Dosimetric analysis of IMRT versus 3DCRT for chest wall irradiation in patients with breast cancer using 6MV X-Rays

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ABSTRACT

Background: For breast cancer irradiation therapy, Three Dimensional Conformal Radiotherapy (3DCRT) and Intensity Modulated Radiotherapy (IMRT) made tremendous change in treatment delivery in recent times.

Aim: We attempt to compare and analyze the dosimetric aspects of IMRT over 3DCRT for chest wall irradiation using 6MV X-Rays.

Methods: CT simulation details of 33 unselected patients were used for our retrospective study. Dose prescribed was 45 Gy/25 fractions (1.8 Gy/Fraction). The prescribed dose was delivered in a 5 fractions per week schedule. For each patient 3DCRT and IMRT plans were calculated. The best treatment plans were compared for Target Minimum, Maximum, Mean, Conformity Index, Homogeneity Index and Organs at Risk doses and analysed.

Results: The target coverage was achieved by both methods with 95% of prescription dose to the 95% of the target volume to all the plans. Dose conformity was significantly higher with IMRT technique; 3DCRT technique showed more dose spillage outside the boost volume. IMRT showed better in sparing critical organs parameters like Lung V20 and Mean, Heart V30 and Mean, and LAD maximum dose.

Conclusion: Both the methods achieved adequate target coverage, IMRT reduces maximum doses and improves Conformity and Homogeneity indices of target volumes, also reduces dose to OAR.

Keywords: intensity modulated radiotherapy (IMRT), three dimensional conformal therapy (3DCRT), left anterior descending artery (LAD)

INTRODUCTION

The most adopted treatment method for breast cancer patients is breast conservation surgery (BCS), or mastectomy followed by adjuvant radiotherapy. Adjuvant radiotherapy improves local control and improves overall survival. There are various treatment options to employ radiotherapy for breast cancer in women. Conventionally tangential fields are employed to treat the whole breast. With recent advances in technology and Multi Leaf Collimators (MLC), the 3DCRT (Three Dimensional Conformal Radiotherapy) is widely used. Conformal therapy reduces normal tissue doses and increases conformity to target volume.

Introduction of Intensity Modulated Radiotherapy (IMRT) to breast cancer treatment further improved conformity and doses to normal tissue. Transition from 3DCRT to IMRT for chest wall irradiation can result in improved Planning Target Volume (PTV) coverage and Organs at Risk (OAR) sparing. Studies have shown improved homogeneity of PTV coverage with the use of IMRT; the median volume of PTV receiving $\geq$110% of prescribed dose was 0.1% with IMRT compared to 10% with conventional wedges.[1]

The main aim of radiotherapy is to increase tumor control probability (TCP) and decrease the normal tissue complications probability (NTCP). With the use of IMRT, we may hope improve the TCP and NTCP in these patients. A study in early breast cancer patients showed that IMRT had better cosmetic results compared to conventional treatment.[2] We were using the IMRT for chest wall irradiation for the past four years. In the present study, we attempt to compare the dosimetric criteria of IMRT over 3DCRT.

MATERIALS AND METHODS

We used CT simulation details of 33 unselected

patients (21 left sides and 12 right sides) for our retrospective planning study. These patients were already treated with IMRT. Radiation therapy was started within 3 weeks after completion surgery and chemotherapy. The same CT data sets, target volumes and OAR at risk volumes were used for 3DCRT study comparison.

TARGET DELINEATION

After CT scan, the DICOM images were transferred to Eclipse version 10.0.34 (Varian Medical Systems, USA) treatment planning system. Then PTV and OAR were delineated. The RTOG breast cancer atlas was used as guideline for target delineation. The PTV includes chest wall muscle, pectoralis muscle, and ribs. A margin of 5mm was given from CTV to PTV to account for daily set up variations; and 3mm superficial skin excluded. The OAR structures are delineated according to clinical and radiological data. The OAR are contoured as lungs, contra lateral breast, heart, LAD (left anterior descending artery), spinal cord, esophagus, trachea, humerus head and liver.

PLANNING DETAILS AND DOSE PRESCRIPTION

6 MV X-ray from Clinac 600CD Linear Accelerator (Varian Medical Systems, USA) which integrated 120 leaves Millennium MLC was used for dynamic IMRT treatment. The central 20cm of field had 5mm leaf width, and outer 20cm of field had 10mm leaf width. The treatment fields were almost evenly spaced within an arc of 180 degree on the side of the tumour. Gantry angles ranged from 330 to 150 (clockwise) for left side tumours, and 50 to 210 (counterclockwise) for right side tumours. The dose prescribed to PTV was 45 Gy in 25 fractions (1.8Gy/fraction) in 5 fractions per week schedule.[3] The target dose uniformity and conformity are calculated and evaluated.

The conformity index (CI) as defined in ICRU 83 is- $CI_{(ref)}$ = Volume of PTV covered by the reference dose / Volume of PTV (CI of 1.0 is ideal).

The Homogeneity Index (HI)= $D_{2\%} - D_{98\%} / D_{50\%}$ (HI of zero is ideal); where, $D_{2\%}$, $D_{98\%}$, $D_{50\%}$ is dose received by 2%, 98%, 50% volume.

3DCRT PLANNING

Using Beams Eye View (BEV), fields were set up to minimize the dose to heart and lung and maximize the target coverage. Two to four coplanar beams were used to produce adequate dose coverage for target volume. Critical organs were shielded using MLC without compromising PTV coverage. Beam weights were adjusted for optimum coverage and acceptable hot spots were achieved. Target volume was set to receive at least 95% of the prescribed dose.

IMRT PLANNING

Five to seven coplanar beams were used so as to achieve a minimum of 95% of the prescribed dose to 95% of the volume. The dose constraints to the target and critical organs is mentioned in Table 1.

Table 1: Optimization objectives for IMRT plans

Organ	Type	Dose(Gy)	Volume (%)
PTV	max	47	0
	min	45	100
Ipsilateral Lung	V20	20	30
	V30	30	15
Heart	V30	30	10
	Max	40	0
Contra lateral Lung	V5	5	43
Contralateral Breast	V5	5	0
LAD	Max	30	0

Inverse plan optimization method was used to create treatment plans. Heterogeneity correction was done using modified Batho method in eclipse. Dose-Volume Histograms (DVH) was used to analyze the volume receiving 20Gy, 30Gy and 40Gy, mean, maximum and minimum doses.

Statistical Analysis was performed using the Wilcoxon Signed Rank test. This matched pair 't' test was applied to determine the statistical difference between the dose–volume data. The reported '*p*' value is two tailed and values of < 0.05 are considered significant.

RESULTS

The planning objectives were met in all cases with both the techniques. 3DCRT plans frequently

showed hotspots near the skin surface. The normalized target coverage of IMRT and 3DCRT are presented in Table 2.

Table 2: Comparison of target volume coverage parameter (Mean) (Prescribed Dose 45 Gy)

Dosimetric Parameter	3DCRT	IMRT	P Value
Minimum Dose (Gy)	24.71	29.88	0.02
Maximum Dose (Gy)	52.2	49.54	0.01
Coverage (%)	95.9	98.36	0.017
Mean Dose (Gy)	39.45	41.13	<0.01
Conformity Index	1.33	1.15	0.021
Homogeneity Index	0.92	0.94	0.011

There was a consistent improvement in conformity index for breast volume from 1.33 for 3DCRT to 1.15 for IMRT ($p < 0.05$). The Homogeneity Index was improved with IMRT for the breast volume ($p< 0.05$).

Ipsilateral lung V20 Gy was significantly reduced with IMRT ($p< 0.01$). Both lungs V20 Gy was significantly improved with IMRT ($p< 0.01$). The heart V30 Gy was 1.12 % in IMRT against 2.5% in 3DCRT. The V40 Gy was insignificant ($p= 0.06$), but LAD maximum dose was 42.17 Gy for 3DCRT and 29.51 Gy for IMRT ($p=0.01$). Dose Volume Histograms (DVH) shows better normal tissue sparing with IMRT than 3DCRT (Table 3).

Table 3: Comparison of Mean values of Normal tissue dose volume parameters

Parameter	3DCRT	IMRT	P Value
Ipsilateral Lung			
V20 Gy (%)	36.51	25.17	<0.01
V30 Gy (%)	15.14	9.11	<0.01
Mean (Gy)	20.14	14.51	0.071
Max (Gy)	44.81	43.68	<0.01
Heart			
V30 Gy (%)	2.5	1.12	NS
V40 Gy (%)	1.05	0.2	0.06
Mean (Gy)	5.44	4.5	NS
Both Lung			
V20 Gy (%)	18.17	11.5	<0.01
Mean (Gy)	12.54	9.32	0.01
Contralateral Breast V5 Gy (%)	9.91	4.27	0.03
Contralateral Lung V5 Gy (%)	59.8	37.5	0.02
LAD Maximum Dose (Gy)	42.17	29.51	0.01

DISCUSSION

Both IMRT and 3DCRT provided similar results regarding PTV coverage. But analysis of dosimteric data revealed significant differences in quality of target coverage and normal tissue doses. We used equally spaced beam angles for IMRT and tangential fields for 3DCRT plans, which improved homogeneity and conformity indices, also reduced the volume of OAR as shown by Hong et al.[4] Even in patients with very thin (1cm) chest wall, we were able to achieve optimized coverage and reduced dose to OAR. IMRT for breast is explored for its ability to confirm the dose to the concave target volume.

With increasing sophistication in radiation treatment plans, homogeneity indices showed improvement with inverse IMRT as reported by Fisher.[5] Compared to conventional tangential field breast radiotherapy, conformal RT proved better normal tissue sparing, furthermore, IMRT proved reduction of skin toxicity and late effects. The inverse-planned IMRT reduced the hotspots further, because of the beam modulation during optimization. Reports from planning studies with multiple fields show that PTV of 95% coverage values ranges from 90% to 99%.[6,7] We also had a coverage values of >95% for all the patients. The incidence of radiation pneumonitis is related to the ipsilateral lung volume irradiated.[8,9] In our study, both lung V20 Gy and mean dose were significantly lower in IMRT than 3DCRT. Contralateral lung V5 Gy and contralateral breast V5 Gy also showed significant differences.

The risk of pericardial events is related to both dose and volume of radiation to the heart. Stewart JR et al., concluded that the dose should be limited to 60 Gy for less than 25% of cardiac volume and 45 Gy for more than 65% of cardiac volume.[10] Gagliardi et al., reported that CAD risk was much reduced at doses less than 30 Gy.[11] In our study the mean values of V30 Gy were 1.12% and 2.5% for IMRT and 3DCRT respectively; compared to studies reporting V30 Gy values in the range of 2% to 5%.[12] Moreover, the LAD maximum dose was below 30Gy with IMRT.

The monitor unit for IMRT is 6-8 times more than the 3DCRT is a concern.[13] This shows that the

integral dose (ID) would also be higher. Pirzkall et al., studied that the ID for IMRT is higher than conventional treatment.[14] In our study, the ID was significantly higher for IMRT than 3DCRT, probably due to the use of multiple beams. This may lead to large volume of healthy tissue involved during optimization, which, in turn increases the treatment time during delivery. Also the leakage and scatter dose to non target tissue is proportional to the number of monitor units used. Some studies reported, increased low dose volumes with increased number of beam angles.[15] The reported rates of the resulting secondary malignancy is 3%.[16] However, long term follow-ups are required to prove this radiation malignancy.

CONCLUSION

IMRT for chest wall treatment is feasible. Both IMRT and 3DCRT proved better in target coverage, however, IMRT reduces maximum doses and improves conformity and homogeneity indices of target volume as well as reducing the dose to OAR.

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REFERENCES

1. Kestin LL, Sharpe MB, Frazier RC, Vicini FA, Yan D, Matter RC, et al. Intensity modulation to improve dose uniformity with tangential breast radiotherapy: initial clinical experience. *Int J Radiat Oncol Biol Phys*. 2000;48:1559-68.
2. Donovan E, Bleakley N, Denholm E, et al. Breast Technology Group: Randomised trial of standard 2D radiotherapy (RT) versus intensity modulated radiotherapy in patients prescribed breast radiotherapy. *Radiother Oncol*. 2007;82:254-64.
3. Vicini FA, Sharpe M, Kestin L, et al. Optimizing breast cancer treatment efficacy with intensity-modulated radiotherapy. *Int J Radiat Oncol Biol Phys*. 2002; 54:1336–44.
4. Hong L, Hunt M, Chui C, et al. Intensity modulated tangential beam irradiation of the intact breast. *Int J Radiat Oncol Biol Phys.1999;44:1155-64.*
5. Fisher J, Scott C, Stevens R, et al. Randomized phase III study comparing best supportive care to Biafine as a prophylactic agent for radiation induced skin toxicity for women undergoing breast irradiation: Radiation Therapy Oncology Group (RTOG) 97-13. *Int J Radiat Oncol Biol Phys*. 2000; 48: 1307–10.
6. Chui CS, Hong L, Hunt M, McCormick. A simplified intensity modulated radiation therapy technique for the breast. *Med Phys*. 2002;29:522–9.
7. Donovan EM, Bleackley NJ, Evans PM, et al. Dose-position and dose-volume histogram analysis of standard wedged and intensity modulated treatments in breast radiotherapy. *Br J Radiol*. 2002;75:967–73.
8. Recht A, Ancukiewicz M, Alm El-Din MA, et al. Lung dose-volume parameters and the risk of pneumonitis for patients treated with accelerated partial-breast irradiation using three-dimensional conformal radiotherapy. *J Clin Oncol*. 2009; 27:3887-89.
9. Marks LB, Bentzen SM, Deasy JO, et al. Radiation dose-volume effects in the lung. *Int J Radiat Oncol Biol Phys*. 2010;76(S):70-7.
10. Stewart JR, Gajardo LF, Gillette SM, Constine LS. Radiation injury to the heart. *Int J Radiat Oncol Biol Phys*. 1995; 31(5):1205-12.
11. Gagliardi G, Constine LS, Moiseenko V, et al. Radiation dose-volume effects in the heart. *Int J Radiat Oncol Biol Phys*. 2010; 76(S):77-85.
12. Rongsriyam K, Rojpornpradit P, Lertbutsayanukul C, Sanghangthum T, Oonsiri S. Dosimetric study of inverse-planed intensity modulated, forward-planned intensity modulated and conventional tangential techniques in breast conserving radiotherapy. *J Med Assoc Thai.* 2008; 91:1571–82.
13. Jothybasu KS, Bahl A, Subramani V, Rath GK, Sharma DN, Julka PK. Static versus dynamic intensity-modulated radiotherapy: Profile of integral dose in carcinoma of the nasopharynx. *J Med Phys*. 2009;34:66-72.
14. Pirzkall A, Carol M, Lohr F, Hoss A, Wannenmacher M , Debus J. Comparison of intensity-modulated radiotherapy with conventional conformal radiotherapy for complex-shaped tumors. *Int J Radiat Oncol Biol Phys*. 2000;48:1371-80.
15. Cho BCJ, Schwarz M, Mijnheer BJ, Bartelink H. Simplified intensity-modulated radiotherapy using pre-defined segments to reduce cardiac complications in left-sided breast cancer. *Radiother Oncol.* 2004;70:231–41.
16. McDonald MW, Godette KD, Whitaker DJ, Davis LW, Johnstone PA. Three-year outcomes of breast intensity-modulated radiation therapy with simultaneous integrated boost. *Int J Radiat Oncol Biol Phys.* 2010;77:523-30.