Dosimetric Comparison of Different 3DCRT Techniques in Left Breast Cancer Radiotherapy Planning

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ABSTRACT

Treatment plan of 10 patients with left-sided breast cancer treated to a prescribed dose of 50 Gy in 25 fractions were selected. The treatment plans were generated by using an Elekta Precise PLAN treatment plan system (TPS) in three different ways namely M1 method, M2 method and M3 method for evaluation of dosimetric parameters based on three dimensional conformal radiotherapy (3DCRT) technique. Pencil beam calculation algorithm was used for dose calculation of Planning Treatment Volume (PTV) as well as Organ At Risk (OAR), with heterogeneity corrections. Plans were compared according to dose-volume histogram (DVH) analysis in terms of PTV homogeneity and conformity indices (HI and CI) as well as OARs dose and volume parameters. All the three treatment methods achieved comparable radiation dose delivery to PTV-95% of the prescribed dose covering > 95% of the breast PTV. The mean volume of PTV receiving 105% (V_{105}) of the prescribed dose was 2.12% (range 0 - 5.7%) for M1 plan, 1.9% for M2 plan, and 3.08% for M3 plan. The homogeneity and conformity indices (HI and CI) were similar for M1 plan and M2 plan, whereas the M3 plan had better conformity index at the cost of less homogeneity. The low-dose volumes (V_{5Gy}) in the heart and lungs were larger in M1 plan than in the other methods. The value of the mean dose to the ipsilateral lung was higher for M2 plan than the values for with M1 plan and M3 plan. Compared with M1 and M3 plan, M2 plan proved to be a simple planning method for 3DCRT breast irradiation.

Keywords: **Breast cancer, 3DCRT, dosimetric parameters, treatment planning system (TPS)**

INTRODUCTION

Breast cancer constitutes approximately 26% of all cancers in women. Breast cancer incidence increases at a rate of 1-2% throughout the world and each year approximately one million new cases are diagnosed (1). External Beam Radiation Therapy (EBRT) is the most common type of radiation used to treat breast cancer. Three-dimensional conformal radiotherapy (3DCRT) uses multiple radiation fields to deliver precise while sparing normal tissue. 3DCRT/quadrant breast irradiation delivers radiation to only a small portion of the breast. Multiple, targeted beams reduce the chances for irradiation of the critical organs such as heart and lungs. Three-dimensional (3D) conformal radiation therapy is a technique where the beams of radiation used in treatment are shaped to match the tumor. The radiotherapy techniques in the treatment of breast cancer vary in different institutions (2-5), but, in general, the issue of radiation dose delivery to the chest wall after total mastectomy or to the breast following breast conservation surgery remains complex. Many earlier works had addressed the efficacy (single or double isocenter) of three-dimensional computerized tomography (3D-CT)-based treatment planning and field shaping, as well as better dose conformity by applying multi-leaf collimator (MLC) optimized tangential beams using field-in-field techniques, in achieving better radiotherapy plans (6-9). Among these combinations with methods like single isocenter, multiple isocenter, half-beam, or full beam are generated. A significant problem with treatment using different isocenters is undesirably increased radiation doses due to overlapping of fields. At this point, the use of a single isocenter seems to be a suitable solution. However, in the literature we did not find a study comparing one and two-isocenters 3DCRT planning.

A tremendous evolution in treatment process has occurred in recent years. This allowed the delivery of the desired radiation dose distribution to target tissue, while delivering an acceptable radiation dose to the surrounding normal tissues with greater dose gradients and tighter margins. Although breast treatment methods continuously improve with developments in technology, there is still not an accepted standard method. The most commonly used easy access method is 3DCRT planning (7). The treatment planning system (TPS) has a central role in the application of 3DCRT. A modern TPS has more sophisticated calculation algorithms, providing more accurate dose calculation capabilities with 3DCRT delivery techniques. At KYAMCH Cancer Center, different beam configuration/isocenter techniques (10) are being used for breast cancer treatment based on 3DCRT plan with pencil beam/convolution algorithm. The main purpose of this study was to evaluate the dose delivery parameters of the isocentric variable angle with parallel opposed tangential fields in the treatment of left breast cancer by using Elekta Precise PLAN treatment planning system with pencil beam algorithm for different 3DCRT planning methods. This study also aimed to minimize the radiation dose to organs at risk (OAR) other than the planning target volume (PTV) during radiation therapy applied for left breast cancer, by using different planning methods based on 3DCRT.

MATERIALS AND METHODS

The radiotherapy treatment data of 10 patients with left-sided breast cancer previously treated (10) with 3DCRT at the KYMCH Cancer Center, Enayetpur, Sirajgonj were selected. Computed tomography (CT) scans from 10 patients previously treated were selected for this dosimetric study. All patients received a prescribed dose of 50 Gy to the left breast in 25 fractions. Patients underwent standard CT simulation at 3.5 mm slice spacing, in the supine position on an angled breast board. Before simulation, the patient was placed supine on a commercially available breast tilt board to make sternum parallel to the table, with both arms fully abducted (90 degrees or greater) and externally rotated and head position was secured.

The PTV was created by adding a uniform margin of 10 mm around the clinical treatment volume (CTV). The PTV (the chest wall or the left breast) and OAR, such as the heart, ipsilateral lung and contralateral lung, were delineated in 3.5mm thick CT slices. For left breast cancer treatment, these OARs are expected to expose more radiation dose. The field borders were clinically defined with radiopaque wires during simulation and also delineated according to the location of the tumor, extent of breast tissue, and adequate set-up margins. The CT images were transferred to Elekta Precise PLAN TPS for radiotherapy treatment planning. All plans were generated using 6 MV photons from an Elekta Precise linear accelerator equipped with an 80 multi-leaf collimator (MLC). The 3DCRT plans of the three different treatment methods were compared for evaluation of dosimetric parameters. Treatment planning was done by using three different methods to supraclavicular area, internal and external tangential fields. Details of the beam arrangements and objectives of plans are described below:

M1: Different isocenter, supraclavicular area half, breast half beam-Planning was set as supraclavicular area half beam, and tangential field half beam with different isocenter.

M2: Single isocenter, supraclavicular area half, breast half beam-Planning was set as supraclavicular area half beam, and tangential field half beam with single isocenter.

M3: Different isocenter, supraclavicular area full beam, breast full beam-Planning was set as supraclavicular area full beam, and tangential field full beam with different isocenter.

On each of the three planning methods, three objectives were fulfilled before the plan was accepted: i) target coverage heterogeneity within +7% and −5% of the prescribed dose (according to ICRU), ii) OAR sparing to at least the limits stated in Table 1, and iii) sparing of healthy tissue. The number of fields and the beam geometry were fixed in order to avoid variability in the results due to different beam arrangements.

In planning method, the beam arrangement consisted of two parallel opposing tangential beams ensuring the best possible coverage of the breast tissue and minimizing the dose to the adjacent critical structures (i.e., ipsilateral lung and heart). The "isocenter" of the treatment machine is positioned at the centre point of the midline joining two parallel opposing fields. Dynamic wedges were then added to both tangential beams in order to improve the dose uniformity to the PTV. Efforts were made to minimize volumes of heart and lung that unavoidably get included within the field borders. Typical tangential beam arrangement with OAR for left breast is shown in Figure 1. The lateral beam eye view (BEV) of the PTV with MLC-defined port displayed is shown in Figure 2.

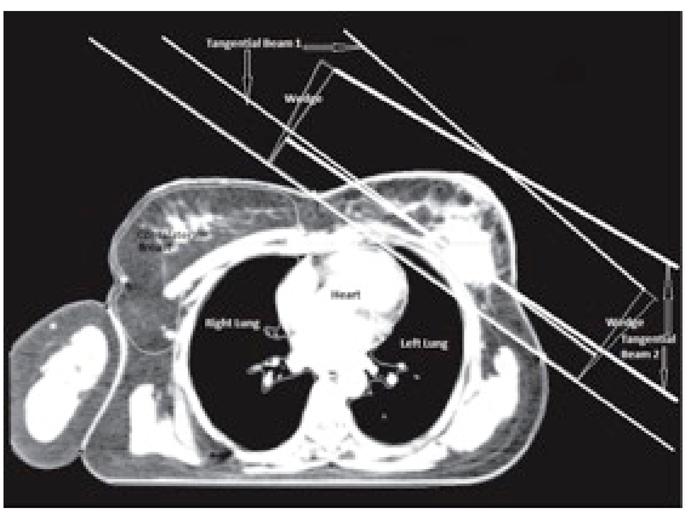

Figure 1. Typical beam arrangement for the two tangential fields with wedges and OAR for left breast irradiation.

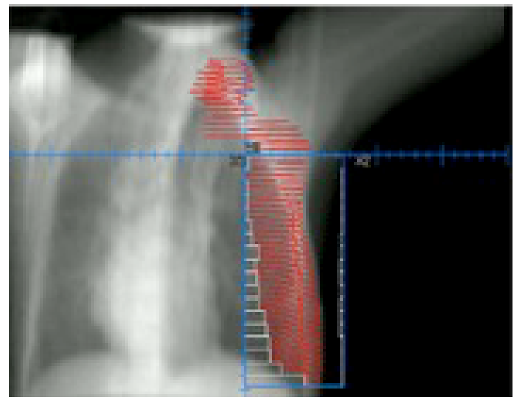

Figure 2. Lateral BEV of the PTV with MLC-defined port displayed

The dose prescribed according to the International Commission on Radiation Units and Measurement (ICRU) Reports 62 and 50 recommendations (11,12). The dose was prescribed to the ICRU reference point, which was usually the iso-center located in the PTV volume centroid. At least 98% of the planned target should receive at least 95% of the prescribed dose, and 2% of the planned target should receive at the outside 107% of the prescribed dose, while a homogeneous dose within 95%-107% of the prescribed dose at target intended to obtain. A dosimetric comparison of the heart was conducted using V_{30}, V_5, and the mean dose. The ipsilateral lung was also evaluated using V_{20} and V_5 (Table 1).

Table 1: Dose-volume constraints for targets and critical structures

Structures	Type	Volume (%)	Dose (Gy)
PTV left breast	Target	95	47.5
	Target	107	53.5
Heart	Organ at risk		
V_{30}		5	30
V_5		50	5
Mean dose			26
Ipsilateral lung	Organ at risk		
V_5		30	5
V_{20}		15	20

Two tangential semi-opposed beams and a multi-leaf collimator were used for different 34DCRT planes. Tangential fields that covered the contoured target volume with MLC blocks and wedges were designed.

All possible combinations of wedges were chosen to optimize coverage of the PTV and to obtain the best planning, a minimum of two and a maximum of four tangential fields in different wedges and energies were used. Gantry angles ranged from 301° to 312° for the medial fields and from 114° to 135° for the lateral fields for patients treated on the left side.

Dose volume histograms of the PTV and OAR of the 3D-CRT plans were generated using mean doses received by D_{98}, D_2, of the breast volume and the mean volumes that received, V_{95}, V_{100}, V_{107} of the doses and dose parameters compared. The dose homogeneity index (DHI) and the conformity index (CI) were defined as follows:

The Homogeneity index (HI) was defined as the fraction of the PTV with a dose between 95% and 107% of the prescribed dose ($V_{95\%}$ -$V_{107\%}$).

$$DHI = (D_2-D_{98}) \div D_{pres} x100\%$$

where, D_{98} is the dose received by 98% of the target volume on the c-DVH; D_2 is the dose received by 2% of the target volume on the c-DVH; D_{pres} is the prescribed dose. The DHI should be less than 15 for an acceptable plan and lower DHI values indicate a more homogeneous dose distribution.

However, CI was defined as the fraction of the PTV surrounded by the reference dose ($V_{95\%}$) multiplied by the fraction of the total body volume covered by the reference PTV dose $[(PTV_{95\%} \div PTV)\times(PTV_{95\%} \div V_{95\%})]$. The CI values ranged from 0-1. A higher CI value indicates higher dose conformity to the target.

RESULTS AND DISCUSSION

In this study, the dosimetric outcomes of different 3DCRT plans in treating the left breast were investigated. The dosimetric comparisons of the treatment volume for the three planning techniques are shown in (Table 2).

Table 2: Summary of Dosimetric values of the treatment volumes for the three 3DCRT planning methods

Dosimetric parameters	Different 3DCRT methods		
	M1	M2	M3
$V_{95\%}$	97.8	98.5	98.2
$V_{100\%}$	78	75	81
$V_{107\%}$	11	10	09
CI	0.95	0.96	0.94
DHI	12.6	12.2	12.3

All the three plans, M1, M2 and M3, achieved comparable good dose coverage, delivering prescribed dose more than 95% to > 95% of the breast PTV. In all these methods, 105% of dose (hot regions) was observed in less than 5% of the target volume. Mean volume of PTV breast receiving 105% was 2.5% (range 0-7.8%) for M1, 2.1% for M2, and 2.8% for M3.

In order to identify the most favourable planning method for PTV coverage, different 3DCRT planning was compared using V_{95} criteria shows a comparison of the three planning methods on the proportion of the PTV receiving 95% of the prescribed dose, it can be seen that the proportion of PTV receiving 95% of the prescribed dose appeared M2 planning (98.5%) compared with the M1 (97.8%) and M3 (98.2%). The M2 planning method gave more consistency in terms of average coverage. In all cases of the plans, there was at least 95% coverage of the 95% isodose. This would seem to suggest that different 3DCRT plans in these cases would give a good homogenous dose distribution. M2 plans would give a much more homogenous dose distribution (Figure 3).

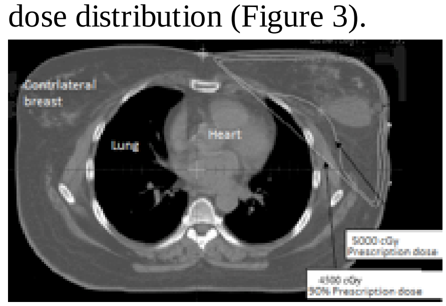

Figure 3: Typical TPS dose distribution for 3DCRT plans for prescription dose and 90 % dose level for left breast.

The DHI in M2 3DCRT method was found to be average 12.2 it was slightly better than M1 and M3 3DCRT as average value of 12.6 and 12.3 respectively. The CI was in M2 3DCRT (0.96) and better than M1 (0.95) and M3 (0.94) 3DCRT planning methods. Figure 4 shows the DVH comparison between the three methods. The values obtained in this study in three different 3DCRT planning were similar to the literature, although the superiority of single isocenter use could not be clearly demonstrated (6, 9).

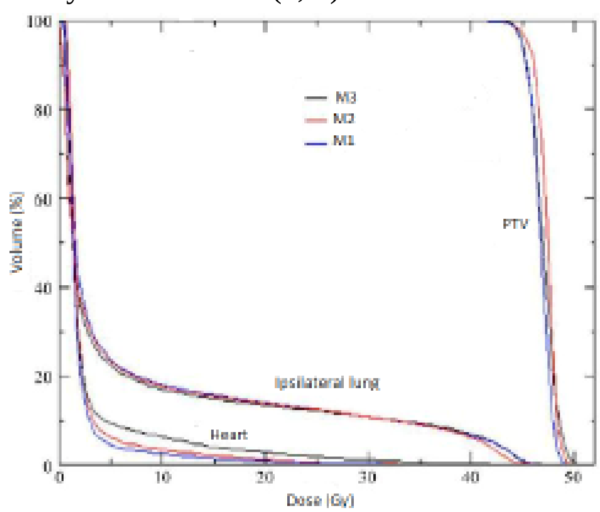

Figure 4: DVH curves for PTV, ipsilateral lung and heart for different 3DCRT plans

The average dosimetric characteristics of the OAR for the three planning techniques are presented in Table 3. The mean volume for V_{20} lung doses were 19, 16 and 13% for the different 3DCRT planning respectively. It shows that M1 method contributes a little more lung dose at the lower values than the other M2 and M3 3DCRT planning methods. The Heart V_{30} was measured for each of the planning methods. It can be seen that the M2 results showed a reduction of the cardiac V_{30} dose 4% versus 7% for M1 and mean heart dose 1350 cGy versus 1400 cGy for M2 and M1 3DCRT planning methods, however M3 plan results showed increase of minimal heart dose, mean 1350 cGy in M2 plan versus 1400 cGy in M1 planning method, when analyzed for dose-volume parameters.

Table 3: Doses to Organs at Risk (OAR) for different 3DCRT planning methods.

OAR	Parameters	Mean value for different planning methods		
		M1	M2	M3
Ipsilateral lung	$V_{20(\%)}$	19	16	13
	$V_{5(\%)}$	25	19	21
Heart	$V_{30(\%)}$	7	4	5
	Mean dose (cGy)	1400	1350	1480
	Minimal dose (cGy)	90	95	85

CONCLUSION

In this study, different dosimetric parameters of PTV as well as OAR were analyzed for different 3DCRT plans of left breast site. All 3DCRT plans are dosimetrically feasible for treating the left breast as a whole PTV, in terms of both PTV coverage and normal tissues sparing. All CI and DHI values are within acceptable limits. Based on these results, the application of single isocenter for 3DCRT technique in left breast cancer provides slightly more advantages especially in PTV and OAR dosages.

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