Journal of Cancer Science & Therapy
ISSN: 1948-5956

Kumar et al., J Cancer Sci Ther 2019, 11:11

Research Article Open Access

Advantages of Deep Inspiration Breath Hold (DIBH) Technique over Free Breath (FB) in Terms of Reduce Risk of Cardiac and Pulmonary Doses for Left Sided Breast Cancer Radiotherapy Treatment

Arvind Kumar[1]*, Bhatt CP[2] and Rishabh Dobhal[3]

[1]*Department of Radiation Oncology, All India Institute of Medical Sciences, Rishikesh, India*
[2]*Department of Radiotherapy, Sarvodaya Hospital, Faridabad, New Delhi, India*
[3]*Department of Radiotherapy, Swami Rama Himlayan University, Jolly Grant, Dehradun, India*

Abstract

Aim: The purpose of this dosimetric study was to find a suitable treatment & planning technique which can serve as an optimized technique with respect of PTV coverage and better sparing of concerned OAR's.

Introduction: DIBH technique for left sided breast cancer is popular now-a-days, because as in DIBH the heart gets separated from the chest wall and left lung volume increases significantly resulting in reduced heart and left lung doses as compared to FB technique. Referring to previous available literature of DIBH studies, it is clearly showed that DIBH has advantage over FB in case of left sided breast cancer radiotherapy treatment in terms of reduced risk of cardiovascular related morbidity and mortality. DIBH is now a well-established technique in case of left sided breast cancer radiotherapy treatment. This dosimetric study explores the benefit of using a suitable treatment & planning technique in case of left sided breast cancer radiotherapy treatment.

Material and methods: In this study we have taken 10 patients of left sided breast cancer (7 MRM + 3 BCS) treated with DIBH technique at our Centre. The Varian's RPM respiratory gating system (Varian Medical System, Palo Alto, CA) was used for respiratory motion monitoring. All patients were coached for three to four days for obtaining the desired respiratory breathing cycle. Once the patient was coached successfully, CT scans were acquired, one with conventional free breath (FB) and also three random scans with deep inspiration breath hold (DIBH) i.e., gated CT scans on SOMATOM Sensation Open CT simulator machine (Siemens Medical System's).

On importing the acquired CT images in TPS, it showed that left lung volume increment in DIBH technique as compared to FB was significant. Patient contouring and treatment planning performed on Eclipse V13.5 and a dosimetric comparison was made between two treatment & planning techniques i.e., ((DIBH *vs.* FB) for (3DCRT *vs.* IMRT) and it is for PTV coverage, left lung, heart, left anterior descending coronary artery (LAD), left ventricle and contralateral breast.

Results: Left lung volume increment in DIBH technique as compared to FB was 69.375% showed that there was a significant increment in left lung volume, which results a larger separation of heart and the PTV chest wall. DIBH showed a significant reduction in doses of associated organ at risk.

Conclusion: This dosimetric study showed that in FB and DIBH techniques, DIBH is showing drastically dose reduction for left lung, heart C/L breast, LAD and left ventricle. From the data of DIBH and FB, we can conclude that DIBH technique in many respect has advantage over FB, which is solving the purpose of reducing cardiac and pulmonary doses without compromising the PTV coverage.

Keywords: Breast cancer; Deep inspiration breath hold; Radiotherapy treatment; Pulmonary doses

Introduction

DIBH technique for left sided breast cancer is popular now-a-days in this technique patient take a deep breath during treatment and hold it while the radiation is delivered, due to this the heart get separated from the chest wall and also left lung volume increases significantly resulting in reduced heart and left lung doses as compared to FB technique [1]. Referring to previous available literature of DIBH studies, it is clearly shows that DIBH has advantage over FB in case of left sided breast cancer radiotherapy treatment in terms of reduced risk of cardiovascular related morbidity and mortality [2]. DIBH is now a well-established technique in case of left sided breast cancer radiotherapy treatment. This dosimetric study explores the benefit of using a suitable treatment & planning technique in case of left sided breast cancer radiotherapy treatment. The pervious DIBH literature's clearly showed that there is an advantage of DIBH over FB in case of left sided breast cancer. Various papers shows that in DIBH case there was significant reduction in left lung doses & also reduction in cardiac morbidity and mortality [3]. Our study shows that the left lung volume increment in DIBH technique as compared to FB was (966.288 cc *vs.* 1612.07 cc i.e., 69.375%), also the distance between chest wall and heart & its associated organ at risk e.g., left anterior descending coronary artery (LAD), left ventricle etc. increases significantly, resulting in a decrease dose to these OAR's.

***Corresponding author:** Arvind Kumar, Department of Radiation Oncology, All India Institute of Medical Sciences, Rishikesh, India, Tel: +918750498817; E-mail: arvinddiundi7@gmail.com

Received October 23, 2019; **Accepted** November 13, 2019; **Published** November 20, 2019

Citation: Kumar A, Bhatt CP, Dobhal R (2019) Advantages of Deep Inspiration Breath Hold (DIBH) Technique over Free Breath (FB) in Terms of Reduce Risk of Cardiac and Pulmonary Doses for Left Sided Breast Cancer Radiotherapy Treatment. J Cancer Sci Ther 11: 299-307.

Methods and Methods

Patient selection

In this study we have taken 10 patients of left sided breast cancer (MRM+BCS) treated initially at our hospital. The selection of patients is based on their age, ability to breath hold, physical fitness etc..

Respiratory gating

The Varian's RPM respiratory gating system (Varian Medical System, Palo Alto, CA) was used for respiratory motion monitoring. All patients were coached for three to four days for obtaining the desired respiratory breathing cycle [4,5]. The patient selection criteria is that the patient were ask to take a deep breath which they can hold with ease and once breath hold done, the breathing pattern should lock at that position and it should not fall below the gated window level, & a minimum time of breath hold should be not be less than 20 seconds [6,7]. During gating process a six point reflective IR marker block was placed at patient thorax usually at the xiphoid level, but has also been placed between xiphoid level and umbilicus. This marker block was simulating the breathing pattern of patient, it was tracked by an infrared camera which is a part of RPM system showing breathing pattern of patient with the help of software.

CT scan acquisition

Once the patient is coached successfully, patient was positioned on all in one board fixed by a indexer consisting of head rest, hand positioning rod, Vac-lock already placed on it by Radiotherapy Technologist (RTT). The Vac-lock had polystyrene balls inside it, once air was pushed into it, then RTT shape it according to the patient body so that proper positioning of patient can be assured during simulation, planning and treatment dose delivery [8,9].

CT scans were acquired, one with conventional free breath and also random scans with deep inspiration breath hold i.e., gated CT scans on Siemens Medical System's SOMATOM Sensation Open computed tomography machine. It is taken care that during the deep inspiration breath hold random scans the breathing pattern was monitored through Varian's RPM respiratory gating system (Varian Medical System, Palo Alto, CA) to make sure that the scan acquisition is within the desired threshold level as of the time of coaching sessions. Finally the acquired CT scans were transferred to the Varian's server [10,11]. As we know that the external marker block tracking is not sufficient which is just simulating the patient's breathing pattern. So prior to target and OAR's delineation, one gated CBCT is also acquired on Truebeam Medical Linear Accelerator of Varian Medical System, Palo Alto, CA and this gated CBCT scan was registered with the gated CT image set. This leads to more accuracy in delineation of structures.

Target and OAR's delineation

The acquired CT images were imported on Eclipse Planning System version 13.5 by Varian Medical System, Palo Alto, CA and the scan with free breath and deep inspiration breath hold were fused together to see the separation of chest wall and heart & its associated organ at risk e.g., left anterior descending coronary artery (LAD), left ventricle etc. and the separation was noted down [12,13]. Once registration of CT images were done then the delineation of planning target volume and OAR's i.e., left lung, heart, left anterior descending coronary artery (LAD), left ventricle, contralateral breast etc. was performed by the Radiation Oncologist.

Treatment planning

After completion of delineation of planning target volume and associated organ at risk, the CT images were handover by the Radiation Oncologist to the Physicist for the treatment planning purpose [14,15]. Two plans for each one of the selected patient, i.e., one with 3DCRT technique and second one with IMRT technique was performed by the Physicist using Eclipse Planning System version 13.5 by Varian Medical System, Palo Alto, CA.

Dose volume histogram analysis

Once the treatment plans was ready for plan evaluation. The plans, i.e., with 3DCRT technique and second one with IMRT technique was evaluated by Radiation Oncologist. After evaluating the desired Planning target volume (PTV) coverage which is 95% of target volume should encompasses with at least 95% of the prescribed dose and following the as low as achievable tolerance doses for organ at risks structures suitable treatment plan was approved [16,17]. Patient reference gated pattern taken prior to CT image acquisition was also send to Truebeam machine, so that at the time of treatment we can make it as a reference pattern to verify the breathing pattern at the treatment dose delivery.

Treatment dose delivery

Treatment of all patients were done on Truebeam Medical Linear Accelerator of Varian Medical System, Palo Alto, CA. Once the patient was taken to the treatment couch, proper positioning of patient was assured by the RTT using whole simulating condition as done at CT simulator. Then a four marker block was placed on the pre-marked position on patient body, the marker block was simulating the breathing pattern of patient, it was tracked by an infrared camera which is a part of RPM system showing breathing pattern of patient with the help of software [18,19]. After proper patient setup, the patient was ask to take a deep hold breath similar to that as done on coaching and CT images acquisition time and successively gated KV, gated CBCT, gated fluoroscopic images as per requirement was performed. Once assuring proper patient positing the patient was treated by DIBH technique i.e., the beam will only ON while the breathing pattern is inside the gated window [20].

Results

Left lung volume increment in DIBH technique as compared to FB was (966.288 cc *vs.* 1612.07 cc i.e., 69.375%) showed that there was a significant increment in lung volume, which causes a larger separation of heart and its related structures. Evaluation of 3DCRT *vs.* IMRT planning for both the cases FB *vs.* DIBH was done and results are given below

FB case

Dose Volume Histogram (DVH) analysis of 3DCRT *vs.* IMRT plans for PTV coverage found that PTV coverage of $V_{95\%}$ (95.37% *vs.* 99.61%), for left lung's V_{5Gy} (35.94% *vs.* 91.07%) and V_{20Gy} (17.17% *vs.* 33.3%), for heart mean dose D_{mean} (3.93 Gy *vs.* 12.8 Gy), for LAD max dose D_{max} (46.75 Gy *vs.* 38.96 Gy), for Left ventricle max dose D_{max} (46 Gy *vs.* 41.16 Gy), and for contralateral breast V_{4Gy} were (0.1941% *vs.* 4.741%).

DIBH case

Dose Volume Histogram (DVH) analysis of 3DCRT *vs.* IMRT plans for PTV coverage found that PTV coverage of $V_{95\%}$ (95.37% *vs.* 99.206%), for left lung's V_{5Gy} (27.17% *vs.* 79.45%) and V_{20Gy} (14.98% *vs.* 24.44%),

for heart mean dose D_{mean} (2.635 Gy *vs.* 9.455 Gy), for LAD max dose D_{max} (37.124 Gy *vs.* 33.499 Gy), for Left ventricle max dose D_{max} (36.746 Gy *vs.* 28.336 Gy), and for contralateral breast V_{4Gy} were (0.5455% *vs.* 11.912%).

Discussion

Deep inspiration breath hold (DIBH) technique for left sided breast cancer radiotherapy treatment has been used effectively to achieve its objective by 3DCRT planning technique as compared to IMRT planning technique. Some other techniques like respiratory gating, Active breath control (ABC) can also be used for such type of challenges. This study shows that PTV coverage is adequate by both these technique and plan made with 3DCRT technique had better left lung, heart, contralateral breast sparing [21,22]. But on the other hand LAD, left ventricle max. doses were more in 3DCRT plans as compared to IMRT plans [23]. As we can clearly see in below given Table 1 that left lung volume increment in FB *vs.* DIBH was 966.288 cc *vs.* 1612.07 cc, which was 69.3749 *vs.* 6902%. It showed a great increment of left lung volume which helps in significant reduction of doses. Due to this there was also a significant reduction in total lung doses (Figures 1-10).

L. Lung Volume (cc)		Increment (%)
FB	DIBH	
756.1	1390.26	83.87250364
1020.2	1996.7	95.71652617
661.7	1357	105.0778298
1393.1	1945.1	39.62386046
915.4	1489.4	62.70482849
950.4	1459.5	53.56691919
910.3	1497.1	64.46226519
1242.4	1744.8	40.4378622
1052.1	2132.8	102.7183728
761.18	1108.04	45.56872225
966.288	1612.07	69.37496902

Table 1: Mean value of left lung volume increment in FB *vs.* DIBH.

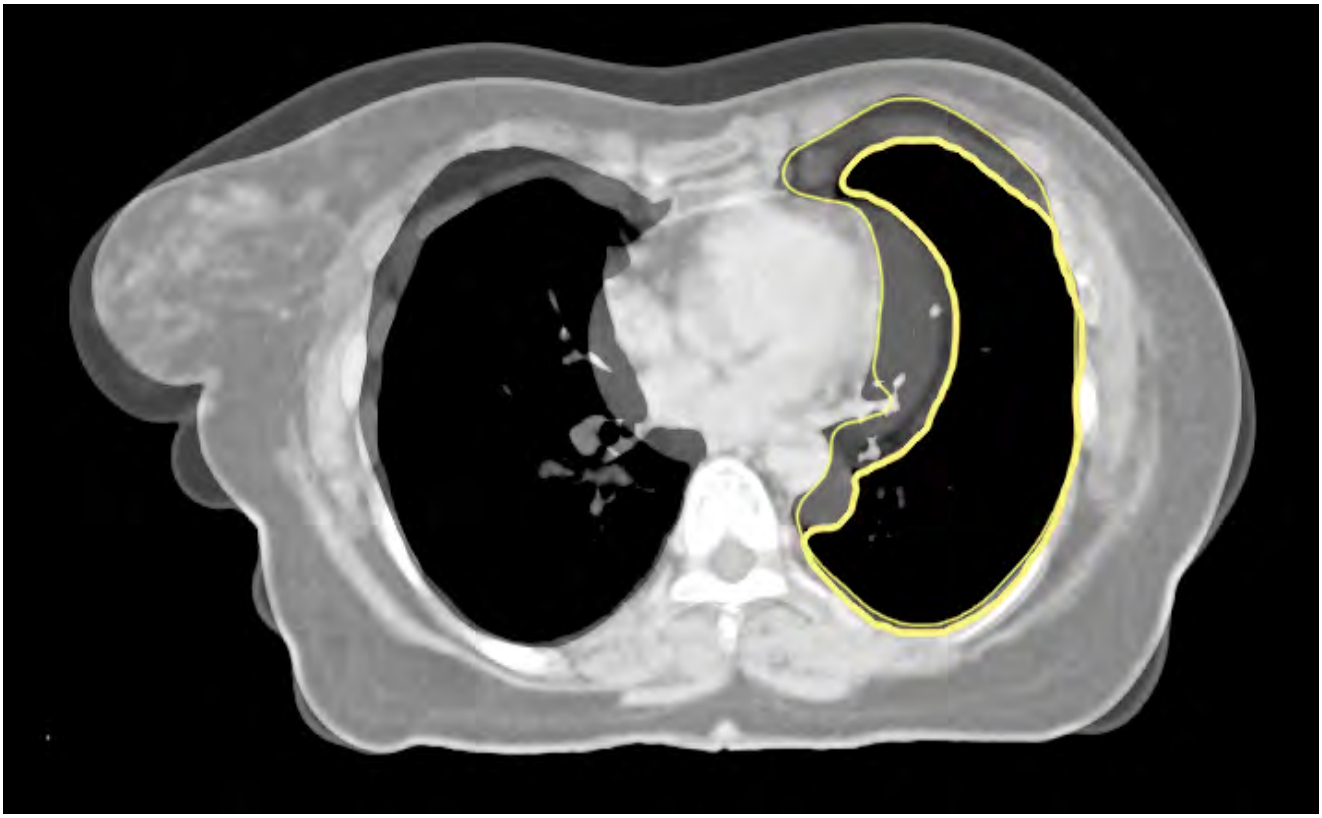

Figure 1: $V_{95\%}$ dose for 3DCRT plan.

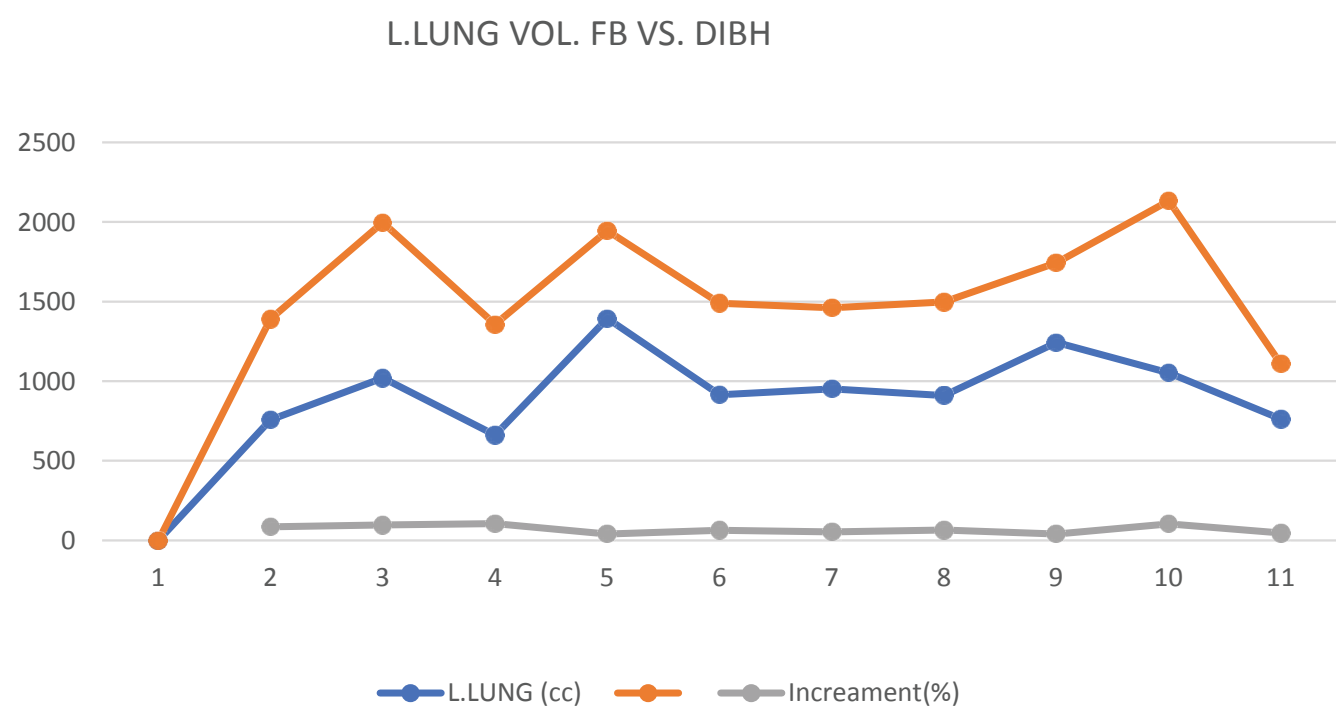

Figure 2: PTV coverage is adequate by both these technique and plan made with 3DCRT technique had better left lung, heart, contralateral breast sparing. But on the other hand LAD, left ventricle max. doses were more in 3DCRT plans as compared to IMRT plans.

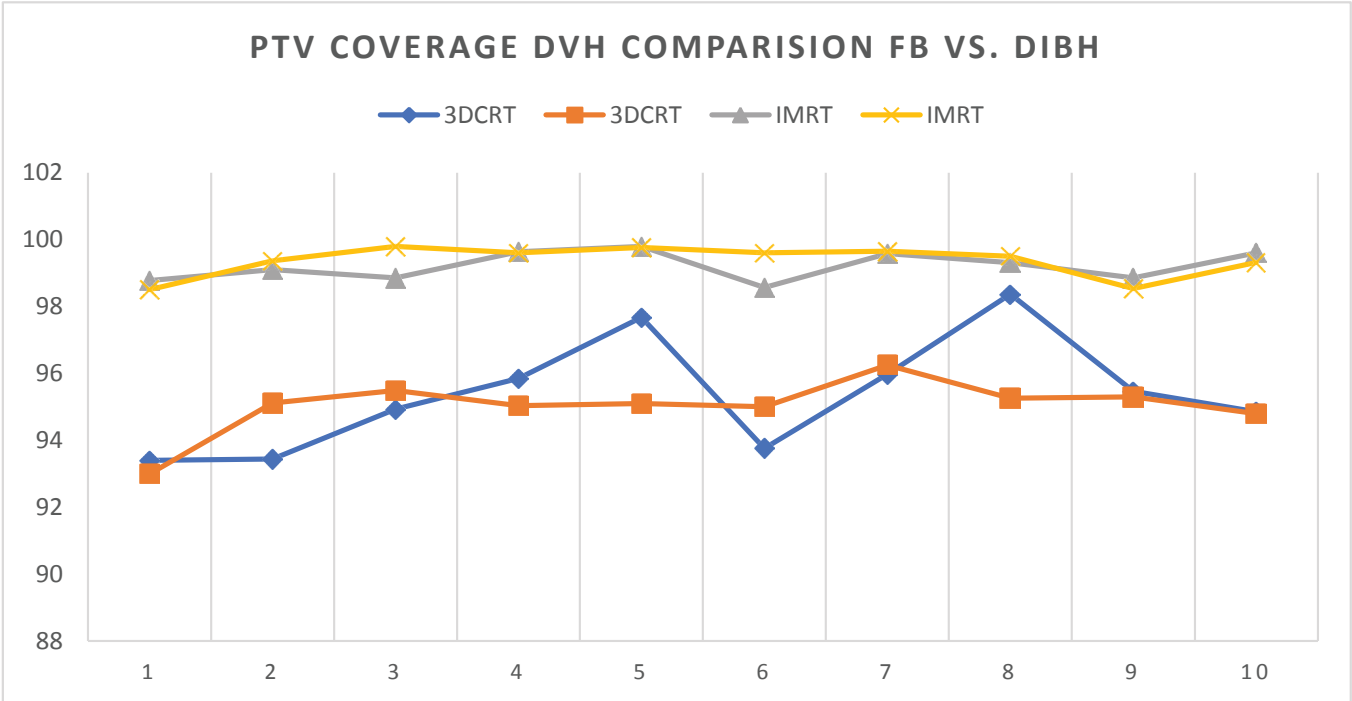

Figure 3: PTV coverage was adequate in both the treatment techniques, as listed in Table (1). Mean of PTV dose coverage V 95% by plans made with 3DCRT technique was 95.37 % versus the plan made with IMRT technique was 99.206%. Obviously the coverage was better in case of IMRT plans but at the same time number of MU's is also much higher i.e., average approximately 1350 MU's versus average 312 MU's for tangent field and approximately average 246 MU's for SCF fields.

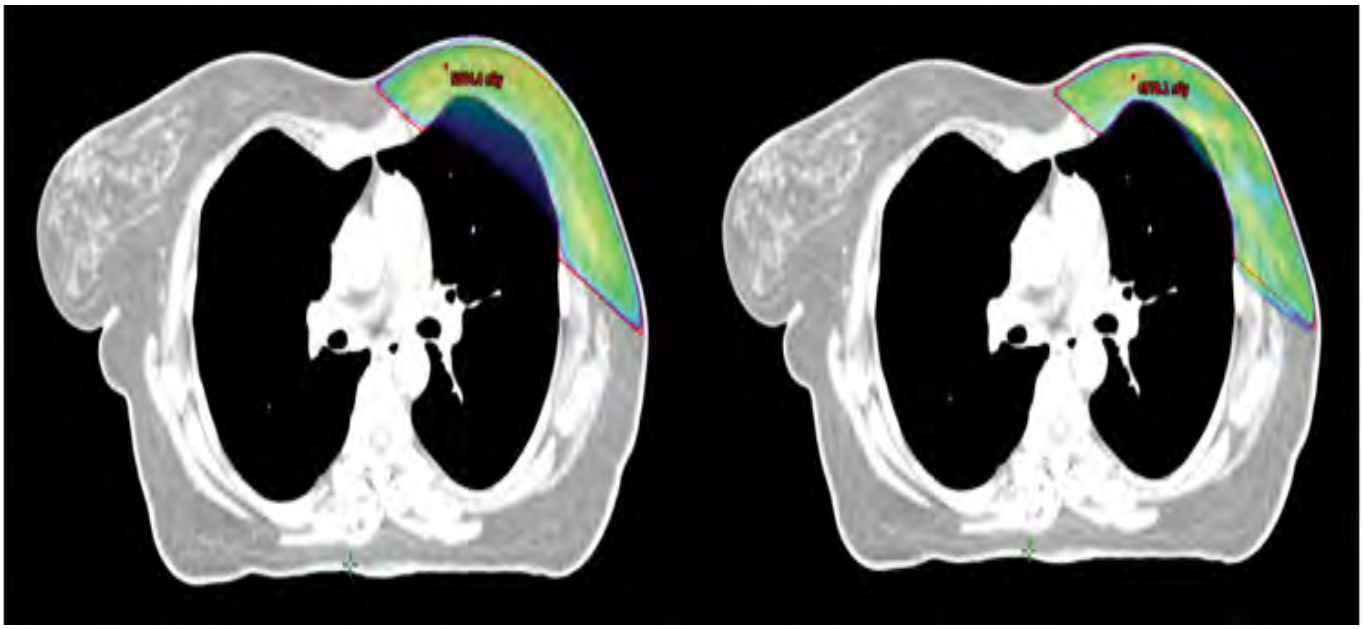

Figure 4: V95% dose colour wash for 3DCRT plan and V95% Dose colour wash for IMRT plan.

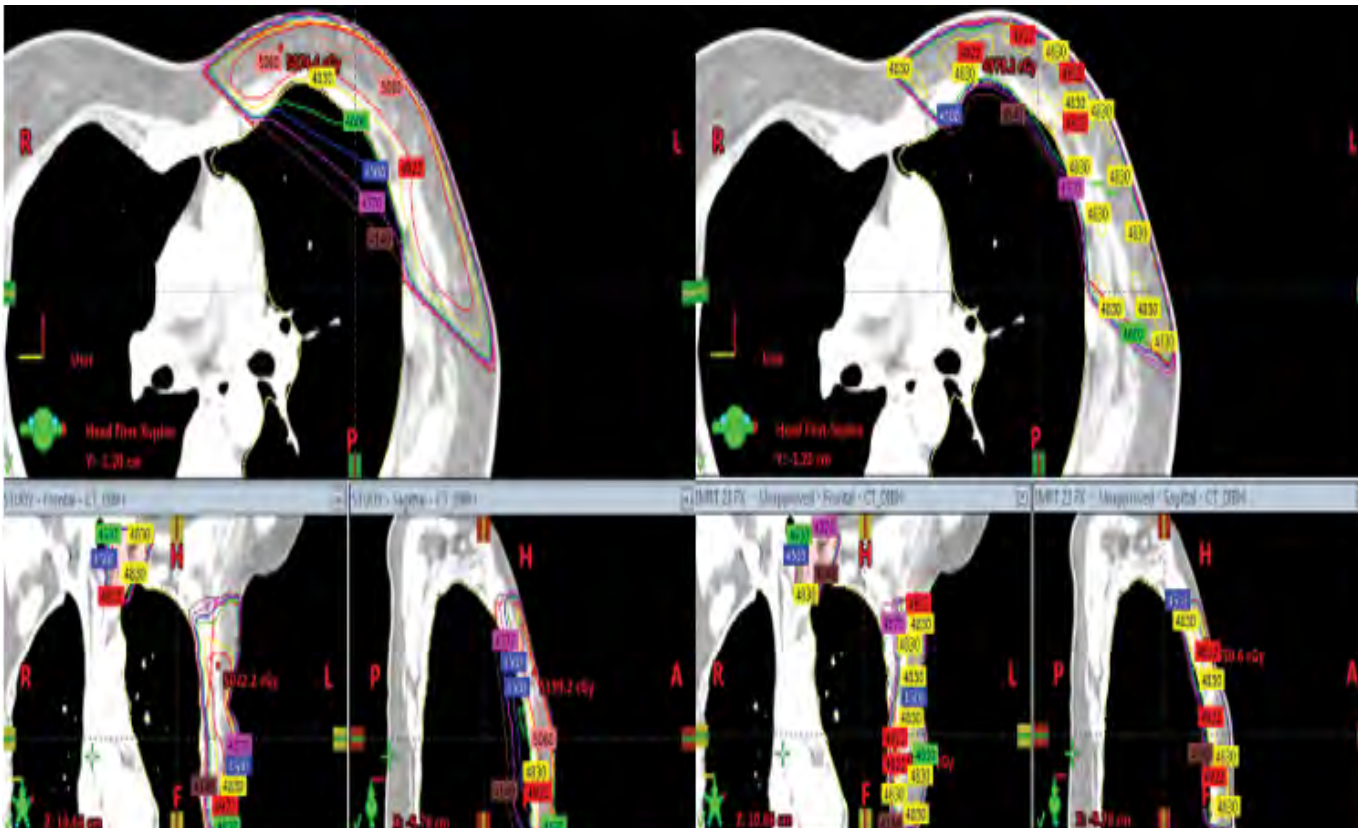

Figure 5: Isodose for 3DCRT plan and isodose for IMRT plan.

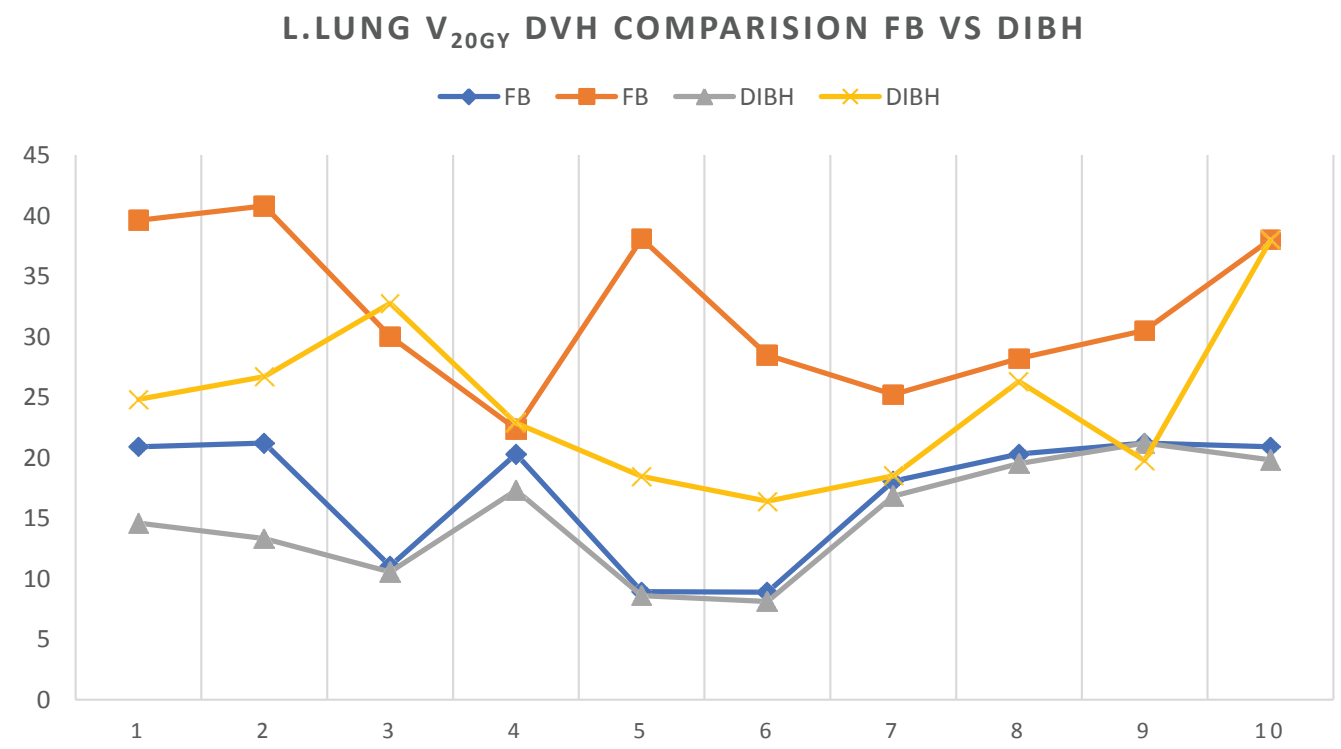

Figure 6: Left lung dose. Left lung V5 Gy (35.94% vs. 91.07%) & (27.17% vs. 79.45%) and V20 Gy (17.17% vs. 33.3%) & (14.98% vs. 24.44%) respectively for 3DCRT and IMRT plans, which clearly showed that there was a significant reduction in left lung doses in 3DCRT plans as compared to those plans created with IMRT technique for both the techniques i.e., FB vs. DIBH. Above data clearly showed that left lung doses are lowest side in case of DIBH 3DCRT case.

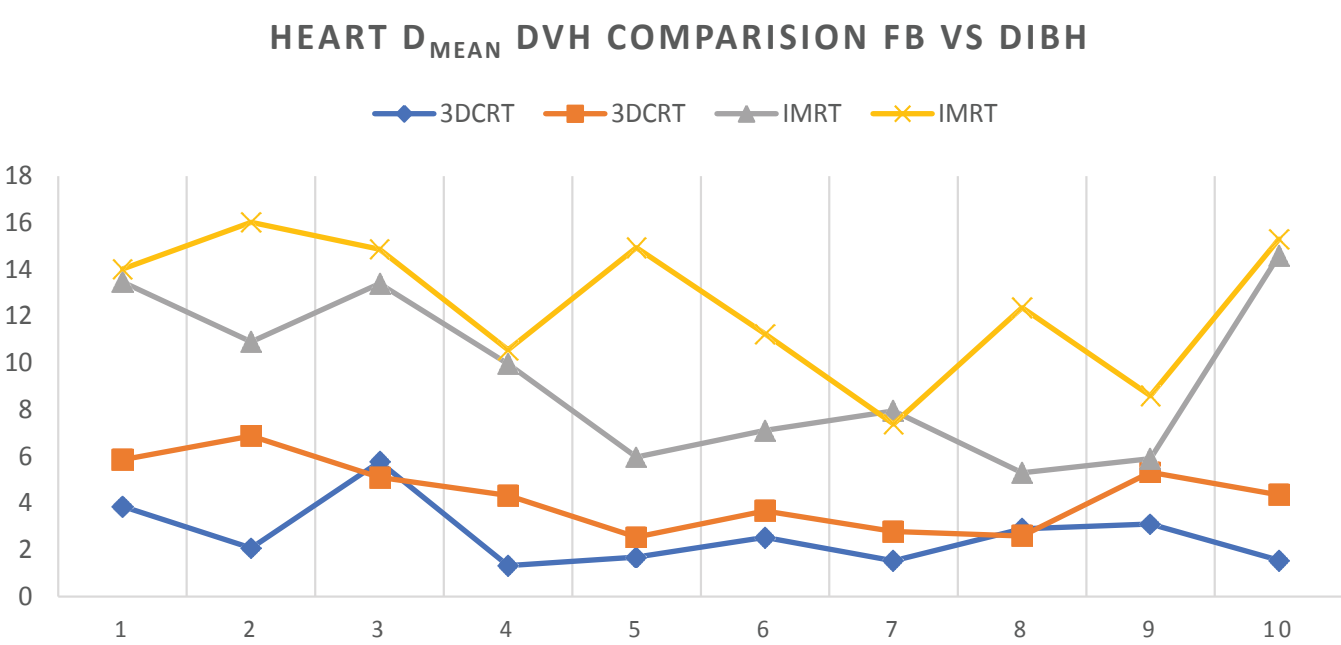

Figure 7: Heart dose. Heart mean dose were Dmean (3.93 Gy *vs.* 12.8 Gy) & (2.635 Gy *vs.* 9.455 Gy) respectively for 3DCRT and IMRT plans, indicates that mean dose of heart is much lower in case of 3DCRT plan whereas in case of IMRT plan it was relatively higher for both the techniques i.e., FB *vs.* DIBH. Hence best heart sparing with DIBH 3DCRT technique.

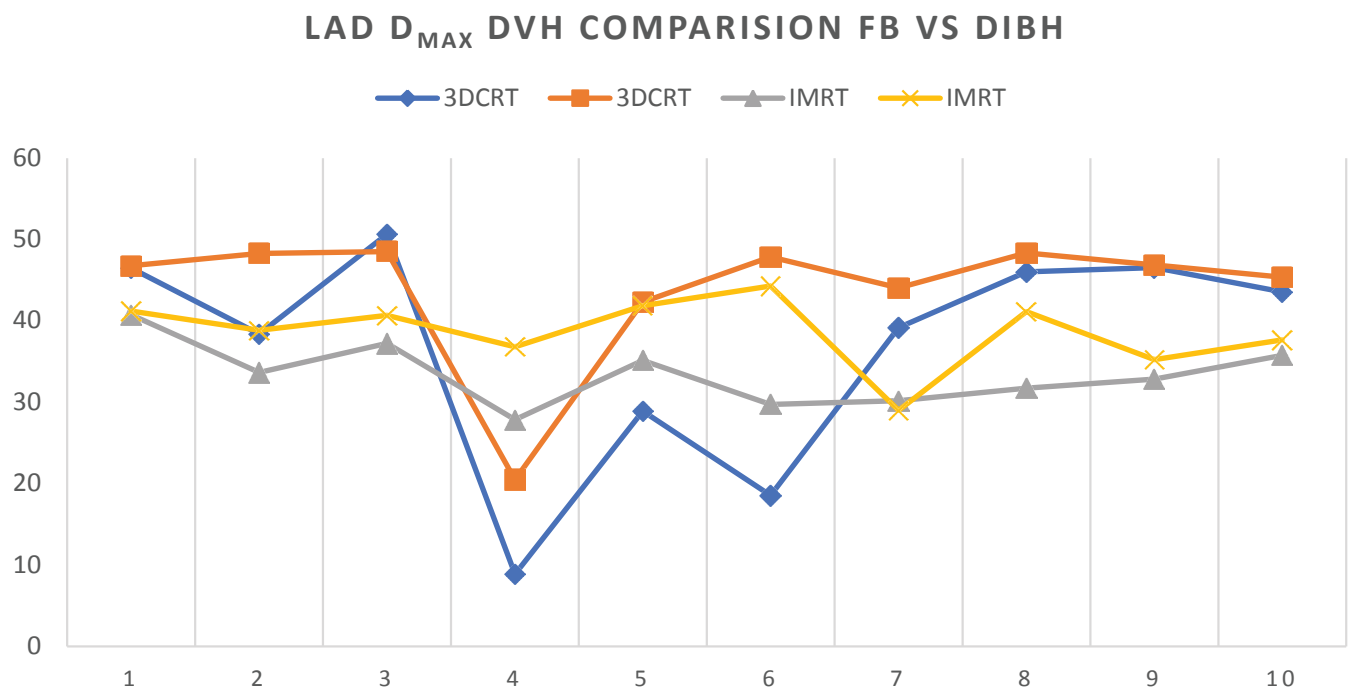

Figure 8: LAD dose. LAD max dose Dmax (46.75 Gy *vs.* 38.96 Gy) & (37.124 Gy *vs.* 33.499 Gy) respectively for 3DCRT and IMRT plans, indicates that max dose of LAD is relatively more in case of 3DCRT as compared to the IMRT plan. This was due to reason that in the case of 3DCRT planning LAD is directly came under beam portal, resulting in more dose to LAD, whereas in case of IMRT plan we were avoiding LAD irradiation. But in those 3DCRT plans where LAD was out of beam portal LAD doses was much lower as can seen in the graph.

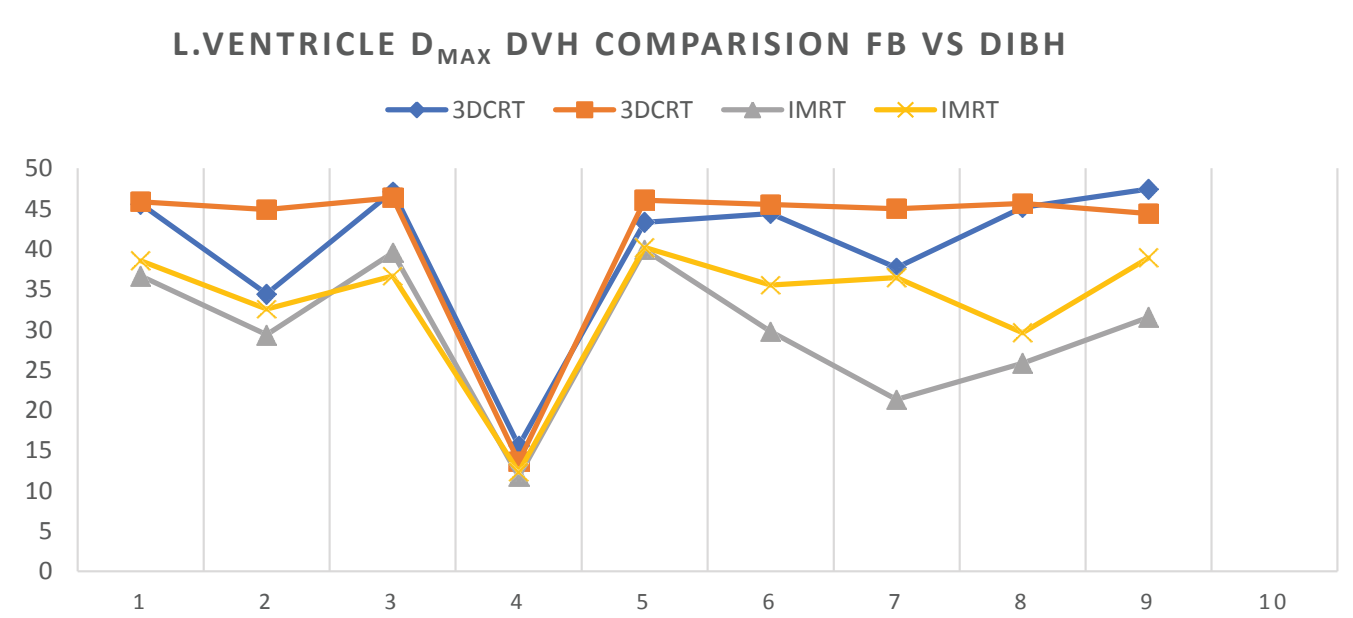

Figure 9: Left ventricle dose. Left ventricle max dose Dmax (46 Gy *vs.* 41.16 Gy) & (36.746 Gy *vs.* 28.336 Gy) respectively for 3DCRT versus IMRT plans, indicates that max dose of LAD is relatively more in case of 3DCRT as compared to the IMRT plan. This was due to reason that in the case of 3DCRT planning left ventricle is directly came under beam portal, resulting in more dose to it, whereas in case of IMRT plan we were avoiding left ventricle irradiation. But in those 3DCRT plans where left ventricle was out of beam portal, it's doses was much lower as can seen in the graph.

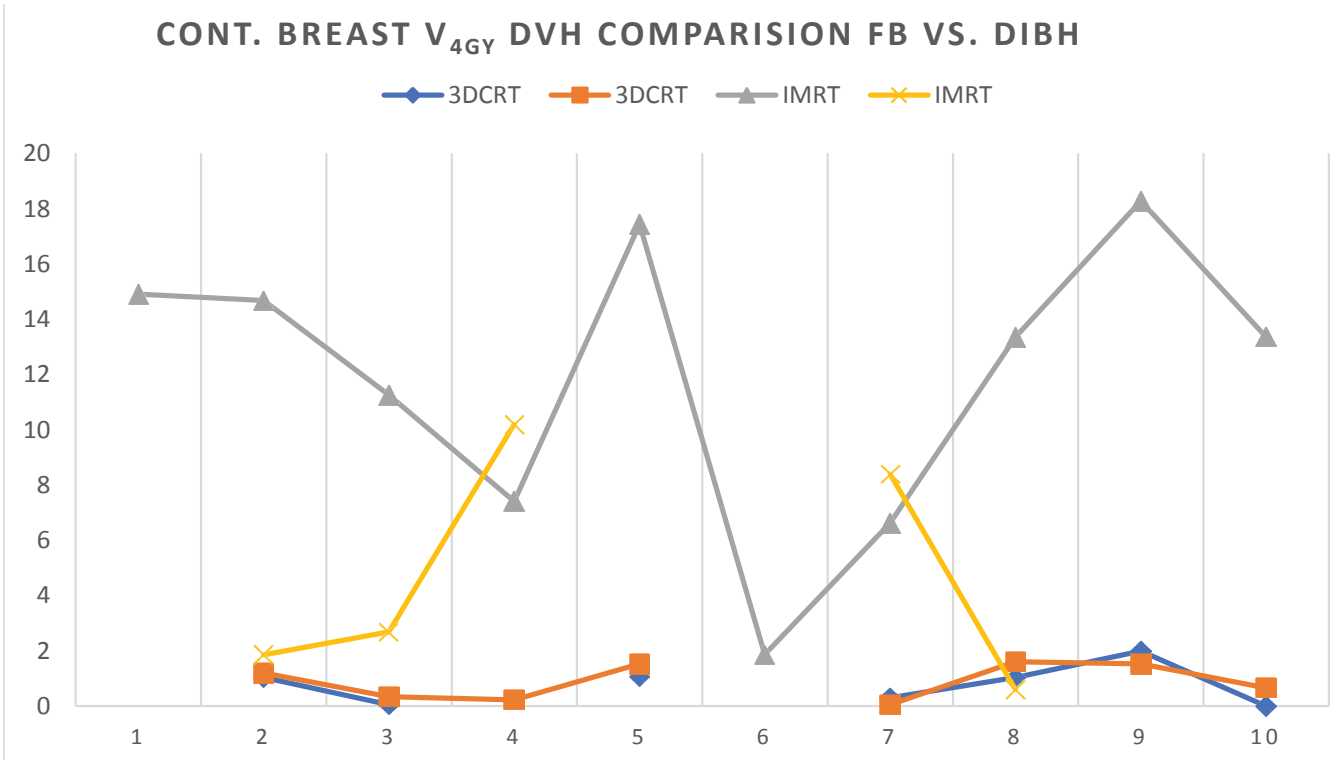

Figure 10: Contralateral breast dose. According to data V4 Gy doses for contralateral breast were (0.1941% *vs.* 4.741%) & (0.5455% *vs.* 11.912%) respectively. Which indicates that contralateral breast doses in the case of 3DCRT plans were much lesser than that with the IMRT plans.

Conclusion

This dosimetric study showed that for both the techniques i.e., FB and DIBH, IMRT has better PTV coverage and LAD, left ventricle sparing, but on the other hand more doses to left lung, heart and contralateral breast as compared to 3DCRT technique. DVH evaluation concluded that 3DCRT plans have been preferable technique in case of left sided breast cancer radiotherapy treatment, as PTV coverage was adequate in both the techniques, and left lung, heart, contralateral breast doses were lesser in case of 3DCRT plans, although a relatively little higher doses to the LAD and left ventricle. On comparing FB and DIBH techniques, DIBH is showing drastically dose reduction for left lung, heart, LAD and left ventricle. From the data of DIBH and FB, we can conclude that DIBH technique in many respect has advantage over FB, which is solving the purpose of reducing cardiac and pulmonary doses without compromising the PTV coverage. Hence DIBH can be effectively used in the clinic for left breast cases.

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