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Dosimetric Study of Voluntary Deep Inspiratory Breath-Hold (V-DIBH) Vs Free Breathing (FB) Technique on Organ Doses for Left-Sided Breast Cancer

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ABSTRACT

Introduction: Long term cardiac morbidity is a concern with left sided breast/chest wall irradiation. In this present study, we have evaluated the Impact of Voluntary deep inspiratory breath hold (V-DIBH) Vs Free Breathing (FB) technique on heart and lung doses for left-sided breast cancer with audio visual guidance.

Material and Methods: A total of 31 patients diagnosed with left breast cancer were found to be suitable for V-DIBH. Patients were trained for breath hold technique for 3 to 4 days on CT simulator. Seven patients being non-compliant to V-DIBH therefore 24 patients were simulated for breath hold. We made tangential IMRT plans for all the patients on both V-DIBH and free breathing scans for dosimetric comparison. D95% target and organ at risk (OARs) like Dmean of heart, LAD, lung and opposite breast were compared for both plans.

Results: A significant reduction of mean cardiac dose from 5.7 ± 1.58 Gy to 3.45 ± 0.68 Gy ($p<.05$) and cardiac V25Gy from 7.28 ±3.97 % to 1.64 ± 1.35% ($p<.05$) in V-DIBH cases as compared to FB. Mean dose to the LAD was reduced by 3.9 Gy in DIBH cases ($p<.05$). Differences between FB and V-DIBH mean lung dose was 2.47 Gy ($p=.106$, ns) and ipsilateral lung V20Gy was 2.57% ($p=.078$, ns).

Conclusion: This study demonstrates dosimetric benefits of V-DIBH over FB in reducing dose to heart, LAD and ipsilateral lung without compromising the target volume coverage. We should opt for V-DIBH over FB for left sided breast cancer cases.

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Introduction

Incidences of breast cancer have increased worldwide leading to the most common cancer among women[1]. Technological advancement, breast cancer screening and awareness programmes helped to detect breast cancer in early-stage. Breast conserving surgery (BCS) combined with post-operative radiotherapy is the well-known practice for these cases.[2] Adjuvant Radiation therapy is given to reduce local recurrence and to increase overall survival. However it results in radiation to Organ at Risk (OARs) like heart, left anterior descending artery (LAD) and ipsilateral lung, leading to long term toxicities like coronary artery disease, myocardial infarction, ischemia, radiation pneumonitis [3-4]. Darby et al have estimated that with 1Gy increase in mean heart dose, the incidence of Radiation Induced Heart Disease (RILD) increases by approximately 7% [2]. Gutt R et al demonstrated an increased risk of radiation induced cardiac related mortality in patients with Ca left breast [3]. Similarly, radiation induced pneumonitis and fibrosis of the lung are also dose dependent [4].

Various studies have indicated that radiation dose to the heart and ipsilateral lung can be reduced with DIBH without any compromise on target coverage [5]. The average mean heart and LAD dose was reduced by 2Gy and 11.7Gy respectively in DIBH plans.

In this present study, we have evaluated the Impact of Voluntary deep inspiratory breath hold (V-DIBH) versus Free Breathing (FB) technique on heart and lung doses during radiation therapy for left-sided breast cancer with audio visual guidance.

Materials and Methods

Eligibility criteria/ patient selection procedure

This was a retrospective study conducted from June 2018 to Dec 2019 in the department of radiation oncology, India. A total of 31 Patients with left sided breast cancer (post op) and without breathing difficulties were considered for V-DIBH training. of the total cohort, 7 Patients were non-compliant at coaching; therefore 24 patients underwent CT simulation in breath hold.

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Setup and delineation procedure

Patients were immobilized in supine position with both hands raised above head. To raise the chest, a 5º wedge was given. Patients were coached for V-DIBH. Varian real time position management (RPM) system (Varian Medical Systems, Palo Alto, CA, USA) was used for assessing patient breathing pattern and amplitude. An external surrogate which is tracked by Infrared (IR) camera was placed on the subject body to track breathing pattern. The marker was placed on the midline anterior abdominal wall at the level of the diaphragm outside the treatment area. Patients were given training for 3 to 4 days for breath hold along with audio- visual guidance.

Once the patient was comfortable and compliant, Thermoplastic DIBH cast was prepared in this position. Radio opaque markers were placed on the breast and inferior, superior, lateral and medial borders. Markers were placed on the right breast also. CT images were taken from mandible to 7cm below the infra-mammary fold with 5 mm slice thickness in CT simulator Discovery RTCT (General Electric Healthcare, U.S.A) in both V-DIBH and FB.

The images were imported and contoured in Eclipse planning system Version 13.7 (Varian Medical Systems, Palo Alto, CA).

Target volumes

CTV and PTV: The Clinical Target Volume (CTV) of breast includes both palpable breast tissue and entire glandular breast parenchyma as per CT scan findings. Before simulation, the palpable breast was demarcated by markers. The breast CTV contouring was done as per European Society for Radiotherapy and Oncology guidelines [6].Anteriorly breast CTV is cropped from skin by 5mm.

For daily set-up uncertainties and respiratory motion, 5 mm margin was added to CTV to create the Planning Target Volume (PTV). PTV was also cropped from the skin by 3 mm margin.

OARs

Contralateral breast was contoured according to the RTOG breast Atlas [7]. Care was taken to include visible glandular breast tissue on CT scan and palpable breast tissue as demarcated by markers before CT simulation.

B/L lungs were contoured by an auto segmentation tool with manual correction.

Heart and LAD were contoured as per study by Feng et al [8].Superiorly, the heart starts just inferior to the left pulmonary artery and inferiorly it extends up to the diaphragm. Ascending and descending aorta, inferior vena cava have to be excluded from heart contour. The Left Anterior Descending (LAD) artery is contoured from its origin (that is left coronary artery) and then followed in an interventricular groove and extending up to the apex of heart.

Treatment planning and evaluation

Tangential IMRT technique with V-DIBH was used for treating patients, with beam arrangements at an interval of 10º to 15º. Plans were made on both V-DIBH and FB scans for comparison . D_{95} of target, Dmean of heart, LAD, lung and right breast were noted for comparison.

The prescribed dose to PTV is 40Gy/15F @(at the rate of) 2.667Gy per fraction.

The main objective of the plan were as follows:

- At least 95% of the PTV should receive >95% of the prescribed dose.
- Hotspots should not exceed 110% and preferably not 107%.
- Planning is done in such a way that the dose to OARs should be minimized without compromising the PTV dose.

Table 1. Describes our treatment planning objectives in detail.

Structure	Parameter	Constraints
PTV	D95%	≥95% of prescribed dose
	D99%	≥90% of prescribed dose
	V105%	<3% of PTV
Left Lung	V5Gy (%)	≤55%
	V10Gy (%)	≤40 %
	V20Gy (%)	≤20%
	V30Gy (%)	≤10%
	MLD (Gy	≤18 Gy
Right Lung	V2Gy (%)	ALARA
	V5Gy (%)	ALARA
	MLD (Gy)	≤2 Gy
Heart	V25Gy (%)	≤5%
	V13Gy (%)	ALARA
	V5Gy(%)	ALARA
	Mean Dose	≤4 Gy
LAD	Mean Dose (Gy)	≤20 Gy
Right breast	Mean dose	≤2 Gy

*as low as reasonably achievable

Statistical analysis

Dose-volume histograms (DVHs) were calculated and compared for both V-DIBH and FB plans.

Continuous variables are presented as a mean and standard deviation. Doses to CTV, PTV and organs at risk were evaluated. PTV volume, mean dose to PTV, PTV V95 and CTV V95, lung volume, were obtained. Max and mean dose to heart, and LAD and mean dose to ipsi lateral and contralateral lung and contralateral breast was also documented. Relative volume of OARs receiving higher doses and lower doses was also assessed with the help of DVH graph. Paired Sample T test was used for statistical analysis of the differences with computer software SPSS version 17.0. Data were considered statistically significant for $p < 0.05$.

Results

In a total of 31 females, treatment by DIBH was completed in 24 patients. The mean age was 43 years (range 29 to 63). Of the 24 patients BCS was done in 14 patients. Ipsilateral supraclavicular fossa (SCF) was treated in 11 patients.

As per the stage wise distribution, 13 patients were stage I/II as compared to 11 patients who presented with either advanced stage or with positive lymph nodes. The PTV and CTV volumes were comparable in the two groups. PTV volume was 1165.9±260 cc in V-DIBH plans as compared to 1119±253.6 cc in FB plan. The mean lung volume increases from 829.08±113.1cc in FB scans to 1649.5±167.77cc in V-DIBH scans. For the other delineated volumes also, no significant difference was found in two groups.

Dosimetric comparison of PTV and OARs doses in both groups (Table 2 a, b, c: Figure 1)

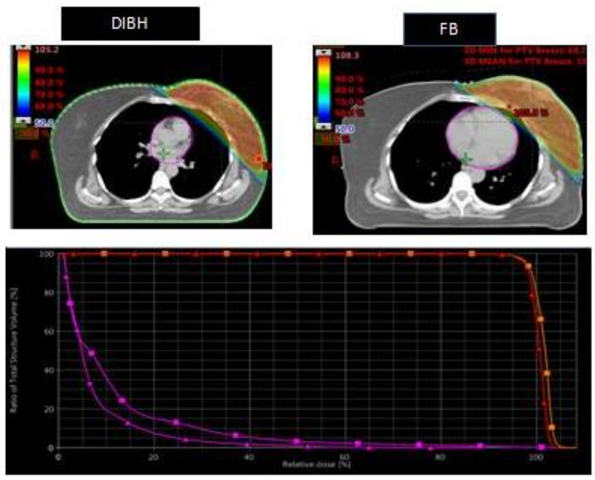

Figure 1. DVH depicting PTV coverage and Cardiac dose in two groups

Table 2 a. Dosimetric comparison of PTV in both groups (n=24)

	V-DIBH	FB	P value
PTV Volume (cc)	1165.9±260	1119±253.6	0.168
PTV Mean Dose (Gy)	40.17±0.2	40.23±0.14	0.274
PTV V95 (cc)	96.47±1.33	96.34±2.00	0.784
CTV V95 (cc)	98.64±1.68	99.0±0.48	0.337

The Mean dose to contralateral breast was 0.5±0.4 Gy in V-DIBH plan as compared to 0.32±0.26Gy in FB plan (P=0.134). Although, the volume of contralateral lung was more in V-DIBH plan as compared to FB (1875± 290 vs 1048±204 cc respectively, P= .0001) but there was no difference in contralateral lung mean dose (0.45±.31Gy in DIBH vs 0.4±.33Gy in FB plan)

Table 2 b. Figure 1. Dosimetric comparison of Heart and LAD doses in both groups (n=24)

	V-DIBH	FB	*P* value
Heart Dmax (Gy)	36±3.26	38.4±2.56	0.010
Heart Mean dose (Gy)	3.45Gy ± 0.68	5.7Gy± 1.58	0.0001
Heart V5(%)	16.4±5.1	25.05±7.85	0.0001
Heart V13(%)	6.4±3.16	14.2±6.8	0.0001
Heart V17(%)	4.17±2.45	11.4±5.85	0.0001
Heart V20(%)	3.03±1.95	9.76±5.14	0.0001
Heart V25(%)	1.64±1.35	7.28±3.97	0.0001
LAD Dmax (Gy)	33.23±4.07	34.88±3.34	0.173
LAD mean dose (Gy)	16.8±6.76	20.7±5.4	0.021
LAD D50 (Gy)	15.32±8.94	22.05±7.54	0.021

Table 2 c. Dosimetric comparison of Ipsilateral lung in both groups (n=24)

	V-DIBH	FB	*P* value
Lung volumes (cc)	1649.5±167.77	829.08±113.1	0.0001
Lung mean dose (Gy)	10.68±1.89	13.15±6.35	0.106
Lung V5(%)	50.07±9.46	54.7±11.8	0.128
Lung V10(%)	35.5±6.66	41.76±10.32	0.012
Lung V20(%)	21.56±4.8	24.13±6.32	0.078
Lung V30(%)	11.74±4.64	12.04±5.12	0.824

Discussion

In the present study we have demonstrated that RPM with audio-visual aid can be used for V-DIBH to reduce the radiation dose to the heart and ipsilateral lung without any compromise in coverage of PTV for tangential whole breast irradiation. RPM with audio-visual aid helps in better compliance and reproducibility of V-DIBH manoeuvre. In a review by Latty et al have also suggested use of RPM as a viable option for DIBH [9].

PTV and CTV coverage were comparable in both arms irrespective of lymph node irradiation. The constraints on PTV coverage in our study, V95% >95% and that for CTV was V95% > 98%. Aiello et al also demonstrated similar CTV and PTV coverage in both V-DIBH vs FB plans [10].

When compared with FB, V-DIBH resulted in a significant reduction of mean cardiac dose from 5.7 ± 1.78Gy to 3.45 ± 0.68Gy (p<.0001). In a study by Aiello et al, an average mean heart dose was reduced from 2.2Gy to 1.3Gy in FB and DIBH plans respectively. Similarly the average mean dose to LAD was also reduced by 8.39Gy in DIBH. Also V13 decreased from 14.2 ± 6.8% to 6.4 ± 3.16% when DIBH was used.[10] In contrast to study by Rice et al., V13 values are higher in present study which is mainly contributed due to strict PTV and CTV coverage constraints [12].

In the present study, Mean dose to the LAD was 20.7 ± 5.4Gy and 16.8 ± 6.76 on FB and V-DIBH, respectively (p=.021). Also LAD D50 (dose to 50% of the LAD volume) was less in the V-DIBH arm as compared to FB group. Similarly in a study by Aeillo et al average mean dose to LAD was reduced by 8.39 Gy in DIBH [10].Vikstrom et al and Sriathi et al had also demonstrated statistical decrease in mean LAD dose and D50 after DIBH as compared to FB [5,11].

Studies have shown that complications like myocardial infarction, ischemic heart disease increase linearly by approximately 7% per Gy increase in the Mean heart dose [13-15]. In a study by Chung et al, no significant changes were found after RT in cardiac function (Ejection function, summed stress defects scores) with mean heart dose of less than 5 Gy [16] As per the anatomy of the heart and the site of tumour, maximum cardiac doses can be received to the apex and the anterior segment in the region of LAD, resulting in higher dose of the LAD. Correa CR et al have confirmed that about 85% of patients had coronary stenosis involving the LAD in regions of higher mean dose [17]. Wennstig et al also demonstrated a positive association between mean radiation doses to mid LAD and a coronary stenosis [18].

Use of V-DIBH has shown to reduce the percent of lung irradiated by any specific dose. V10 and V20 (Volume receiving 10Gy/20Gy) were less in V-DIBH plans as compared to FB plans. Sripathi et al have demonstrated a decrease in V20 values if DIBH is used as compared to FB [11]. Contrary, Rice et al have not demonstrated significant difference in two groups [12].

Systemic review by Deng G et al have suggested that dosimetric parameters like irradiated volume of lung (V_{20} , V_{10}),Mean lung dose (MLD) are predictors for Radiation Induced Lung Injury (RILI) [19]. Hernando et al had demonstrated that MLD < 10Gy is associated with a 10% radiation pneumonitis (RP) rate as compared to 16% RP with an MLD of 11–20Gy [20].

Similar to, study by Vikstorm et al there is a mild increase in contralateral breast mean dose although non-significant when using DIBH [5].

In our study, sample size was relatively small. Moreover we have not performed any dose verification using phantom. These are a few limitations of present study.

Further studies can be done by contouring PRV heart and LAD as per movement in 4DCT scan. In present study tangential IMRT technique was used for planning. In future we can expand our study by comparing rapid arc and IMRT technique for the DIBH cases.

Conclusion

In FB cases, without compromising PTV coverage we failed to spare OARs. With V-DIBH, we managed to reduce cardiopulmonary doses without compromising PTV coverage. Moreover, we are able to control the lung dose due to increase in lung volume. Although V-DIBH requires more labour and effort in comparison to FB as you need to spend quality time for training the patient, but it helps in increasing the quality of life of patients. Therefore, we recommend that if the patient is comfortable and has no breathing issues then we should opt V-DIBH over FB in left breast cases.

References

1. Bray F, Ferlay J, Soerjomataram I, Siegel RL, Torre LA, Jemal A. Global cancer statistics 2018: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. CA: a cancer journal for clinicians. 2018 Nov;68(6):394-424
2. Early Breast Cancer Trialists' Collaborative Group (EBCTCG), Darby S, McGale P. Effect of radiotherapy after breast-conserving surgery on 10-year recurrence and 15-year breast cancer death: meta-analysis of individual patient data for 10,801 women in 17 randomised trials. Lancet. 2011; 378:1707.
3. Gutt R, Correa CR, Hwang WT, Solin LJ, Litt HI, Ferrari VA, et al. Cardiac morbidity and mortality after breast conservation treatment in patients with early-stage breast cancer and preexisting cardiac disease. Clin Breast Cancer. 2008;8:443 – 8.
4. Gagliardi G, Bjohle J, Lax I, Ottolenghi A, Eriksson F, Liedberg A, et al. Radiation pneumonitis after breast cancer irradiation: Analysis of the complication probability using the relative seriality model. Int J Radiat Oncol Biol Phys. 2000;46:373 – 81.
5. Vikström J, Hjelstuen MH, Mjaaland I, Dybvik KI. Cardiac and pulmonary dose reduction for tangentially irradiated breast cancer, utilizing deep inspiration breath-hold with audio-visual guidance, without compromising target coverage. Acta Oncologica. 2011 Jan 1;50(1):42-50.
6. Offersen BV, Boersma LJ, Kirkove C, Hol S, Aznar MC, Biete Sola A, et al. ESTRO consensus guideline on target volume delineation for elective radiation therapy of early stage breast cancer. Radiother Oncol. 2015;114:3-10.
7. Li XA, Tai A, Arthur DW, Buchholz TA, Macdonald S, Marks LB, et al. Variability of target and normal structure delineation for breast cancer radiotherapy: An RTOG multiinstitutional and multiobserver study. Int J Radiat Oncol Biol Phys. 2009;73:944-51.
8. Feng M, Moran JM, Koelling T, Chughtai A, Chan JL, Freedman L, et al. Development and validation of a heart atlas to study cardiac exposure to radiation following treatment for breast cancer. International Journal of Radiation Oncology* Biology* Physics. 2011 Jan 1;79(1):10-8.
9. Latty D, Stuart KE, Wang W, Ahern V. Review of deep inspiration breath-hold techniques for the treatment of breast cancer. J Med Radiat Sci. 2015 Mar;62(1):74-81.

10. Aiello D, Borzì GR, Marino L, Umina V, Di Grazia AM. Comparison of deep inspiration breath hold and free breathing technique in left breast cancer irradiation: a dosimetric evaluation in 40 patients. Journal of Radiation Oncology. 2019 Mar;8(1):89-96.
11. Sripathi LK, Ahlawat P, Simson DK, Khadanga CR, Kamarsu L, Surana SK, et al. Cardiac dose reduction with deep-inspiratory breath hold technique of radiotherapy for left-sided breast cancer. Journal of medical physics. 2017 Jul;42(3):123.
12. Rice L, Goldsmith C, Green MM, Cleator S, Price PM. An effective deep-inspiration breath-hold radiotherapy technique for left-breast cancer: impact of post-mastectomy treatment, nodal coverage, and dose schedule on organs at risk. Breast Cancer: Targets and Therapy. 2017;9:437.
13. Darby SC, Ewertz M, McGale P, Bennet AM, Blom-Goldman U, Brønnum D, et al. Risk of ischemic heart disease in women after radiotherapy for breast cancer. New England Journal of Medicine. 2013 Mar 14;368(11):987-98.
14. Harris EE, Correa C, Hwang WT, Liao J, Litt HI, Ferrari VA, et al. Late cardiac mortality and morbidity in early-stage breast cancer patients after breast-conservation treatment. Journal of clinical oncology. 2006 Sep 1;24(25):4100-6.
15. Jacobse JN, Duane FK, Boekel NB, Schaapveld M, Hauptmann M, Hooning MJ, et al. Radiation dose-response for risk of Myocardial infarction in Breast Cancer survivors. International Journal of Radiation Oncology* Biology* Physics. 2019 Mar 1;103(3):595-604.
16. Chung E, Corbett JR, Moran JM, Griffith KA, Marsh RB, Feng M, et al . Is there a dose-response relationship for heart disease with low-dose radiation therapy?. International Journal of Radiation Oncology* Biology* Physics. 2013 Mar 15;85(4):959-64.
17. Correa CR, Litt HI, Hwang WT, Ferrari VA, Solin LJ, Harris EE. Coronary artery findings after left-sided compared with right-sided radiation treatment for early-stage breast cancer. Journal of clinical oncology. 2007 Jul 20;25(21):3031-7.
18. Wennstig AK, Garmo H, Isacsson U, Gagliardi G, Rintelä N, Lagerqvist B, et al. The relationship between radiation doses to coronary arteries and location of coronary stenosis requiring intervention in breast cancer survivors. Radiation Oncology. 2019 Dec 1;14(1):40.
19. Deng G, Liang N, Xie J, Luo H, Qiao L, Zhang J, et al. Pulmonary toxicity generated from radiotherapeutic treatment of thoracic malignancies. Oncology letters. 2017 Jul 1;14(1):501-11.
20. Hernando ML, Marks LB, Bentel GC, Zhou SM, Hollis D, Das SK, et al. Radiation-induced pulmonary toxicity: a dose-volume histogram analysis in 201 patients with lung cancer. International Journal of Radiation Oncology* Biology* Physics. 2001 Nov 1;51(3):650-9.