

Original Research Article

Comparison between 3D Conformal radiotherapy, Intensity Modulated Radiotherapy and Volumetric Modulated Arc Therapy treatment plans for left sided breast cancer patients using deep inspiration breath hold technique

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Abstract

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Comparing between 3-Dimensional conformal radiotherapy (3DCRT), Intensity Modulated Radiotherapy (IMRT), Volumetric Modulated Arc Therapy (VMAT) using Deep Inspiratory Breath Hold (DIBH) techniques regarding target volume coverage and dose to heart and left lung for patients with left sided breast cancer. C-T simulation was done for 25 patients with left sided breast cancer using DIBH through the use of Active breath coordinate device (ABC), 3 plans were done for every patients, one by 3DCRT, second by IMRT and the third using VMAT techniques, comparison between these techniques was done regarding target volume coverage and dose to left lung and heart. The VMAT plans showed significantly higher mean dose coverage to the PTV than that of 3DCRT and IMRT plans ($p < 0.001$). The VMAT plans demonstrated significantly lower mean doses to OARs than that of 3DCRT and IMRT plans. The maximum heat dose was the least in VMAT plans ($p < 0.001$). Whereas the median dose of the V25 of the heart was also less in the VMAT plans than that of 3DCRT and IMRT plans ($p = 0.015$). Regarding the ipsilateral (left) lung, the median dose of V20 of left lung was the same of the 3 plans with no significant difference between them. The use of VMAT technique with DIBH technique showed better target volume coverage and significant reduction in the heart dose compared to 3DCRT and IMRT using DIBH.

Keywords: 3DCRT, IMRT, VMAT, DIBH

INTRODUCTION

Breast cancer is the most common malignancy among females, and one of the leading causes of cancer mortality (Jacques et al., 2010). Management of primary breast cancer embraces a multi-modality approach including surgery, chemotherapy, and radiation therapy.

Adjuvant radiotherapy is known to reduce local recurrence, which in turn increases breast cancer specific survival and overall survival (Early Breast Cancer Trialists' Collaborative Group, 2005).

In 2013, New England Journal of Medicine reported an

article on cardiac toxicity occurred in 2168 women treated for breast cancer in Sweden and Denmark between 1958 and 2001. In this group, 963 women complained of major coronary events and 1205 were controls. They found that rates of major coronary events increased linearly with increase in the mean dose to the heart by a relative rate of 7.4% per Gy. The risk was noted to start within five years of treatment and to continue for at least 20 years (Darby et al., 2013).

Respiratory motion studies in the past have showed that deep inspiration results in increased distance between the heart and left anterior chest wall. Breath holding during CT simulation and during treatment each day, has been shown to significantly decrease heart dose (Vincent et al., 2003; Krauss et al., 2005).

Using the three-dimensional conformal radiotherapy (3D-CRT) and intensity-modulated radiotherapy (IMRT) had shown an improvement in the treatment delivery through improving target volume coverage and decreasing dose to organs at risk (OAR) (Lo et al., 2000; Evans et al., 2000; Li et al., 2000).

A Volumetric Modulated Arc Therapy (VMAT) technique has been proposed that reduces dose to patients including other breast, contralateral lung and heart through the use of tangential VMAT partial arcs for treatment of the breast only with keeping good target volume coverage (Dogan et al., 2007; Virén et al., 2015).

In the present study, we are dosimetrically comparing the 3 techniques, 3DCRT, IMRT, VMAT for patients with left sided breast cancer treated using deep inspiration breath hold (DIBH) technique, regarding target volume coverage, dose to the ipsilateral lung as well as dose to the heart.

PATIENTS AND METHODS

Twenty one patients with left sided breast cancer were accrued between June 2018 and December 2018.

Inclusion Criteria

It included patients with non-metastatic left breast cancer after undergoing breast conserving surgery or mastectomies who are candidates for post-operative radiotherapy with or without chemotherapy.

Exclusion Criteria

It included patients with pre-existing chest conditions, including but not limited to, TB, severe bronchial asthma, and interstitial pulmonary fibrosis, patients with uncontrolled co-morbidities as diabetes and hypertension, patients with ischemic heart disease, and

patients not able to hold deep inspiration for duration of CT simulation (~20 seconds).

CT Simulation

The patients were positioned in the supine decubitus with their arms above their heads on breast board. Thin metallic wires were placed along the midline (medial) and mid-axillary line (lateral) at the time of image acquisition. The area of CT scanning included the clavicular head (cranial) and contralateral inferior breast border (caudal). Spiral CT scans were performed on General Electric CT with 2.5-mm slice thicknesses.

Patients were simulated using the deep inspiration breath hold technique device (Active Breath Co-ordinator (ABC), Elekta, UK) after initial training of all the patients prior to simulation.

The CT image data sets were then transferred to the treatment planning system (Monaco 5.11, Elekta, UK) where target and organs at risk were contoured according to RTOG protocols.

The 3DCRT treatment plans were created using 2 tangential fields for covering the Planning target Volume (PTV), the plans were created with mono-isocenter using the field-in-field technique to minimize the hot spots and increase the coverage using both 6 and 10 MV energies.

For the IMRT treatment plans, template and dose prescribed for treatment were done using dynamic multileaf collimators (d MLC), four fields were used (2 tangential fields and 2 oblique fields in between). Optimization was done by using automatic weight for each coast function then by individual adaptation to achieve the clinical objectives. The montcarlo algorithm was used to calculate the dose using 6 and 10 MV energies.

Regarding the VMAT treatment plans, template was created for plans and prescribed dose, the weights of the functions were adjusted manually using the mont-carlo algorithm. For all plans, two partial arcs were used, one in a clockwise direction and the other one in anticlockwise direction within the same isocenter producing $210^{\circ} \pm 10^{\circ}$ arc with an increment of 30° with 6 MV energy, such that the start and the end of the arc is the same as the tangential beams.

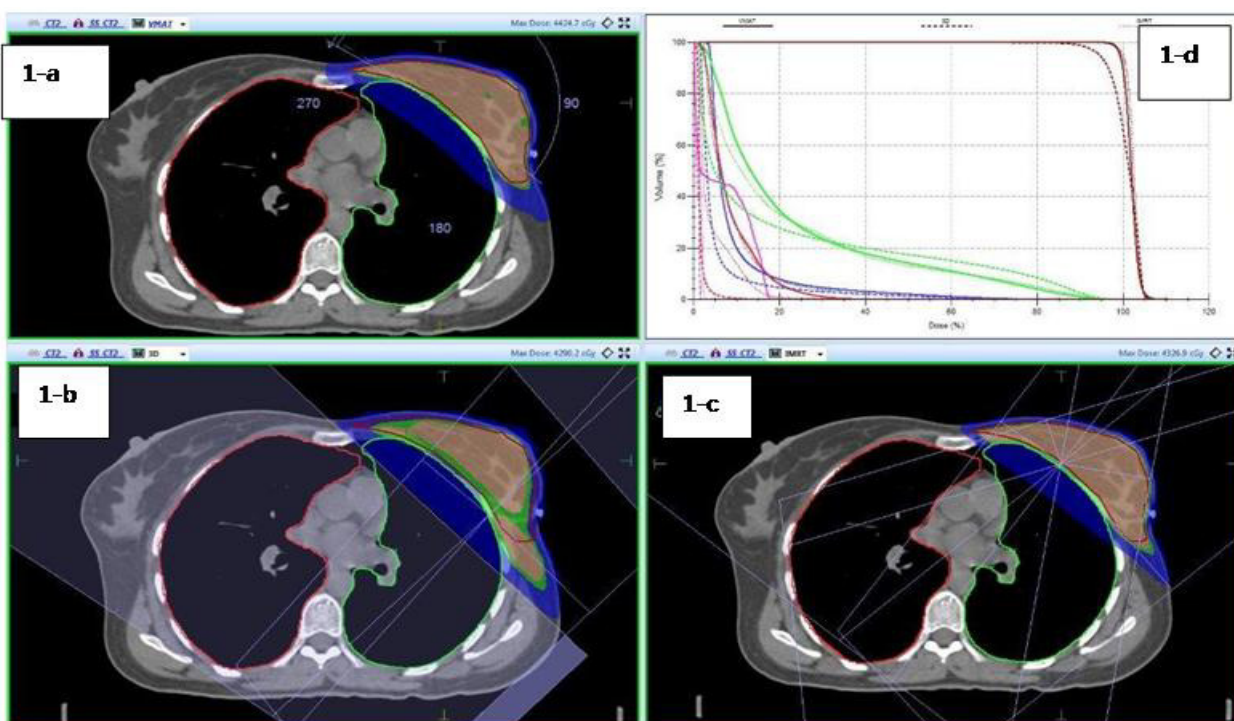
RESULTS

Target volume coverage to the PTV and organs at risk using 3DCRT, IMRT and VMAT is shown in table (1), whereas Representative dose distributions between 3DCRT treatment plans, IMRT treatment plans and VMAT treatment plans are shown in figure (1)

The VMAT plans showed significantly higher mean dose coverage to the PTV than that of 3DCRT and IMRT plans ($p < 0.001$).

Table 1. Dose distribution to the PTV and organs at risk using 3DCRT, IMRT and VMAT

	3 DCRT	IMRT	VMAT	P value
	Mean±SD (%)	Mean± SD (%)	Mean± SD (%)	
PTV coverage	87.3±8.6	86.6±15.9	92.3±6.9	<0.001
Heart	Mean±SD (cGY)	Mean± SD (cGY)	Mean± SD (cGY)	
Mean heart	307±98	467.7±51	475±90	<0.001
Maximum heart	3750±554	3562±380	3408±543	<0.001
	Median (range) (%)	Median (range) (%)	Median (range) (%)	
V10	6.8 (0-22)	9.2(5-17)	7.8(3-18)	0.035
V20	3.3 (0-8)	3.3(0-10)	2.2(0-8)	0.165
V25	2.03(0-6)	1.8(0-7)	1.07(0-6)	0.015
Ipsilateral Lung	Median (range) (%)	Median (range) (%)	Median (range) (%)	
V20	18.99(12-31)	19.27(9-95)	20.07(8-28)	0.227

**Figure 1.** An example of dose distribution between VMAT (1-a), 3DCRT (1-b), IMRT (1-c) breast cancer treatment plans and DVH (1-d) comparing between the 3 plans

The VMAT plans demonstrated significantly lower mean doses to OARs than that of 3DCRT and IMRT plans. The maximum heart dose was the least in VMAT plans ($p < 0.001$). Whereas the median dose of the V25 of the heart was also less in the VMAT plans than that of 3DCRT and IMRT plans ($p = 0.015$).

Regarding the ipsilateral (left) lung, the median dose of V20 of left lung was the same of the 3 plans with no significant difference between them.

DISCUSSION

The current study is comparing between 3 different radio-

therapy treatment planning techniques which are 3DCRT, IMRT, VMAT using deep inspiration breath hold technique for 21 patients who had left sided breast cancer so as to compare between the 3 techniques when used with DIBH regarding covering of the planning target volume (PTV) and dose to heart and left lung.

According to the results which are shown in our study, we found that the VMAT technique produces significantly better covering of the PTV than that of 3DCRT and IMRT techniques.

Where as in terms of organ sparing, our study showed that VMAT was the best in sparing different volumes of the heart compared with the other 2 techniques, inspite of theta the mean heart dose was the least in 3DCRT plan.

Regarding the V20 lung dose, the 3 techniques produced acceptable criteria for sparing of the lung according to RTOG 1005 protocol (Haydaroglu et al., 2013) with no difference between them.

Popescu et al. (2010) compared between VMAT and IMRT treatment planning for left sided breast cancer, data showed that VMAT produced same PTV coverage and sparing of OARs, but with less Motor Units (MUs) and shorter delivery time than conventional IMRT. This study also showed that the percentage of normal tissue volume receiving 5 Gy were significantly higher with VMAT (33.1% \pm 2.1%) and IMRT (45.3% \pm 3.1%) than with conventional modified wide-tangent technique (19.4% \pm 3.7%).

RapidArc, is able to produce better plans than IMRT for cases which were examined by Oliver et al. (2009), where the conformity of dose distribution to target is better in RapidArc compared with IMRT.

According to Nicolini et al. (2009), RapidArc showed better dosimetric results compared to IMRT. But they also have mentioned that mean dose to heart was 6.0 \pm 2.7 Gy for the RapidArc technique and 7.4 \pm 2.5 Gy to the IMRT technique.

William Vladimir Ona Rodriguez (Johansen et al., 2009), reported that for coverage of the PTV boost of the breast tumor bed, the plan obtained with the VMAT technique with double arc had the best conformation, also the results showed by VMAT reduced the average dose for the ipsilateral lung compared to other techniques.

According to study conducted by Johansen et al. (2009), homogeneity and conformation in PTV was better in the VMAT plans than IMRT plans. In terms of OAR sparing, both the IMRT and RapidArc plans spare ipsilateral- lung by the same degree.

CONCLUSION

As per our study, using the DIBH technique in the 3 different treatment plans (3DCRT, IMRT, VMAT), helps in reducing the dose to different volumes of the heart as well as mean and maximum dose to the heart

Also the use of the current plan parameters in the VMAT technique in our study helps in making the best regarding higher target volume coverage and the best in sparing the organs at risk.

Conflict of Interest

The authors declare that they have no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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