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Comparative Dosimeteric Evaluation of Intensity Modulated Radiation Therapy versus Conventional Radiotherapy in Postoperative Radiotherapy of Breast Cancer

Pooja Khullar*, **Niloy Ranjan Datta, G Venkadamanickam, Charu Garg and Sujeet Sinha**

Rajiv Gandhi Cancer Institute and Research Centre, Delhi, India

***Corresponding author:** Pooja khullar, Rajiv Gandhi Cancer Institute and Research Centre, Delhi, India, Tel: 918860650974; E-mail: poojagogia06@yahoo.co.in

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Abstract

Aim: To dosimetrically compare and evaluate Intensity Modulated Radiation Therapy (IMRT) versus conventional five field radiotherapy (5FCRT) in postmastectomy radiotherapy (PMRT).

Material and Methods: This study included 25 consecutive patients for PMRT. Target volumes (chest wall, axilla, supraclavicular regions [SCF]) and normal structures (lungs, heart, spinal cord, opposite breast) were delineated on the planning CT scans. For each patient, one IMRT and one 5FCRT plan were generated for 50 Gy and corresponding dose volume histograms were compared. Differences in means of each set of variables were tested for significance.

Results: CTV and PTV of chest wall, IMC, axilla level I, II, III and SCF were evaluated by variables $D_{98\%}$,$D_{2\%}$, $D_{50\%}$ $V_{<95}$, $V_{>105}$, $V_{>107}$, homogeneity index (HI). Coverage of the PTV given chest wall was significantly better with IMRT than conventional. The HI was more with conventional 0.6+0.2, IMRT 0.1+0.1, p<0.001. PTV of axilla and SCF, $D_{98\%}$ were better with IMRT than conventional. In IMRT HI was 0.1+0.1 while 0.4+0.2 conventional p<0.02. In lung V_{20} of the ipsilateral lung with IMRT was significantly lower than that of the conventional. In heart $D_{33\%}$ by IMRT was 17.3 + 10.0 Gy and 33.2+11.3Gy in conventional (p<0.001). Mean dose received by opposite breast was 5.8 + 1.8 Gy by IMRT and 2.0+1.0Gy by conventional p<0.001.

Conclusion: IMRT technique is superior to the conventional technique due to its better chest wall, axilla and SCF coverage. IMRT significantly reduced heart, lung and spinal cord doses as compared with conventional technique.

Keywords: Comparative; Dosimeteric; IMRT; Conventional; Radiotherapy; Breast cancer

Introduction

Breast cancer is the commonest cancer among females in Delhi and Mumbai and other urban based registries [1]. Various treatment options available for carcinoma breast are surgery, radiotherapy and systemic chemotherapy. Radiation therapy offers an improvement in overall survival and post mastectomy radiation therapy has been reported to reduce the 15 year isolated loco-regional recurrence rate from 29% to 8% in node positive subjects with a 5% reduction in mortality rate [2]. Patients treated with conservative surgery and irradiation resulted in pneumonitis in 1% of the treated patient with local radiation therapy only while it increased to 4% in local-regional irradiation [3] and cardiac toxicity like myocardial infarction to 2% of women with left sided radiation compared with 1% of women with right sided radiation therapy [4]. Unique technical problems are posed in conventional methods of irradiation to the different regional lymph node drainage areas, supraclavicular nodes, internal mammary nodes and axillary nodes, as they are present at different sites at varying depth. Supraclavicular nodes usually lie at 0.5 to 1 cm depth, infraclavicular axillary apical nodes at 1 cm depth, internal mammary nodes at 0.7 to 5.3 cm depth and central axillary nodes at depth of 6-7 cm [5]. Various conventional methods, like 5 field method, extended tangents are used to encompass these regions and also to minimize the inadvertent doses to the adjacent normal structures lungs, heart, spinal cord and contralateral breast. Intensity Modulated Radiation Therapy (IMRT) is expected to minimize dose to normal tissue while delivering optimum dose to the tumor bed and regional lymphatics. IMRT treatment allows the delivery of dose distributions with concave isodose profiles so that radiosensitive normal tissues close to, or even within the concavity of tumor may be spared from radiation injury. With better target coverage IMRT possibly would yield an improvement in loco-regional disease control [6].There is a paucity of studies comparing standard conventional 5 field technique with IMRT for postoperative radiation therapy in breast cancer. Therefore, this study attempts to compare the different doses to clinical target volume and organs at risk in both these methods.

Material and Methods

Twenty five consecutive patients referred to the radiation department for postoperative radiotherapy following mastectomy and adjuvant chemotherapy and who opted for IMRT treatment were included in this study. Patients with unilateral stage II or III breast cancer were eligible for this study. Ineligibility criteria included bilateral breast cancer and previous history of radiation. This study was approved by the Institutional Review Board and appropriate informed consent was obtained from patients before treatment.

All cases were treated with IMRT with 6MV photon, however, for the purpose of dosimetric comparison standard 5 field radiation treatment plan was generated with 6 MV photon energy to supraclavicular, axillary field, internal mammary (first 3 intercostal spaces) and chest wall for each of these 25 cases. The target volumes and organ at risk were kept constant as for the IMRT plan.

CT simulation and Target delineation: Patient was taken on an immobilization board with both arms above head. Universal bolus placed on the operated site of the patient. Orfit cast was made. CT compatible linear markers placed on the midaxillary line, in the inframammary fold of the contralateral breast, mid line. 5 mm thick sections taken of the area of interest plus 5 cm margin cranio-caudally. The DICOM (Digital Imaging and Communications in Medicine) images from the CT scan is transferred to the contouring station (Nucletron Oncentra Anatomy modeling or Siemens Coherence Oncologist work station). For each patient the following target and organ at risk were contoured, CTV for chest wall (CTV CW) is defined medially at the lateral edge of the sternum, inferiorly at the inframammary fold and superiorly at the inferior edge of the medial head of the clavicle. The CT compatible markers placed at the mid axillary line, mid line and in the contralateral inframammary fold at the time of CT scan also aid in contouring. CTV for internal mammary chain (CTV CW) start from the superior aspect of the medial 1st rib and caudally up to visible internal mammary vessel (approximately 1 to 3 intercostal spaces). CTV (chest wall + internal mammary node) is extended uniformly by 5 mm to form PTV chest wall (PTV CW) to account for the effect of set up error and intrafraction motion because of respiration as recommended by the ICRU 5025. CTV for Supraclavicular fossa (CTV SCF), cranially field start below the cricoid cartilage and caudally end at junction of brachioceph.-axillary or caudal edge clavicle head. Inferior border abut the superior border of PTV of chest wall. The medial border follows the medial border of sternocleidomastoid muscle to the thyrocricoid. The lateral border is at the level of the coracoid process, just medial to the humeral head. For axillary lymph nodes, the field is extended laterally to cover at two thirds of humeral head. The thyroid and trachea are excluded medially. Axilla Level I (CTV AXL1), cranially start from axillary vessels cross the lateral edge of the pectoral minor muscle. Caudally, it extends up to the insertion of the pectoral major muscle into ribs. Laterally, it extends from the medial border of the lattismus dorsi muscle to reach medially up to the lateral border of the pectoral minor muscle. Axilla Level I(CTV AXL2), cranially it starts from axillary vessels crossing the medial edge of pectoral minor muscle while caudally, up to axillary vessels crossing the lateral edge of pectoral minor muscle. Laterally it extends from the lateral border of the pectoral minor muscle to reach the medially the medial border of the pectoral minor muscle. Axilla Level III (CTV AXL3), cranially the region starts from insertion of the pectoral minor muscle to the cricoids and then caudally up to axillary vessels crossing the medial edge of pectoral minor muscle. Laterally, it starts from medial border of pectoral minor muscle and medially up to the thoracic inlet. CTV for supraclavicular fossa and axilla extended uniformly by 5 mm to form PTV for supraclavicular fossa and axilla (PTV AXL & SCF) The organs at risk were contoured and considered for evaluation include lung, heart, contralateral breast, spinal cord.

IMRT Planning: Dose prescription to the clinical target volume and the planning target volume was 50 Gy in 5 weeks in 25 fraction at 2 Gy per fraction. The planning was done by the inverse planning (Plato Sunrise, Nucletron) system by the medical physicists. In IMRT plans, optimization of the number of beams and gantry angles was undertaken. The beam energy was preselected by the planner and remained fixed during the optimization process (D_{min} and D_{max}) and are set for the entire volumes. The inverse planning for IMRT optimized to give an ideal fluence profile which was subsequently translated into MLC sequences for delivering the dose. The inverse planning, calculated the leaves sequencing for the step and shoot IMRT delivery. The optimal plan respecting the doses prescribed was finalized.

Dosimerty Evaluation: The various parameters that were used to evaluate the target volumes are, $D_{98\%}$-dose to which 98% of the PTV is irradiated, $D_{50\%}$-dose to which 50% of the PTV is irradiated, D_2–maximum dose to which at least 2% of the PTV in irradiated, $V_{<95\%}$-Volume of PTV receiving less than 95% of the prescription dose, $V_{>105\%}$ -Volume of PTV receiving more than 105% of the prescription dose, $V_{>107\%}$ -Volume of PTV receiving more than 107% of the prescription dose, D_{mean} - The determination of average, the median and modal doses is based on the calculation of the dose at each one of large number of discrete point, Homogeneity index (HI) $HI=D_{2\%}-D_{98\%}/D_{50\%}$

An HI of zero indicates that the absorbed-dose distribution is almost homogeneous.

$D_{50\%}$ is suggested as the normalization value because reporting of $D_{50\%}$ is strongly recommended in Level 2 reporting [7] Evaluation parameters for organs at risks were,V_{20}- Volume of organ receiving 20 Gy of dose, V_5-Volume of organ receiving 5 Gy of dose, D_{33}-Dose to which 33% of organ is irradiated, D_{66}- Dose to which 66% of organ is irradiated, D_{100}-Dose to which 100% of organ is irradiated. IMC can be treated by photon (as in our study), or a combination of electron & photon. The use of electrons for IMC minimizes the dose to deeper structures, particularly heart. However, it is resource-intensive,due to more complicated treatment planning and delivery. Junctioning between the photon and electron match-line contributes to the increased dose in homogeneity. In this study, we compared the IMC treated by photons in both IMRT and conventional technique.

Conventional Planning: In the conventional method, the supraclavicular axillary field the medial border drawn 1 cm over the midline and extended superiorly to the thyrocricoid groove, the lateral border extended laterally to cover at least two third of the humeral head. The lower border at the level of the second costal cartilage, Posterior Axillary boost, the superior border follows the spine of scapula, superiolateral border bisect the humeral head, the inferior border match the lower border of the supraclavicular field anteriorly with not more than 1 cm overlap. Internal Mammary Nodes, medial border drawn at the midline, superior border abuts the inferior border of the supraclavicular field, lateral border 5-6 cm lateral to the mid line, inferior border at xiphoid.In tangential fields medial field abutting the lateral border of the internal mammary field. The lateral field aligned with the mid axillary line.The superior border abuts the lower border of the supraclavicular field. The inferior border 2-3cm below the inframammary fold. Patient, disease and treatment variables were summarized as means and standard deviations or as proportions or percentages.

Statistical analysis was performed to compare doses of conventional therapy with doses given in IMRT by using 't' test for comparison of means between all the parameter of the 2 groups. All statistical computations were carried out using SPSS Version 16.0 for Windows (Chicago, USA).

Results

Dosimetrically compare and evaluate Intensity Modulated Radiation Therapy versus conventional radiotherapy techniques to the various clinical target volumes and planning target volumes in supraclavicular and axillary lymph node regions, Internal mammary lymph node and chest wall regions, doses to various organs at risk are Ipsilateral lung, Heart, Contralateral lung, Spinal cord and Contralateral breast.

The patient characteristics were showed in Table 1. The mean age of patients was 52.20 (range, 28-69) years. A total of 4 to 7 beams were used to deliver the IMRT plans. In the most of the patients, 3 to 4 beams were placed from the ipsilateral side and 1 to 3 beams were delivered from the contralateral side. Comparison of dose and volume parameters for target volumes and OARs by IMRT Plan and conventional plan is shown in Tables 2 and 3. The coverage of the CTV given chest wall was significantly better with IMRT than conventional techniques. The homogeneity index was more with conventional technique (Mean+SD: conventional technique 0.6+0.2, IMRT 0.1+0.0, p<0.001), IMC in conventional treatment plans a cold spot was seen at the junction of tangential and internal mammary fields because of the two separate fields used to cover both the target regions. IMRT plans showed a more uniform dose coverage with no cold spot. There was an improvement in the coverage of PTV chest wall and PTV axilla and supraclavicular nodes. Organs at risk, V_{20} of the ipsilateral lung with IMRT 49.2+3.5% was significantly lower than that of the conventional technique 59.8% + 7.4% (p<0.001). (Table 3). Dose received to 33% of the volume of the heart ($D_{33\%}$) by IMRT was 17.3+10.0 Gy and 33.2+11.3Gy in conventional technique (p<0.001). Mean dose received by opposite breast was 5.8+1.8 Gy by IMRT and 2.0+1.0Gy by conventional technique p<0.001 (Table 3). In the conventional plans the D_{max} of the spinal cord ranged from 46.9 Gy to as high as 64.3 Gy. (Table 3).

	No. of patients n=25	**(%)**
Side	15	60
Left side	10	40
Right side		
Group stage		
Stage- II	9	36
Stage- III	16	64
T Stage	16	64
T2	8	32
T3	1	4
T4		
N Stage	11	44
N1	10	40
N2	4	16
N3		

Table 1: Patient disease and characteristics.

Parameter	**IMRT**			**Conventional**			**p value**	**Favors**
	Range		**Mean+SD**	**Range**		**Mean+SD**		
	Minimum	**Maximum**		**Minimum**	**Maximum**			
CTV IMC $D_{98\%}$	44.5 Gy	53.3 Gy	47.7 + 1.8 Gy	37.1 Gy	51.7 Gy	47.7 + 3.5 Gy	NS	Equivocal
CTV IMC $D_{2\%}$	51.0 Gy	64.8 Gy	53.4 + 2.8 Gy	52.0 Gy	67.9 Gy	56.5 + 4.5 Gy	p=0.01	IMRT
CTV IMC $D_{50\%}$	47.2 Gy	53.4 Gy	50.7 + 1.4 Gy	50.0 Gy	57.2 Gy	52.4 + 1.5 Gy	p<0.001	IMRT
CTV IMC HI	0.1	0.29	0.1 + 0.1	0	0.3	0.1 + 0.1	p=0.02	IMRT
CTV IMC D_{mean}	48.4 Gy	54.7 Gy	50.9 + 1.5 Gy	50.6 Gy	55.1 Gy	52.8 + 1.1 Gy	p<0.001	IMRT
CTV IMC $V_{<95\%}$	0.00%	33.00%	4.0 + 7.7%	0.00%	8.40%	2.1 + 2.8 %	NS	Equivocal
CTV IMC $V_{>105\%}$	0.00%	59.80%	19.6 + 16.1%	8.00%	95.90%	64.2 + 23.0 %	p<0.001	IMRT
CTV IMC $V_{>107\%}$	0.00%	43.20%	8.1 + 11.3%	0.00%	82.50%	39.5 + 21.7 %	p <0.001	IMRT
CTV AXL1$D_{98\%}$	45.2 Gy	50.4 Gy	49.0 + 1.0 Gy	36.0 Gy	49.3 Gy	44.2 + 2.9 Gy	p<0.001	IMRT
CTV AXL1 $D_{2\%}$	49.3 Gy	57.2 Gy	55.0 + 1.3 Gy	51.8 Gy	88.4 Gy	71.7 + 10.8 Gy	p<0.001	IMRT
CTV AXL1 $D_{50\%}$	47.3 Gy	53.4 Gy	51.6 + 1.3 Gy	46.3 Gy	56.0 Gy	51.0 + 2.0 Gy	NS	Equivocal
CTV AXL1 HI	0	0.2	0.1 + 0.1	0.1	0.8	0.5 + 0.2	p<0.001	IMRT
CTV AXL1D_{mean}	48.3 Gy	53.8 Gy	52.7 + 0.7 Gy	47.5 Gy	55.8 Gy	52.1 + 2.0 Gy	NS	Equivocal
CTV AXL1 $V_{<95\%}$	0.00%	15.70%	0.1 + 0.1%	0.00%	47.80%	16.2 + 13.3%	p<0.001	IMRT

CTV AXL1 $V_{>105\%}$	0.00%	56.20%	39.3 + 9.9%	4.90%	87.00%	34.5 + 20.5%	NS	IMRT
CTV AXL1 $V_{>107\%}$	0.00%	41.70%	22.2 + 10.8%	1.40%	78.60%	27.3 + 18.1%	NS	IMRT
CTVAXL2 $D_{98\%}$	40.2 Gy	50.5 Gy	48.5 + 2.1 Gy	40.1 Gy	50.6 Gy	46.0 + 2.9 Gy	p<0.005	IMRT
CTVAXL2 $D_{2\%}$	49.0 Gy	58.5 Gy	54.9 + 1.30 Gy	56.3 Gy	88.2 Gy	69.5 + 8.0Gy	p<0.001	IMRT
CTVAXL2 $D_{50\%}$	48.3 Gy	54.8 Gy	51.7 + 1.5Gy	49.0 Gy	57.1 Gy	53.7 + 1.9Gy	p<0.001	IMRT
CTVAXL2 HI	0	0.2	0.1 + 0.1	0.1	0.8	0.3 + 0.1	p<0.001	IMRT
CTVAXL2 D_{mean}	48.8 Gy	54.6 Gy	52.5 + 1.4Gy	50.7 Gy	65.8 Gy	55.0 + 2.9Gy	p<0.001	IMRT
CTVAXL2 $V_{<95\%}$	0.00%	10.30%	0.8 + .2.2%	0.00%	15.80%	5.3 + 5.0%	p<0.001	IMRT
CTVAXL2 $V_{>105\%}$	0.00%	87.00%	42.6 + 21.4%	26.40%	90.50%	69.0 + 15.7%	p<0.001	IMRT
CTVAXL2 $V_{>107\%}$	0.00%	74.40%	23.4 + 18.2%	16.90%	85.10%	60.3 + 17.0%	p<0.001	IMRT
CTVAXL3 $D_{98\%}$	46.2 Gy	50.6 Gy	48.8 + 1.1Gy	32.5 Gy	50.6 Gy	44.1 + 4.8Gy	p<0.001	IMRT
CTVAXL3 $D_{2\%}$	50.1 Gy	58.1 Gy	54.6 + 2.0Gy	55.2 Gy	74.1 Gy	62.4 + 4.7Gy	p<0.001	IMRT
CTVAXL3 $D_{50\%}$	49.0 Gy	56.7 Gy	52.2 + 1.8 Gy	49.0 Gy	57.2 Gy	53.7 + 1.8Gy	p<0.001	IMRT
CTVAXL3 HI	0	0.1	0.1 + 0.0	0.1	0.5	0.3 + 0.1	p<0.001	IMRT
CTVAXL3 D_{mean}	49.5 Gy	55.2 Gy	52.4 + 1.3Gy	50.8 Gy	57.2 Gy	54.2 + 1.7Gy	p<0.001	IMRT
CTVAXL3 $V_{<95\%}$	0.00%	8.30%	0.8 + 1.9%	0.00%	22.90%	7.0 + 5.9%	p<0.001	IMRT
CTVAXL3 $V_{>105\%}$	0.00%	87.90%	39.0 + 19.5%	41.60%	92.90%	73.0 + 14.1%	p<0.001	IMRT
CTVAXL3 $V_{>107\%}$	0.00%	79.40%	21.2 + 17.4%	25.70%	91.10%	65.0 + 16.5%	p<0.001	IMRT
CTV CW $D_{98\%}$	45.1 Gy	50.1Gy	47.9 + 1.3 Gy	16.5 Gy	41.7 Gy	29.2 + 8.7 Gy	p<0.001	IMRT
CTV CW $D_{2\%}$	51.7 Gy	58.4 Gy	55.8 + 1.9 Gy	54.7 Gy	79.5 Gy	63.6 + 7.1Gy	p<0.001	IMRT
CTV CW $D_{50\%}$	49.7 Gy	53.7 Gy	51.9 + 1.1 Gy	47.6 Gy	58.9 Gy	52.6 + 2.4 Gy	NS	Equivocal
CTV CW HI	0.1	0.2	0.1 + 0.0	0.3	1	0.6 + 0.2	p<0.001	IMRT
CTV CW D_{mean}	49.7 Gy	53.9 Gy	52.3 + 1.1 Gy	48.3 Gy	58.7 Gy	52.2 + 2.0 Gy	NS	Equivocal
CTV CW $V_{<95\%}$	0.00%	12.30%	1.5 + 3.1%	2.70%	20.10%	9.7 + 4.1 %	p<0.001	IMRT
CTV CW $V_{>105\%}$	5.20%	66.80%	46.2 + 15.3%	33.30%	94.10%	65.1 + 16.5 %	p<0.001	IMRT
CTV CW $V_{>107\%}$	2.30%	53.10%	28.6 + 13.9 %	19.70%	93.40%	48.4 + 19.3 %	p<0.001	IMRT
CTV SCF $D_{98\%}$	45.3 Gy	51.9 Gy	48.8 + 1.8Gy	40.8 Gy	50.2 Gy	45.6 + 2.4Gy	p<0.001	IMRT
CTV SCF $D_{2\%}$	50.6 Gy	58.4 Gy	54.8 + 2.0Gy	52.7 Gy	60.2 Gy	56.1 + 1.9Gy	p=0.034	IMRT
CTV SCF $D_{50\%}$	48.2 Gy	55.1 Gy	51.9 + 1.6Gy	47.6 Gy	54.7 Gy	51.0 + 2.0Gy	NS	Equivocal
CTV SCF HI	0.1	0.2	0.1 + 0.04	0.1	0.3	0.2 + 0.1	p<0.001	IMRT
CTV SCF D_{mean}	48.2 Gy	55.8 Gy	52.4 + 1.6Gy	48.4 Gy	55.4 Gy	51.9 + 1.7Gy	NS	Equivocal
CTV SCF $V_{<95\%}$	0.00%	13.20%	1.4 + 3.2%	0.00%	58.20%	9.8 + 5.9%	p<0.001	IMRT
CTV SCF $V_{>105\%}$	0.00%	81.50%	39.8 + 21.5%	10.90%	87.80%	50.2 + 20.1%	p=0.053	IMRT
CTV SCF $V_{>107\%}$	0.00%	58.50%	20.7 + 15.7%	0.60%	82.60%	36.1 + 21.8%	p=0.003	IMRT

Table 2: Comparison of dose and volume parameters of CTV IMC, CTV AXILLA1, CTV AXILLA2 , CTVAXILLA3 CTV CW and CTV SCF by IMRT and conventional plan.

Parameter	**IMRT**			**Conventional**			**p value**	**Favors**
	Range		**Mean+SD**	**Range**		**Mean+SD**		
	Minimum	**Maximum**		**Maximum**	**Minimum**			
Ipsilateral lung V_{20}	41.00%	56.70%	49.2 + 3.5%	44.20%	73.90%	59.8 + 7.4%	p<0.001	IMRT
Ipsilateral lung V_5	70.50%	100.00%	97.0 + 6.1%	90.10%	100.00%	98.7 + 1.8%	NS	Equivocal
Ipsilateral lung $D_{33\%}$	25.7 Gy	39.9 Gy	33.7 + 4.1 Gy	25.5 Gy	48.7 Gy	39.4 + 5.1Gy	p<0.001	IMRT
Ipsilateral lung $D_{66\%}$	7.2 Gy	23.8 Gy	14.5 + 3.4 Gy	10.1 Gy	30.3 Gy	16.5 + 5.3 Gy	NS	Equivocal
Ipsilateral lung $D_{100\%}$	0.1 Gy	8.2 Gy	3.8 + 2.5 Gy	0.2 Gy	99.8 Gy	7.2 + 19.3Gy	NS	Equivocal
Contralateral lung V_{20}	0.00%	1.20%	0.2 + 0.3%	0.00%	9.50%	2.7 + 2.3%	p<0.001	IMRT
Contralateral lung V_5	2.10%	31.60%	12.2 + 7.1%	0.70%	21.20%	9.7 + 5.3%	NS	Equivocal
Contralateral lung $D_{33\%}$	1.7 Gy	14.2 Gy	3.8 + 2.3 Gy	1.9 Gy	5.3 Gy	2.8 + 0.6 Gy	p=0.043	Conventional
Contralateral lung $D_{66\%}$	0.0 Gy	3.8 Gy	1.9 + 0.8 Gy	1.3 Gy	3.2 Gy	1.9 + 0.45 Gy	NS	Equivocal
Contralateral lung $D_{100\%}$	0.0 Gy	1.8 Gy	0.6 + 0.4 Gy	0.3 Gy	4.5 Gy	1.07 + 0.7 Gy	p=0.050	IMRT
Heart $D_{33\%}$	4.2 Gy	35.6 Gy	17.3 + 10.1Gy	4.7 Gy	44.0 Gy	33.2 + 11.3Gy	p<0.001	IMRT
Heart $D_{66\%}$	0.0 Gy	34.9 Gy	9.4 + 9.3Gy	1.6 Gy	35.9 Gy	13.1 + 12.6Gy	NS	Equivocal
Heart $D_{100\%}$	0.0Gy	7.6 Gy	2.3 + 1.7Gy	0.2 Gy	5.6 Gy	2.1 + 1.5Gy	NS	Equivocal
S cord D_{max}	3.0 Gy	49.4 Gy	39.5 + 7.1Gy	46.9 Gy	64.3 Gy	55.7 + 5.2Gy	p<0.001	IMRT
Opposite breast D_{mean}	1.6 Gy	9.4 Gy	5.8 + 1.8Gy	0.6 Gy	5.4 Gy	2.0 + 1.1Gy	p<0.001	conventional

Table 3: Comparison of dose and volume parameters of ipsilateral and contralateral lung, heart, spinal cord and opposite breast by IMRT and conventional plan.

Discussion

In the present study, target volume was contoured as CTV CW, CTV IMC, PTV CW, CTV axilla 1, CTV axilla 2, CTV axilla 3, CTV SCF and PTV axilla & SCF. According to the ICRU–83, the parameters evaluated for the target volume were $D_{98\%}$, $D_{2\%}$, $D_{50\%}$ and HI while additional dose volume parameters in order to draw a comparison from the literature were $V_{<95\%}$,,$V_{>105\%}$,$V_{>107\%}$ and $V_{110\%}$ [7]. Comparison of dose and volume parameters for target volume and OAR with IMRT plan and standard plan of different studies is shown in Table 4. In our study target volume coverage of the D_{98} was better in IMRT as compared to conventional except in CTV IMC. Dogan et al. showed the D_{95} for PTV breast was 50 Gy in 3DCRT and IMRT. PTVLtSCN D_{95} was 43.7+2.8 and 50.7+0.5 in 3DCRT and IMRT which was significantly different. PTVLtAXN D95 was 25.9+11.4 and 50.3+1.0 in 3DCRT and IMRT which was significantly different [8]. Ahmed et al. 95% volume receivied a median dose of 48.83Gy in IMRT compared to 45.59cGy in standard plan (p=0. 00419) [9].

	Structure	**Parameters**	**IMRT**	**Standard plan**	**p value**
Beckham et al. [10]	PTV	HI , CI	0.95 , CI 0.91	0.74 , CI 0.48	<0.001,<0.001
Chen-Shou Chui et al. [11]	PTV (%)	V_{100} , D_5	93.34 , 107.6	88.23 , 109.5	0.003, .015
Dogan et al. [8]	PTVLtBreast PTVLtIMN PTVLtSCN	D_{95}, D_2, HI D_{95}, D_{90}, D_2, HI D_{95}, D_{90}, D_2, HI	50 + 0.0, 55.4 + 1.6, 10.8 + 3.2 50.3 + 0.8, 49.5 + 0.8, 54.2 + 0.9, 7.9 +2.1*	50 + 0.0, 56.3 + 1.8, 12.7 + 3.6 48.9 + 4.2, 46.6 + 1.3, 54.2 +4.2,10.4 + 3.9	*significant

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	PTVLtAXN	D_{95}, D_{90}, D_2, HI	50.3 + 0.6*, 50.6 + 0.7*, 54.6 + 1.3, 8.6 + 2.2* 50.2 + 0.8*, 50.6 + 0.9, 54.4 + 1.8, 8.4 + 2.7*	43.7 +2.8, 42.2 + 6.2, 56.2 +3.2, 24.9 +9.6 25.9 + 11.4, 28.4 + 16.7, 56.0 + 2.6, 60.1 + 25.5	
Krueger et al. [12]	CW	Minimal dose	43.7 + 1.1 Gy	31.2 +16.5 Gy	p = 0.04
	IMC	Minimal dose	42.8 + 2.1 Gy	21.8 + 13.2 Gy	p = 0.001
Barnett et al. [13]	PTV	Absolute volume >107% (cm^3)	10.5 (30.3)	44.5 (72.3)	p < 0.00005,
Guang-Hua Jin et al. [14]	CTV,	Absolute volume<95%(cm^3)	132.7 (91.7	180.8 (107.8)	p < 0.00005,
	PTV	D_{98}(Gy),D_2(Gy),D_{50}(Gy),V_{95}%, CI, HI	47.3 ± 0.6, 52.4 ± 0.5, 50.7 ± 0.4, 96.1 ± 1.7A 1.3 ± 0.1Bb , 0.11 ± 0.02B	47.3 ± 0.4,53.2±0.6,) 50.6 ± 0.6, 96.2 ± 1.6A, 2.0 ± 0.5Aa, 0.13 ± 0.02A	p>0.05 p<0.05 p<0.05

Table 4: Comparison of dose and volume parameters of target volume with different studies by IMRT plan and conventional plan.

In the present study, hot spot V_{105}, V_{107}, all were more in conventional than IMRT except in CTV AXL1 $V_{105\%}$, CTV AXL1 $V_{107\%}$, PTVAXLSCF V107% which were equal in both the plans. Landau D et al showed percentage volume >105% in standard tangents was 5.4 and four-field IMRT was 0.9 [15]. Li et al. described the $V_{105\%}$ of CTV was reduced from 23% to 7.9% as comparison of conventional plan with IMRT plan [16]. Barnett et al. showed mean decrease of 2.3% in the volumes receiving >107% in IMRT [16]. In present study, cold spot $V_{<95}$ was more in conventional plan than IMRT, except in CTV IMC. Similarly, Barnett et al. reported a mean decreased 3.9% in the IMC volumes receiving <95%, in IMRT [13].

In the present study D_2, was more in conventional plan. Hong et al. reported that the isodose level encompassing 5% of the PTV (D_5), was reduced from 113% in the standard plan to 108% in the IMRT plan and the maximum dose decreased from 121% to 113% [17]. In the present study, homogeneity index was more in a conventional plan, and IMRT plan was more homogenous. Beckham et al. showed that the IMRT plan significantly improved the Homogeneity index (0.95 vs 0.74) (p <0.001) [16]. Dogan et al. showed that the average HI for the PTV to the left breast (PTVLtBreast), improved from 12.7+3.6 for 3D-CRT to 10.8+3.2 for 6-field IMRT. The average PTVLtSCN HI improved from 24.9+9.6 for 3D-CRT to 7.6+2.6 for 4-field IMRT [10].

In the present study, the mean dose received by D_{33} of heart by IMRT was 17.3 +10.0 Gy and 33.2 +11.3 Gy with conventional technique (p<0.001). Beckham et al. showed heart V30 was 1.7% for IMRT compared with best standard plans of 12.5%, respectively (p<0.001) [10]. Li et al. reported that V_{30Gy} was 0.5% in IMRT and 5% in standard plan (p<0.0002) [16].

In the present study, the V_{20} of the ipsilateral lung with IMRT 49.2+3.5% and that was significantly lower than that of the conventional technique of 59.8%+7.4% (p<0.001). Beckham et al. showed the left lung V_{20} was 17.1% for IMRT compared with 26.6% for best standard plans (p<0.001) [10]. Krueger et al. found a statistically significant difference between the average mean lung dose from the IMRT (9.5+2.5 Gy) and PWTF (17.6+3.3 Gy) plans [13]. In the present the study values of lung doses were more than other studies. Because in the present study, we treated the chest wall, IMC, SCF and axillary lymph nodes, so that irradiation of large target volume caused higher dose to lung as compared to other studies, in which only breast or chest wall was treated. IMC and other regional lymph were treated in only a few studies.

In the present study, the mean dose received by opposite breast was 5.83Gy+1.87 by IMRT and 2.04 Gy+1.05 by conventional technique (p<0.001). Beckham et al. showed mean dose (Gy) at IMRT was 4.3 Gy and 2.9 in conventional (p<0.001) [10]. For the contralateral breast Chen-Shou Chui et al. showed the averaged mean dose and D_5 were 2.5% and 1.4% (p<0.0006) and 5.5% and 4.6% (p<0.007), for the three-field wedge and three-field IMRT techniques,respectively [11]. In the present study conventional plans the D_{max} of the spinal cord ranged from 46.9 Gy to as high as 64.3 Gy. A closer look at the plans showed that such high dose was due to the junction of the supraclavicular field with the IMC field. No such hot spot were evident in the IMRT planning the D_{max} of spinal cord ranging from 3 Gy to 49.4 Gy. Krueger et al. reported dose to the spinal cord, in IMRT was 6.7+3.3 Gy and 7.1+ 3.3 in conventional plan [12].

With regard to the target volume, the standard tangents technique delivered the hot spots to the overlapping area, which was consistent with report by van der Laan et al. [18]. The biggest disadvantage of this technique was that it failed to irradiate the IMN adequately for some patients, which was similar to report by Severin et al. [19]. With regard to the normal tissue, the heart is an important normal organ at risk for breast cancer patients, as previous reports have shown an increase in cardiac mortality due to irradiation techniques [20]. Therefore, limiting the dose to the heart for these patients becomes critical. Since the suggestion of a threshold dose of 30 Gy for cardiac effects [21]. Results of this study showed that the heart dose was the lower with the IMRT technique. Another critical structure is ipsilateral lung. The incidence of symptomatic pneumonitis after RT with standard tangents technique is generally less than 5% [22]. Techniques covering IMN radiated at least 10% more lung volume than the techniques not covering IMN [23]. This could result in higher pneumonitis rates for some patients which radiated IMN [24]. IMRT had the lower mean lung dose compared with the conventional technique while giving adequate coverage to IMN. The ipsilateral lung V_{20} with the IMRT was significantly lower than that conventional. IMN in conventional treatment plans a cold spot was seen at the junction of tangential and internal mammary fields because of the two separate fields used to cover both the target regions. On the other hand the IMRT plans showed a more uniform dose coverage with no cold spot. In our study, the IMRT not only reduced the mean lung dose, but also decreased the V_5, compared with conventional technique. The utilization of IMRT resulted in significantly improved target coverage and dose homogeneity as compared to 5 field plans.

Conclusions

IMRT technique is superior to the conventional due to its better chest wall, axilla and SCF coverage. Cold spots and hot spot were less in the IMRT technique. IMRT significantly reduced heart, lung and spinal cord doses as compared with conventional techniques. IMRT seems to provide the optimum balance between the chest wall and regional node coverage and normal tissue sparing and treatment complexity. Long term follow up is needed to determine whether the improvements in dose homogeneity will translate into improvements in disease control and reduction in toxicity.

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