International Refereed Journal of Engineering and Science (IRJES)
ISSN (Online) 2319-183X, (Print) 2319-1821
Volume 7, Issue 7 Ver. I (Jul 2018), PP. 01-05

Dosimetric Evaluation Of Intensity Modulated Breast Cancer Treatment Techniques

Bora Tas[1,]*, Ismail Faruk Durmus[1]
[1] *Department of Radiation Oncology, Yeni Yuzyil University Gaziosmanpasa Hospital, Istanbul, Turkey*
**Corresponding Author: Dr. Bora Tas*

ABSTRACT:*Background:Radiotherapy is an effective treatment method for managing breast cancer, since a large portion of the breast cancer patients are cured from their disease and hence become long term survivors. The modern technologies in radiotherapy (RT) based on inversed treatment planning.*
Objectives:The aim of this study was determining the better dose distribution and effective treatment of intensity modulated left breast cancer treatment technique. Additionally, we compared DIBH and FB techniques especially for LAD dose and mean heart dose while using partial VMAT technique.
Method:A retrospective analysis was performed on nine early stage breast cancer patients treatment planning with eight FF beams for IMRT treatment. All plans were re-optimized with FFF beams using the same optimization parameters. Then, the treatment planning were performed for IMRT treatment and partial arcs for VMAT treatment while using the same optimization parameters for ten patients. Finally, fourteen patient's treatment planning were performed for DIBH and FB technique while using partial arcs VMAT fields.
Results:We determined an average MUs difference with FFF beams %12 more than FF beams and an average total delivery time difference with FFF beams %2 more than FF beams for IMRT planning. We obtained partial VMAT plan's V10 Gy, V20 Gy of lung volumes and mean heart doses were lower than IMRT plans. When we compared DIBH and FB techniques, we determined an average %22 lower maximum heart doses, %33 lower mean heart doses and %29 lower mean LAD doses with DIBH technique.
Conclusions:The results show that dose coverage of target and OARs doses are feasible by using partial VMAT for intensity modulated left breast cancer treatment. DIBH technique while using partial VMAT may decrease cardiac disease possibility for left breast radiotherapy more than FB technique.
KEYWORDS: *IMRT, VMAT, Breast Ca, DIBH*

Date of Submission:10-09-2018 Date of acceptance: 12-10-2018

I. INTRODUCTION

Breast-conserving surgery (BCS) combined with postoperative radiotherapy to the residual whole breast has become the standard treatment for the majority of early stage breast cancer patients. Whole-breast irradiation (WBI) followed by tumor bed boost improves local control and overall survival.[1,2] Radiotherapy is an effective treatment method for managing breast cancer, since a large portion of the breast cancer patients are cured from their disease and hence become long term survivors, with the 5 years survival being approximately %90[3], but patients may have cardiac disease as a late radiation effect after completing radiotherapy. The modern technologies in radiotherapy (RT) based on inversed treatment planning, such as intensity modulated radiotherapy (IMRT) and volumetric modulated arc therapy (VMAT), allow to achieve highly conformed dose distributions on the target volume and to spare organs at risk (OAR) in respect to 3D-conformal RT, as showed in several studies in different region.[4-6] Volumetric-modulated arc therapy (VMAT), a novel intensity-modulated technique, can precisely and accurately deliver radiation dose by dynamic adjustment of multi leaf collimators (MLC)s motion, dose rates, and gantry rotations.[7] Many groups have also evaluated and introduced VMAT in clinical practice for breast region.[8-11] Therefore, there has been much focus in the last years in breast cancer radiotherapy to develop treatment techniques that reduce the dose to OARs, such as IMRT and VMAT. Also, treatment during deep inspiration breath-hold (DIBH) has been shown to decrease the cardiopulmonary doses by using 3 dimensional or field and field IMRT techniques. The left anterior descending (LAD) coronary artery mean dose and mean heart dose are playing a major role for cardiac disease. Darby et al.[12] have shown that the relative risk of ishemic heart disease with mean heart dose. This relationship was recently validated by van den Bogaard et al.[13] for more modern radiotherapy techniques. Also, a higher incidence of coronary artery disease has been observed for the LAD coronary artery for left sided compared to right sided breast radiotherapy.[14]

The optical surface scanning systems such as the Sentinel™ and Catalyst™ (C-Rad Positioning AB, Uppsala, Sweden) project light onto the patient's skin surface and reconstruct a three dimensional surface of

patient. This system could useful for positioning, intra-fraction motion detection and gating solution. These are shown in figure 1a-1b. The system is used to trigger the beam for treatment delivery in DIBH.[15]
The aim of this study was evaluating the best dose distribution and effective treatment of intensity modulated early stage left breast cancer treatment technique and left side breasts were considered to evaluate the heart sparing.

II. MATERIALS AND METHODS

A retrospective analysis was performed on nine early stage breast cancer patients randomly selected from the internal database of patients, patient's treatment planning were performed by using Monaco 5.11® with eight flattening filter (FF) beams IMRT treatment for an Elekta Versa HD (Elekta AB, Stockholm, Sweden). The planning target volume (PTV) was defined according to the breast-cancer delineation atlas of the Radiation Therapy Oncology Group (RTOG). The tumor bed was determined according to tumor bed clips, surgery related seroma, or postoperative skin scars. The prescribe dose was 60 Gy to PTV(tumor bed) and 47 Gy to PTV(breast) in 28 fractions by simultaneous integrated boost (SIB) technique. Intensity Modulated Radiotherapy plan of breast cancer patient is shown in figure 1. All plans were re-optimized with flattening filter free (FFF) beams by using the same optimization parameters while optimizing two technique's plan. Minimum segment width was adjusted 0.5 cm, fall off parameter was adjusted 2.0 cm and grid space was adjusted 0.3 cm. 6MV FFF beam had got maximum 1800 MU/minute dose rate, and 6MV FF beams had got maximum 600 MU/minute dose rate. We compared MUs and total delivery time for both plans.

Secondly, the treatment planning were performed with 5 to 7 fields for IMRT treatment and 2 symmetrical partial arcs 50° to 70° for VMAT treatment while using the same optimization parameters for ten patients. We analyzed retrospectively MUs, delivery time, Heterogeneity Index (HI), organs at risk (OAR)s doses and target doses for both methods.

From 2015 to 2017, fourteen patients underwent supine computed tomography (CT) in separate scans for free breathing and DIBH. All structures were delineated in both the DIBH and FB CT sets. We used Sentinel™ and Catalyst™ (C-Rad Positioning AB, Uppsala, Sweden) surface guided radiotherapy gating device for DIBH technique and fourteen patient's treatment planning were performed for DIBH and FB techniques(figure 2a-b), we aimed to achive a similar dose conformity and homogeneity to the PTV(tumor bed) and PTV(breast) while using 2 symmetrical partial VMAT fields. We compared mean heart dose, maximum heart dose, mean LAD dose, V5 Gy, V10 Gy and V20 Gy doses percentage of lung volume.

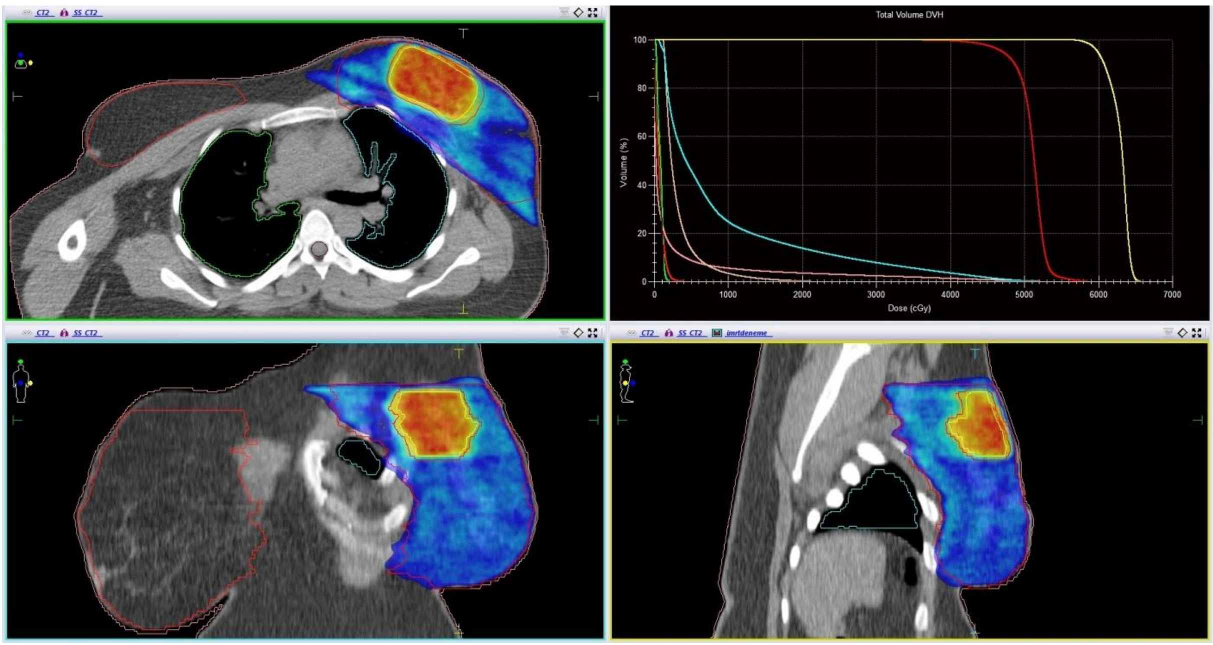


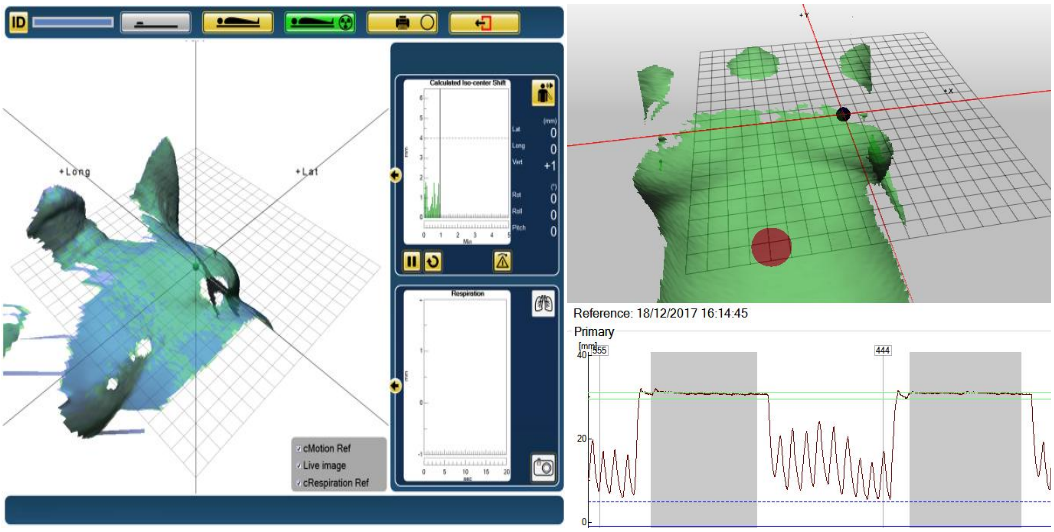
Figure. 1. Intensity Modulated Radiotherapy plan of breast cancer patient

III. RESULTS

We determined an average MUs difference with FFF beams %12 more than FF beams and an average total delivery time difference with FFF beams %2 more than FF beams for early stage breast cancer patient's IMRT planning. When we compared IMRT and partial VMAT technique (figure2), These results were shown that VMAT plan's V10 Gy, V20 Gy of lung volumes and mean heart doses were lower than IMRT plans.

Additionally, VMAT plans were decreasing total MUs and delivery time for breast cancer patients. At the same time, we determined HI of PTV_{60} and PTV_{47} less than VMAT by IMRT method.

Finally, we determined an average 3.8 Gy mean heart doses, 9.0 Gy mean LAD doses and 40.4 Gy maximum heart doses with FB technique by using partial VMAT method for fourteen patients, it is shown in table 1. We significantly reduced mean heart, maximum heart and mean LAD doses with DIBH technique while using Sentinel^{TM} and Catalyst^{TM} gating system, it is shown in table 2. We determined an average %22 lower maximum heart doses, %33 lower mean heart doses and %29 lower mean LAD doses with DIBH, also, an average lung volume were enlarged %66. We didn't determine significant percentage difference for V5 Gy, V10 Gy and V20 Gy doses of lung volume between two techniques.



(a) (b)

Figure. 2. a) Intra-fraction motion detection b) Gating window of C-RAD system

Patient	Left Lung V5(%)	Left Lung V10(%)	Left Lung V20(%)	Max. Heart (cGy)	Mean Heart (cGy)	Mean LAD (cGy)	Left Lung Vol. (cc)	PTV %95 (cGy)	MUs	Max. Dose (cGy)	HI PTV
1	36,73	18,13	11,53	4373,3	425,5	1309,4	896,679	4699,4	724,94	6618,9	1,09
2	56,73	33,24	16,49	3810,5	312,1	933,9	1450,773	4821,8	580,38	6450,6	1,06
3	41,68	24,01	13,45	3002,1	201,1	765,3	1613,758	4742,8	673,49	6705,9	1,08
4	63,99	38,71	25,19	4523,1	490,1	683,8	1242,258	4686,5	670,28	6436,3	1,06
5	51,54	27,21	13,32	4598,4	471,2	653,9	948,892	4565,2	705,07	6522,5	1,12
6	52,46	28,82	19,16	4696,1	472,5	1136,1	1142,521	4551,7	686,25	6444,7	1,09
7	48,52	28,51	14,79	3937,3	322,2	557,2	1080,273	4593,1	617,09	6503,2	1,13
8	44,97	29,27	19,91	4111,2	438,7	1077,6	986,541	4679,1	675,03	6616,8	1,11
9	47,06	25,86	17,05	3835,1	334,6	778,4	1270,377	4618,3	803,25	6511,6	1,08
10	53,61	29,04	12,05	3668,1	325,8	718,7	683,181	4708,3	711,21	6371,6	1,05
11	47,61	29,87	21,01	3557,6	259,9	817,2	1204,215	4710,9	619,14	6523,8	1,11
12	58,07	27,74	11,61	4245,1	458,1	1112,5	921,001	4711,9	715,49	6523,7	1,07
13	47,25	25,95	11,71	4337,4	484,7	1023,1	905,292	4523,2	819,01	6688,8	1,10
14	52,81	30,75	16,62	3798,5	366,1	1050,2	1280,421	4593,7	725,18	6495,1	1,11
Mean ±SD	50,22 ±7%	28,37 ±5%	15,99 ±4%	4035,3 ±467	383,0 ±92	901,2 ±221	1116,156± 248	4657,6 ±85	694,70 ±66	6529,5 ±97	1,09 ±0,03

Table 1: Dose distribution of free breathing (FB) technique for left breast cancer

Patient	Left Lung V5(%)	Left Lung V10(%)	Left Lung V20(%)	Max. Heart (cGy)	Mean Heart (cGy)	Mean LAD (cGy)	Left Lung Vol. (cc)	PTV %95 (cGy)	MUs	Max. Dose (cGy)	HI PTV
1	51,84	24,43	13,37	3643,4	257,6	763,3	1400,565	4690,7	778,39	6495,6	1,07
2	36,07	21,16	10,57	2503,1	193,3	612,5	2264,346	4764,2	734,07	6521,9	1,06
3	43,57	22,31	12,61	1862,6	162,9	444,4	2277,219	4761,2	636,31	6444,2	1,05
4	59,52	38,03	21,23	4021,9	395,1	493,7	1344,252	4601,7	840,03	6548,3	1,09
5	61,16	35,52	15,63	3825,4	277,2	500,8	2231,266	4642,5	714,58	6525,6	1,10
6	52,96	33,78	20,72	4262,5	397,6	677,6	1546,362	4508,4	699,65	6550,7	1,09
7	48,61	28,63	14,31	1821,5	176,7	376,8	1723,497	4594,7	649,65	6305,6	1,06
8	49,19	29,43	17,04	3210,1	243,6	941,7	1705,554	4619,9	683,38	6590,4	1,11
9	45,02	24,89	14,17	3654,7	235,6	631,1	2159,601	4550,3	873,77	6527,4	1,08
10	53,31	31,68	13,01	2951,8	241,9	439,4	1235,971	4761,4	664,87	6562,3	1,10
11	34,62	21,79	15,13	2518,3	189,1	543,9	2251,194	4666,5	674,61	6453,4	1,08
12	53,24	36,85	16,53	3540,3	312,5	831,9	1909,431	4724,1	737,54	6487,1	1,08
13	46,73	26,29	15,14	2923,9	277,1	771,5	1781,466	4575,9	718,81	6589,8	1,10
14	55,47	32,94	15,21	3479,1	259,9	915,2	2203,527	4582,8	799,27	6596,4	1,08
Mean ±SD	49,38 ±8	29,12 ±6	15,33 ±3	3157,5 ±762	258,6 ±72	638,8 ±183	1859,589 ±378	4646,0 ±84	728,92 ±71	6514,2 ±77	1,08 ±0,02

Table 2: Dose distribution of deep inspiration breath-hold (DIBH) technique for left breast cancer

IV. DISCUSSION/CONCLUSION

Newer modalities of whole breast irradiation such as IMRT and VMAT appear to provide better PTV dose coverage, homogeneity and conformity that is likely to decrease the skin toxicity and thereby improve cosmesis.

The results show that IMRT plans with FFF beams are not reducing total radiation delivery time for early stage breast cancer patients because of large field size in spite of high dose rate. Therefore, we have already treated early stage breast cancer patient's IMRT plan with FF beams in our clinic.

Jing yu et al.[16] have shown that the VMAT plan reduced the MU from 878±50 to 713±112 and treatment time from 421±24 to 164±9seconds. We determined that the VMAT plan reduced the MUs from 1064±107 to 845±129 and treatment time from 390±42 to 119±17 seconds. Our results were within similar range presented study.

Studies showed that patients who received radiotherapy for breast cancer had an increased risk of developing nonbreast complications in the long term.[17-19] Darby et al.[12] have shown that the relative risk of ishemic heart disease increases with %7.4 per Gy increased mean heart dose, with no apparent threshold.

Our study showed that using Sentinel^{TM} and Catalyst^{TM} gating system for DIBH treatments with visual guidance significantly reduces mean heart, maximum heart and mean LAD doses for early stage left breast cancer. Symyth et al.[20] reviewed ten treatment planning studies comparing DIBH and FB, all showing a significant reduction of the mean heart and LAD dose using DIBH. The relative reduction in the mean dose was between 38% and 65% for the heart and between 31% and 71% for LAD. The average relative reductions of the mean heart was 33% and the mean LAD was %29 in our study by using partial VMAT technique. Our results was similar to presented study. The difference could be related with the treatment technique such as 3D conformal and VMAT.

Partial VMAT methodology yielded superior target-volume coverage, dose conformity, and protection of normal tissue such as mean heart and mean LAD doses, when compared to other intensity modulated radiotherapy technique. Furthermore, it reduced treatment time and the number of MU required. In addition, DIBH while using partial VMAT method may decrease cardiac disease possibility for left breast radiotherapy more than FB technique.

ACKNOWLEDGEMENT

The authors have no fundings or conflicts of interest to disclose.

Statement of Ethics

The authors have no ethical conflicts to disclose.

Disclosure Statement

The authors have no conflicts of interest to declare.

Funding Sources

The authors have no fundings to disclose.

Author Contributions

The authors have no conflicts of interest to disclose.

REFERENCES

[1]. Darby S, McGale P, Correa C, Taylor C, Arriagada R, Clarke M, et al. Early Breast Cancer Trialists' Collaborative Group (EBCTCG). 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;378:1707–1716.

[2]. Donker M, Litière S, Werutsky G, Julien JP, Fentiman IS, Agresti R, et al. Breast-conserving treatment with or without radiotherapy in ductal carcinoma in situ: 15-year recurrence rates and outcome after a recurrence, from the EORTC 10853 randomized phase III trial. J Clin Oncol. 2013;31:4054–4059.

[3]. American Cancer Society. Breast cancer facts and figures 2011-2012 [Accessed December 20,2017]. Available from: https://www.cancer.org/content/dam/cancer-org/research/cancer-facts-and-statistics/breast-cancer-facts-and-figures/breast-cancer-facts-and-figures-2011-2012.pdf.

[4]. Kjær-Kristoffersen F, Ohlhues L, Medin J, Korreman S. RapidArc volumetric modulated therapy planning for prostate cancer patients. Acta Oncol. 2008;48(2):227e32.

[5]. Verbakel W, Cuijpers J, Hoffmans D, Bieker M, Slotman B. Volumetric intensity modulated arc therapy versus conventional IMRT in head and neck cancer: a comparative planning and dosimetric study. Int J Radiat Oncol Biol Phys. 2009;74:252e9.

[6]. Lagerwaard F, Meijer O, van del Hoorn E, Verbakel W, Slotman B, Senan S. Volumetric modulated arc radiotherapy for vestibular schwannomas. Int J Radiat Oncol Biol Phys. 2009;74:610e5.

[7]. Yu CX. Intensity-modulated arc therapy with dynamic multileaf collimation: an alternative to tomotherapy. Phys Med Biol. 1995; 40:1435–1449.

[8]. Popescu CC, Beckham WA, Patenaude VV, Olivotto IA, Vlachaki MT. Simultaneous couch and gantry dynamic arc rotation (CG-Darc) in the treatment of breast cancer with accelerated partial breast irradiation (APBI): a feasibility study. J Appl Clin Med Phys. 2013;14(1):4035.

[9]. Scorsetti M, Alongi F, Fogliata A, Pentimalli S, Navarria P, Lobefalo F, et al. Phase I-II study of hypofractionated simultaneous integrated boost using volumetric modulated arc therapy for adjuvant radiation therapy in breast cancer patients: a report of feasibility and early toxicity results in the first 50 treatments. Radiat Oncol. 2012;7:145.

[10]. Subramaniam S, Thirumalaiswamy S, Srinivas C, Gandhi GA, Kathirvel M, Kumar KK, et al. Chest wall radiotherapy with volumetric modulated arcs and the potential role of flattening filter free photon beams. Strahlenther Onkol. 2012;188(6):484e90.

[11]. Yin Y, Chen J, Sun T, et al. Dosimetric research on intensity-modulated arc radiotherapy planning for left breast cancer after breast-preservation surgery. Med Dosim. 2012;37(3):287e92.

[12]. Darby SC, Ewertz M, McGale P, Bennet AM, Blom-Goldman U, Bronnum D, et al. Risk of ishemic heart disease in women after radşotherapy for breast cancer. N Engl J Med. 2013;368:987-998.

[13]. Van der Bogaard VA, Ta BD, van der Schaaf A, Bouma AB, Middag AM, Bantema-Joppe EJ, et al. Validation and modification of a prediction model for acute cardiac events in patients with breast cancer treated wşth radiotherapy based on three-dimensional dose distributions to cardiac substructures. J Clin Oncol. 2017;35:1171-1178.

[14]. Nilsson G, Holmberg L, Garmo H, Duernoy O, Sjögren I, Lagerqvist B, et al. Distribution of coronary artery stenosis after radiation for breast cancer. J Clin Oncol. 2011;30:380-386.

[15]. Boda-Heggemann J, Knopf AC, Simenova-Chergou A, Wertz H, Stieler F, Jahnke A, et al. Deep inspiration breath hold based radiation therapy: a clinical review. Int J Radia Oncol Biol Phys. 2016;94:478-492.

[16]. Jing Yu, Tao Hu, Yeshan Chan. Small-arc volumetric-modulated arc therapy: A new approach that is superior to fixed-field IMRT in optimizing dosimetric and treatment-relevant parameters for patients undergoing whole-breast irradiation following breast-conserving surgery. Medicine(Baltimore). 2016 Aug;95(34):e4609.

[17]. Henson KE, McGale P, Taylor C, et al. Radiation-related mortality from heart disease and lung cancer more than 20 years after radiotherapy for breast cancer. Br J Cancer. 2013; 108:179–182.

[18]. Grantzau T, Thomsen MS, Vaeth M, Overgaard J, et al. Risk of second primary lung cancer in women after radiotherapy for breast cancer. Radiother Oncol. 2014;111:366–373.

[19]. Berrington de Gonzalez A, Gilbert E, Curtis R, Inskip P, Kleinerman R, Morton L, et al. Second solid cancers after radiation therapy: a systematic review of the epidemiologic studies of the radiation dose–response relationship. Int J Radiat Oncol Biol Phys. 2013; 86:224–233.

[20]. Symyth LM, Knight KA, Aarons YK, Wasiak J. The cardiac dose-sparing benefits of deep inspiration breath-hold in left breast irradiation: a systematic review. J Med Radiat Sci. 2015;62:66-73.