with 6 MV photon

Treatment Planning: Computerized 3D radiation treatment planning system (RTPS) Eclipse (version 15.1, Varian Ag, USA) was used for treatment planning.

Dose Calculation:

Dose calculation was performed using anisotropic analytical algorithm (AAA) version 10.028 with heterogeneity correction.

Plan Evaluation and Dosimetric Analysis:

In plan evaluation, target volume coverage was assessed carefully, and then the doses to Organ at risk were checked according to guideline.

Plans were accepted when 90% of the target volume was covered by at least 95% of the isodose line.

Hotspots (area of 15 cc volume outside target volume receiving >107% dose) were avoided.

Statistics:

Calculation of mean, median and percentage were done using Microsoft Excel 2021 to analyze the data. Data were also compiled in SPSS26 for analysis. The variables with normal distribution were analyzed using two tailed student t-test with independent variables. Results were calculated at $p<0.05$ with 95% confidence interval.

Observation and Results:

Descriptive statistics:

Total 60 patients retrospectively selected between 2020 to 2022 who were diagnosed as left sided breast cancer patients received Adjuvant Radiotherapy using Free Breathing technique, Conventional Voluntary DIBH and Modified Voluntary DIBH technique in Ruby General Hospital.

Patient Characteristics:

Features	Free Breathing	cv-DIBH	mv-DIBH
Total Number of Patients	20	20	20
Age (years) ***Mean***	57 yrs. (31-80)	57 yrs. (33-76)	46.45 yrs. (25-69)
Performance Status			
0	8 (40%)	10(50%)	12(60%)
1	12(60%)	8(40%)	8(40%)
2	0	2(10%)	0
Surgery			
MRM	14(70%)	13(65%)	17(85%)
BCS	6(30%)	7(35%)	3(15%)

Results

As reported In the Tables below, we found a statistically significant reduction in doses of some of the variables of cardiac and Pulmonary doses using mv-DIBH techniques in comparison between Free Breathing and v-DIBH groups. We also reported the mean reductions of V5GyHeart, V10GyHeart, V30GyHeart, V5GyLAD, V5Gy I/L Lung, V10GyI/L Lung, V20GyI/L lung, and V20GyTotalLung and their significance.

Cardiac Dosimetric comparisons between Free Breathing and mv-DIBH groups:

Average Heart Dmean reduced from 5.07Gy to 3.08Gy in FB and mv-DIBH respectively. The average relative reduction in Dmean was 40% which is statistically significant with p <0.0001. Heart Max dose between the FB and mv-DIBH has no significant reduction. Average Mean LAD dose reduction from 17.86Gy to 17.17Gy in FB and mv-DIBH respectively.

The average relative reduction in LAD Dmean was 4% which is statistically insignificant (p 0.737). LAD Dmax between the FB and mv-DIBH has no significant reduction.

	Technique	Mean Dose (Gy)	SD	Mean Dose Difference (Gy)	Mean Dose Reduction (%)	p Value
$D_{MeanHeart}$	FB	5.07	1.95			
	mv-DIBH	3.08	1.155	1.99	**40.24**	***0.00001***
$D_{MaxHeart}$	FB	39.65	6.5			
	mv-DIBH	40.06	2.11	-0.42	-1.02	0.787
$D_{MeanLAD}$	FB	17.86	6.56			
	mv-DIBH	17.17	6.44	0.7	3.9	0.737
D_{MaxLAD}	FB	37.517	8.32			
	mv-DIBH	38.139	6.35	0.62	1.65	0.792

Table 1: Heart and LAD Dmean and Dmax in FB and mv-DIBH techniques.

The average V5Gy heart was 18% in the FB group and 9.41% in the mv-DIBH group with an average relative volume decrease of 47% with a p 0.0001. The average V10Gy Heart was 13.5% in the FB group and 7.3% in the mv-DIBH group with an average relative volume decrease of 46% which is statistically significant (p = 0.002). The average V30Gy Heart was 6.7% in the FB group and 3.42% in mv-DIBH with an average relative volume reduction of 49% which is statistically significant with p = 0.0008. The average V5Gy LAD was 60.51% in the FB group and 53.73% in mv-DIBH with an average relative volume decrease of 11.2% which is statistically insignificant (p=0.206).

	Technique	Mean Volume (%)	SD	Mean Volume Difference (%)	Mean Volume Reduction (%)	p Value
$V_{5GyHeart}$	FB	17.77	7.8			
	mv-DIBH	9.41	4.32	8.36	**47**	***0.0001***
$V_{10GyHeart}$	FB	13.5	7.2			
	mv-DIBH	7.3	3.88	6.21	**45.93**	***0.002***
$V_{30GyHeart}$	FB	6.7	4.74			
	mv-DIBH	3.42	2.23	3.26	**48.96**	***0.008***
V_{5GyLAD}	FB	60.51	18.05			
	mv-DIBH	53.73	15.17	6.78	11.2	0.206

Table 2: Heart and LAD Volumes in FB and mv-DIBH techniques

Pulmonary Dosimetric comparisons between Free Breathing and mv-DIBH groups:

The mean and p-value of the mean Ipsilateral lung dose and Ipsilateral lung volume receiving 5Gy, 10Gy, and 20Gy are reported in the table. The mean dose reduction of 16% in Ipsilateral Dmean was observed with a p-value of 0.018. The mean dose reduction of the total lung of 18% in the Dmean total lung was observed with a p-value of 0.012.

	Technique	Mean Dose (Gy)	SD	Mean Dose Difference (Gy)	Mean Dose Reduction (%)	p Value
$D_{I/L\ Lung\ Mean\ Dose}$	FB	9.46	2.36			
	mv-DIBH	7.92	1.5	1.54	**16.27**	***0.018***
$D_{Mean\ Total\ Lung}$	FB	4.58	1.26			
	mv-DIBH	3.74	0.67	0.84	**18.34**	***0.012***

Table 3: Ipsilateral Lung and Total Lung Dmean in FB and mv-DIBH techniques

The Ipsilateral Lung V5Gy was reduced from 35.5% to 29% in the FB group and mv-DIBH group respectively with an average relative reduction of 18.5% which is statistically significant with a p-value of 0.035. The average ipsilateral lung V10Gy was reduced from 27% to 22% with an average relative reduction of 20% which is statistically significant with a p-value of 0.038. The average ipsilateral lung V20Gy was reduced from 21% to 16% with an average relative reduction of 21% which is statistically significant [p <0.00001].

	Technique	Mean Volume (%)	SD	Mean Volume Difference (%)	Mean Volume Reduction (%)	p Value
$V_{5Gy I/L\ Lung}$	FB	35.5	12.35			
	mv-DIBH	28.93	5.41	6.57	**18.5**	***0.035***
$V_{10Gy I/Llung}$	FB	27.5	10.7			
	mv-DIBH	21.93	4.53	5.57	**20.25**	***0.038***
$V_{20Gy I/L\ Lung}$	FB	20.87	6.85			
	mv-DIBH	16.36	3.45	4.51	**21.61**	***0.0001***
$V_{20Gy Total\ Lung}$	FB	9.79	3.51			
	mv-DIBH	8.22	2.24	1.57	15.93	0.1

Table 4: Ipsilateral Lung and Total Lung Volumes in FB and mv-DIBH techniques

Cardiac Dosimetric comparisons between Conventional Voluntary DIBH and Modified Voluntary - DIBH:

The dosimetric comparisons between the cv-DIBH and mv-DIBH groups showed no significant reduction in all the heart dosimetric parameters such as Heart Mean and Max dose, LAD Mean and Max Dose, Heart V5Gy / V10Gy / V30Gy, and LAD V5Gy.

	Technique	Mean Dose (Gy)	SD	Mean Dose Difference (Gy)	Mean Dose Reducation (%)	p Value
$D_{MeanHeart}$	cv-DIBH	2.98	1.06			
	mv-DIBH	3.08	1.16	0.15	-5	0.777
$D_{MaxHeart}$	cv-DIBH	39.98	2.17			
	mv-DIBH	40.06	2.11	0.08	-0.2	0.907
$D_{MeanLAD}$	cv-DIBH	14.46	7.63			
	mv-DIBH	17.17	6.44	2.71	-18.7	0.232
D_{MaxLAD}	cv-DIBH	34.82	8.56			
	mv-DIBH	38.14	6.35	3.22	-9.55	0.172

Table 5: Heart and LAD Dmean and Dmax in cv-DIBH and mv-DIBH techniques

	Technique	Mean Volume (%)	SD	Mean Volume Difference (%)	Mean Volume Reducation (%)	p Value
$V_{5GyHeart}$	cv-DIBH	8.8	3.9			
	mv-DIBH	9.4	4.32	0.61	-7	0.642
$V_{10GyHeart}$	cv-DIBH	6	3			
	mv-DIBH	7.3	3.9	1.28	-21	0.242
$V_{30GyHeart}$	cv-DIBH	3	2			
	mv-DIBH	3.42	2.23	-0.5	-16	0.534
V_{5GyLAD}	cv-DIBH	54.32	19.16			
	mv-DIBH	53.73	15.17	0.6	1	0.915

Table 6: Heart and LAD Volumes in cv-DIBH and mv-DIBH techniques

Pulmonary Dosimetric comparisons between Conventional Voluntary DIBH and Modified Voluntary - DIBH:

Average Ipsilateral Lung Dmean reduced from 9.15Gy to 7.92Gy in cv-DIBH and mv-DIBH with the average relative reduction in Dmean was 14% which is statistically significant with a p-value of 0.0037. The average total lung Dmean reduced from 4.46Gy to 3.75Gy in cv-DIBH and mv-DIBH with the average relative reduction in Dmean was 16% which is statistically significant with a p-value of 0.016.

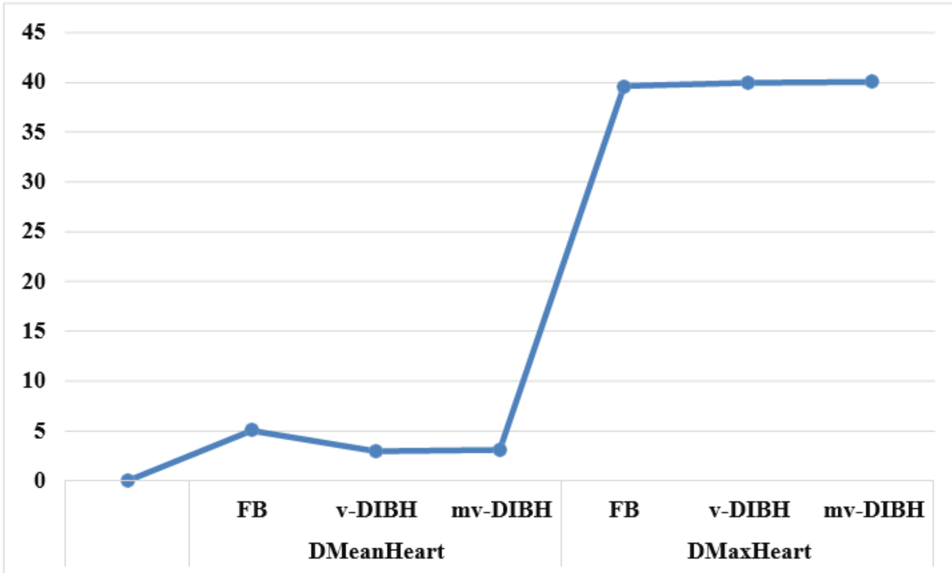
	Technique	Mean Dose (Gy)	SD	Mean Dose Difference (Gy)	Mean Dose Reducation (%)	p Value
$D_{Mean\ Dose\ I/L\ Lung}$	cv-DIBH	9.18	2.13			
	mv-DIBH	7.92	1.5	1.25	13.7	***0.037***
$D_{Mean\ Total\ Lung}$	cv-DIBH	4.46	1.07			
	mv-DIBH	3.75	0.67	0.72	16	***0.016***

Table 7: Ipsilateral Lung and Total Lung Dmean in cv-DIBH and mv-DIBH techniques:

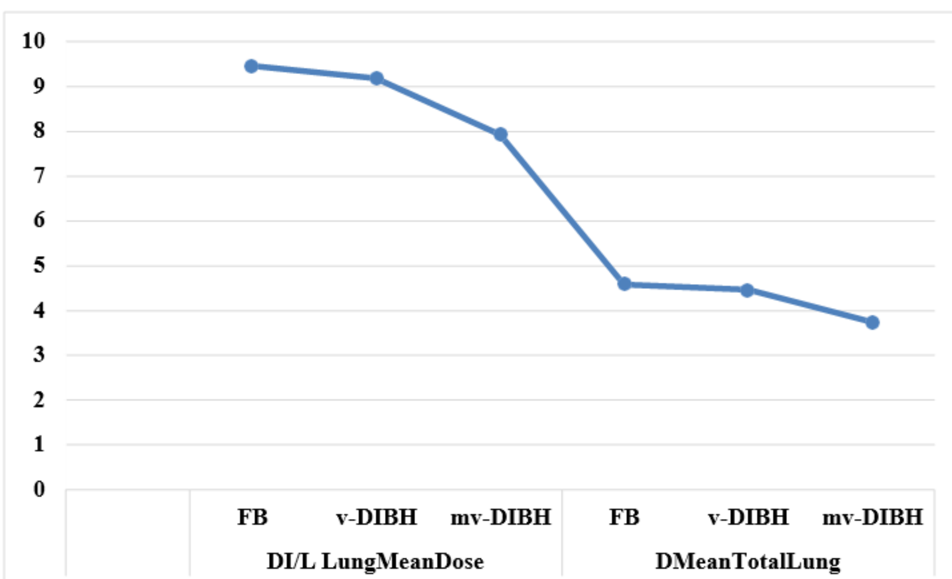
The ipsilateral lung volume V5Gy was reduced from 32.5% to 29% with an average relative reduction of 26% though which is statistically insignificant. Ipsilateral lung volume V10Gy was reduced from 25% to 22% with an average relative reduction of 30% which is also statistically insignificant. The ipsilateral V20Gy was reduced from 16% to 9.5% with an average relative reduction of 38% which is statistically significant with a p-value of 0.015. The total lung V20Gy was reduced from 9.54% to 8.23% with an average relative reduction of 14% which is statistically insignificant.

	Technique	Mean Volume (%)	SD	Mean Volume Difference (%)	Mean Volume Reducation (%)	p Value
$V_{5Gy\ I/L\ Lung}$	cv-DIBH	32.5	7.33			
	mv-DIBH	28.93	5.41	3.6	26.2	0.088
$V_{10Gy\ I/L\ Lung}$	cv-DIBH	25.04	6.45			
	mv-DIBH	21.93	4.43	3.11	29.75	0.086
$V_{20Gy\ I/L\ Lung}$	cv-DIBH	20.1	5.58			
	mv-DIBH	16.36	3.45	3.73	**38.12**	***0.015***
$V_{20Gy\ Total\ Lung}$	cv-DIBH	9.54	2.71			
	mv-DIBH	8.23	2.24	1.31	14	0.104

Table 8: Ipsilateral Lung and Total Lung Volumes in cv-DIBH and mv-DIBH techniques



Line diagram : **1** showing the Heart Dmean and Dmax in all three different techniques



Line diagram: 2 showing the I/L lung and Total lung Mean dose in all three different techniques:

Discussion

Radiotherapy (RT) is an integral component of multimodality management of breast cancer the effectiveness of which was shown in numerous randomized trials and meta- analyses in improving locoregional control and survival. (16 ,17). However, the risk of radiation therapy (RT) associated with cardiovascular and pulmonary disease in women with breast cancer has been a concern for decades. (17) Since then, many techniques were being analyzed to reduce heart and LAD doses in left-sided breast carcinoma patients that require adjuvant radiotherapy of which the DIBH technique is one among them.

Our study is in concordance with the other study that showed the benefit of DIBH techniques over the conventional Free Breathing technique in reducing Heart dose in cases of Left-Sided Breast Carcinoma. There are various techniques of DIBH currently practiced all over the world among them most commonly practiced is Forced Voluntary DIBH in which patients are asked to hold their breath while treatment. The main disadvantage of this method is it's very difficult to assure patients' breath hold while treatment. To avoid this in our institution we created the modified voluntary DIBH technique with the presence of touch sensors, light, and alarm in place it is very easy to monitor the patient while treatment, and patients are also avered of it.

Analysis from our study showed a significant reduction in mean heart dose, V5Gy, V10Gy, and V30Gy heart in patients treated using the mv-DIBH technique compared to the conventional Free Breathing technique. Our study not only analyzed reduced cardiac doses but also analyzed the reduction in the ipsilateral lung mean dose, V5Gy, V10Gy, and V20Gy of Ipsilateral Lung and Total Lung mean dose.

Darby et al. [18] have reported that the risk of heart disease and coronary events is estimated to increase linearly with Dmean heart by 7.4% for each 1 Gy. In our study, the value decreased by 40% using the mv-DIBH technique almost similar to Hayden et al (42%) [19]. The results implied that the dose of the heart in the DIBH group was significantly lower than that in the FB group. Furthermore, some cardiac structures such as the LAD because of the anatomical position may receive a higher dose of left tangential radiotherapy [20,21]. Therefore, LAD related myocardial infraction tends to lead to more severe clinical outcomes than infraction related to major coronary arteries. [22] Nowadays, definitive dose-volume constraints for this branch are difficult to determine.[23] A recent review highlighted that LAD Dmean (12.4Gy) observed in 80 left-sided breast cancer treatment sessions was considerably higher than the Hear Dmean(3.6Gy).

Additionally, in the literature search, a wide range (1.9 to 40.8Gy) of LAD mean dose has been reported.[24] In our group of patients, the LAD Dmean is 17.17Gy in the mv- DIBH group which is 4% lesser than the Free Breathing group. In our study, we also recorded a significant reduction in the Heart V5Gy, V10Gy, and V30Gy 47%, 46%, and 49% respectively in the mv-DIBH group in comparison with Free Breathing.

Lung irradiation induces pneumonitis or fibrotic reaction, especially for patients affected by previous respiratory disorders [25]. To reduce radiation pneumonitis risk to ≤ 20%, Marks et al. recommended using V20Gylung ≤ 30–35% and Dmeanlung ≤ 20–23 Gy [26].

Additionally, research conducted by Gokula et al. and Kasmann et al. implied that Locoregional radiotherapy increased the mean lung dose, and ipsilateral lung volume receiving 20 Gy (V20)

>30% have been identified as risk factors for RP [27,28]. In our study, ipsilateral lung dosimetric indicators (Dmean, V20, V10, and V5) were recorded. We observed an Ipsilateral Lung Dmean of 7.9Gy in mv-DIBH with an average relative reduction between Free Breathing of 16%.

Lastrucci et al [29] have obtained a mean reduction of 23.6%. We also observed in the mv-DIBH technique an overall mean ipsilateral lung V5Gy, V10Gy, and V20Gy of 28.9%, 20.87%, and 9.79% respectively with an average relative reduction of 18.5%, 20.25%, 21.6% compared to FB. Vikstrom et al. [30] reported a mean volume reduction of 18% between the two techniques. We can conclude that mv-DIBH technology may reduce the incidence of RP by reducing the mean Ipsilateral lung dose, V20Gy, V10Gy, and V5Gy.

In our study, we also compared the cardiac and pulmonary doses of the conventional voluntary DIBH with the modified voluntary DIBH. Among the cardiac dosimetric parameters, we didn't find out any significant difference between the two techniques. In pulmonary dosimetric parameters, we found a significant relative dose reduction in the Ipsilateral Lung Mean dose of 13.7% in the mv-DIBH technique compared with the cv-DIBH technique which is statistically significant (p-value =0.037). We observed in the mv-DIBH techniques an overall mean ipsilateral lung V20Gy of 16.36% with an average relative reduction of 38.12% compared to cv-DIBH which is statistically significant (p-value=0.015). The Total Lung Dmean in the mv-DIBH technique has an overall Dmean of 3.75Gy with an average relative reduction of 16% compared to the cv-DIBH technique which is statistically significant(p-value=0.016).

The potential limitation that exists in this study may be due to different surgical interventions that the patient underwent either with Modified Radical Mastectomy or Breast Conservative Surgery. Even though we achieved a significant dose reduction in the Heart Dmean in the mv-DIBH technique, the LAD mean and max dose reduction difference is insignificant it may be due to one the reasons such as different age groups, less sample size, or anatomical variation.

Conclusion

Heart complications could compromise the benefits of adjuvant left breast radiotherapy in improving local control and survival. The modern techniques such as DIBH allows a better sparing of the heart and ipsilateral lung. Our findings confirm the literature data about the DIBH technique advantage in terms of dose reduction of cardiac and pulmonary doses for tangentially treated left-sided breast cancer patients. This was a retrospective study, further prospective study with larger samples is warranted to evaluate the long-term clinical implication of this institutional mv-DIBH technique and its relevant dosimetric results.

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