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Original Article

Oncology Section

Dosimetric Comparison between TomoHelical and TomoDirect Radiotherapy in Locally Advanced Left-sided Breast Cancer Patients: A Retrospective Observational Study

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ABSTRACT

Introduction: India has the highest incidence of breast cancer, with treatment typically involving neoadjuvant chemotherapy, surgery, and radiotherapy. Newer techniques like Intensity-modulated Radiation Therapy (IMRT) and tomotherapy, including TomoDirect and TomoHelical, offer improvements over traditional 3Definitive Chemoradiotherapy (DCRT).

Aim: To quantify the variabilities of TomoDirect (TD) and TomoHelical (TH) plans for chest wall and Supra-clavicular Fossa (SCF) irradiation in locally advanced left breast cancer treatment.

Materials and Methods: The present retrospective observational dosimetric study was conducted from March 2019 to September 2019 at a private cancer centre in eastern India. TD and TH both plans were created in five left breast cancer patients using tomotherapy machine for chest wall and SCF region volumes. The prescription doses for both plans were 50 Gy in 25 fractions. The study measured dosimetric parameters such as Planning Target Volume (PTV) coverage, doses to Organ At Risk (OAR), and treatment times etc. Data analysis was performed using IBM Statistical Package for Social Sciences (SPSS) software, version 25.0.

Result: Both plans were almost similar in terms of PTV coverage except for hot areas, which are more common in the TD plans {V107 2.075 cc (TD) vs. 0.4 cc (TH)}. For OARs, values of V5 for the ipsilateral lung and contralateral breast, mean dose (Dmean) were lower in TD, but other parameters were almost similar in both modes. Although TomoHelical improves homogeneity and regulates a high dose gradient better than the TD plan, it comes at the cost of a high integral dose to surrounding normal tissue. The average treatment time is less for TD as compared to TH (mean 325.5 sec vs. 403.35 sec, p-value=0.013).

Conclusion: TomoHelical and TomoDirect plans have almost similar PTV coverage and conformity. TD achieves a lower ipsilateral lung low dose area and contralateral breast mean dose, whereas TH offers a more homogeneous plan. Hence, both plans are feasible modes of treatment. For intricate plans, like those incorporating chest wall plus SCF with or without axilla, TH will be a superior option; however, TD will be better for simpler plans, like those that need just chest wall irradiation.

Keywords: Breast cancer, Post-mastectomy radiotherapy, Supra-clavicular fossa

INTRODUCTION

India has the greatest incidence and prevalence of breast cancer [1]. The cornerstones of treatment for locoregionally advanced breast cancer remain Neoadjuvant Chemotherapy (NACT) followed by surgery and adjuvant radiotherapy, or upfront surgery followed by adjuvant chemotherapy and radiotherapy with or without hormone therapy. Compared to surgery or chemotherapy alone, radiotherapy improves patients' overall survival [1-5]. The conventional approach for treating breast cancer, 3DCRT, was widely accepted since it satisfied the requirements to maximise tumour dose and reduce OAR effects. Subsequently, other techniques were introduced for Post-Mastectomy Radiotherapy (PMRT), such as IMRT, hybrid IMRT and helical tomotherapy [6,7]. Both helical and direct modalities of treatment are offered by contemporary tomotherapy devices, and both are useful in the management of breast cancer. While employing moderately modified plans, the TomoDirect module duplicates the dose delivery and planning properties of 3DCRT on a helical tomotherapy platform, and the TomoHelical Mode is utilized to provide IMRT with a 360-degree rotation using a fan beam [8-10]. However, for the Indian population, the published literature comparing the dosimetric variables for both techniques is sparse [11-13], in terms of treatment time and use of breath hold technique in tomotherapy [14]. We here generated paired plans on five available patients for chest wall with supraclavicular nodal station radiotherapy to compare the homogeneity, conformity, organ sparing, target coverage for plan quality metrics, and treatment time for both implementations on the new Radixact X9 helical tomotherapy platform.

MATERIALS AND METHODS

The present retrospective observational dosimetric study was conducted from March 2019 to September 2019 at HCG EKO Cancer Centre, Kolkata, India. Ethical approval was not necessary for the preparation of this article as it was a retrospective study and no intervention was done in terms of patient care.

Inclusion criteria: Female patients with newly diagnosed locally advanced left-sided breast cancer, eligible for locoregional RT.

Exclusion criteria: Any patients with early or recurrent/metastatic breast cancer, right-sided breast cancer, and prior history of any anti-cancer treatment was excluded from the study.

A total of five patients were selected with a diagnosis of locally advanced left-sided breast cancer, who underwent neoadjuvant or adjuvant chemotherapy and Modified Radical Mastectomy (MRM) at a private cancer hospital in eastern India. All of them received PMRT to chest wall and ipsilateral Supraclavicular Fossa (SCF) in view of locally advanced disease.

For those five patients, matched plans were generated on the same volume for TomoDirect as well as TomoHelical techniques. All selected patients had locally advanced histopathologically proven invasive breast cancer with stages greater than IIB to IIIC according to American Joint Committee on Cancer (AJCC) cancer staging system, 8th edition [15]. They had a T2 or upwards primary tumor and multiple axillary nodes positive, requiring radiotherapy to the chest wall as well as supraclavicular regions. Two patients had an exceptionally curved and thinned-out chest wall with a median thickness of less than 1 cm in places, and hence, it was challenging to come up with suitable deliverable plans in both the TomoDirect and TomoHelical techniques.

Study Procedure

Simulation and contouring: Patients were simulated using a Siemens Biograph® 128-slice scanner. Positioning was done using a breast cushion (Macromedics®) with the head turned in the opposite direction and hands positioned overhead with handgrip support. Computed Tomography (CT) images were acquired with a 2.5-mm slice thickness and three laser coordinate systems for localisation. The image series was transferred to Integrated Data Management System (IDMS) and imported into Precision 1.1.1.1 (Accuray Inc.)® Treatment Planning System (TPS). Plans were created for both modalities, TH and TD, on the Precision® planning system. The target volumes and OARs were delineated by radiation oncologists according to the Radiation Therapy Oncology Group (RTOG) atlas [16].

Planning: TomoDirect plans were generated with beam angles selected to cover the PTV with consideration of maximal OAR sparing. TomoHelical plans were also created using optimisation parameters in the following range: Pitch 0.215-0.298, field width 2.5/5 cm, modulation factor ranging 2.0-2.5 selected depending upon the case. Both plans had relatively good coverage of PTV and OAR. The dose prescription for PTV was 50 Gy in 25 fractions of 2 Gy daily dose. Our institutional protocol has migrated to a hypo fractionated regimen in line with the START B protocol [17] for chest wall irradiation; however, for this study, we decided to use conventional 2 Gy fractions for diametric plan comparison. Pre-approved plan acceptance criteria were set at PTV coverage requiring at least 95% of the dose to 95% of the PTV. OAR was maintained within Quantitative Analyses of Normal Tissue Effects (QUANTEC) guidelines [18] for each individual organ, with emphasis on contralateral breast, underlying and contralateral lungs, and heart.

Evaluation: The evaluation of the plans was based on isodose coverage for PTV, ensuring a maximum dose less than 107% and a minimum dose greater than 95% for all regions of the PTV, Conformity Index (CI), and Homogeneity Index (HI). The following definitions were used for CI and HI, respectively: CI=Volume of PTV covered by the reference dose/volume of PTV. CI=1.00 was for an ideal case. HI=homogeneity index was the ratio of the dose difference between D2 (the dose to 2% of the target volume) and D98 (the dose to 98% of the target volume) to D50 (the median target dose). The HI varies from 0-1 and the lower value confirms the good homogeneity.

The following parameters were compared for both the plans- PTV coverage, CI, and HI for target volume assessment. For OARs ipsilateral lung doses (V5, V20, Dmean) and heart doses (Dmean, V5, V30), contralateral breast mean doses. Apart from dosimetric parameters, we checked for total beam-on time (treatment time) for both plans.

STATISTICAL ANALYSIS

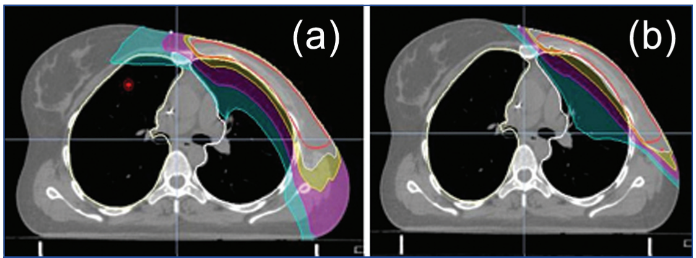
All the continuous variables were expressed as mean±Standard Deviation (SD) and categorical variables as frequency and percentage after the normality assumptions checked by the Shapiro-Wilk test. The comparison between TH and TD was done using the Student t-test. A p-value<0.05 was considered statistically significant. Data analysis was done using IBM SPSS, version 25.0 software.

RESULTS

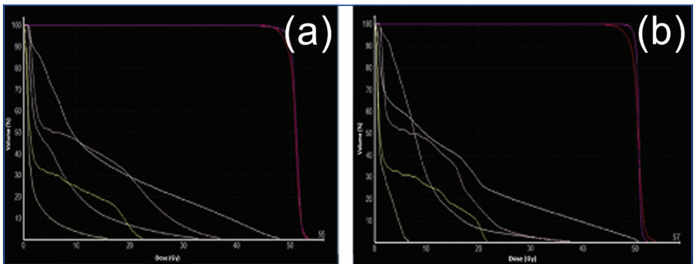
[Table/Fig-1,2] show the dose colour wash and Dose-volume Histogram (DVH) for both the representative TH and TD plans, respectively. All the dose parameters for target coverages are similar in both the TH and TD plans (p>0.05), except for Dmax (p=0.001) [Table/Fig-3].

For ipsilateral lung, Dmean and V20 are similar for both plans (p>0.05), but the low dose area of V5 is greater in the TH plan (p=0.004). The mean dose to contralateral breasts is also higher in the TH plan as compared to the TD plan (p=0.01) [Table/Fig-4].

The average treatment time for the TD and TH plans is 325.5 seconds and 403 seconds (p-value=0.013), respectively [Table/Fig-5].



[Table/Fig-1]: Comparison of dose colour wash and isodose lines between TomoHelical (a) vs TomoDirect (b).



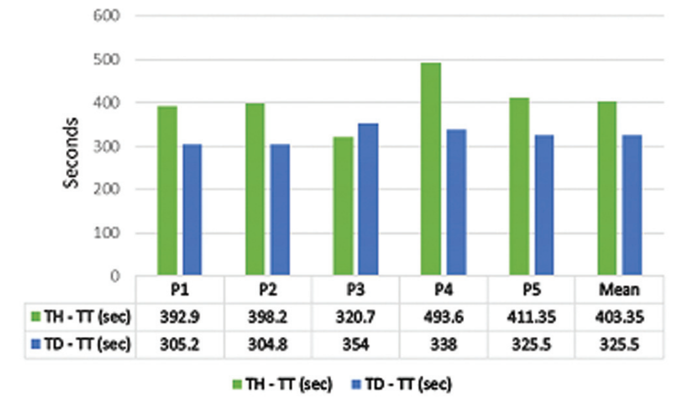
[Table/Fig-2]: Comparison of dose volume histogram between TomoHelical (a) and TomoDirect (b).

Parameters	TomoHelical			TomoDirect			p-value (Student t-test)
PTV	Mean	Range	Standard deviation	Mean	Range	Standard deviation	
D min	30.00 Gy	(41.97-22.33) Gy	7.554	26.89 Gy	(33.90-18.68) Gy	6.151	0.446
D mean	50.82 Gy	(51.44-50.23) Gy	0.431	50.58 Gy	(51.00-50.29) Gy	0.290	0.343
D max	55.19 Gy	(56.28-54.16) Gy	0.752	57.10 Gy	(57.76-56.59) Gy	0.476	0.001
V95	96.95 %	(98.30-95.40) %	1.128	95.77 %	(96.80-94.30) %	0.923	0.109
V107	0.4 %	(1.0-0.10) %	0.374	2.075 %	(5.10-0.60) %	1.805	0.077
D2	52.66 Gy	(53.22-51.92) Gy	2.559	53.26 Gy	(54.34-52.61) Gy	0.704	0.724
D98	46.49 Gy	(47.72-45.32) Gy	1.065	46.10 Gy	(46.91-45.27) Gy	0.599	0.502
HI	0.118	(0.14-0.10)	0.017	0.139	(0.16-0.11)	0.021	0.120
CI	0.96	(0.98-0.95)	0.858	0.95	(0.96-0.94)	0.011	0.363

[Table/Fig-3]: Comparison of dosimetric parameters for PTV between TomoHelical and TomoDirect.
Dmin=Minimal dose received by 99% of target volume; Dmean=mean dose; Dmax=maximum dose; V95=PTV volume (%) received 95% of the prescribe dose; V107=PTV volume (%) received 107% of the prescribe dose; D2=the dose to 2% of the target volume; D50=the dose to 50% of the target volume; D98=the dose to 98% of the target volume; CI: Conformity Index; HI: Homogeneity Index.

Parameters	TomoHelical			TomoDirect			p-value (Student t-test)
	Mean	Range	Standard deviation	Mean	Range	Standard deviation	
Ipsilateral lung							
D mean	13.29 Gy	(14.64-11.97) Gy	1.568	12.47 Gy	(15.36-09.39) Gy	2.463	0.548
V5	68.95%	(76.00-58.40)%	6.701	51.47%	(60.30-42.10)%	7.107	0.004
V20	22.80%	(29.20-17.00)%	5.497	22.52%	(30.50-14.60)%	6.796	0.945
Heart							
Mean	7.17 Gy	(8.49-6.00) Gy	0.891	7.65 Gy	(10.24-5.54) Gy	2.122	0.670
V5	22.86%	(26.94-17.90)%	3.301	28.20%	(46.14-14.96)%	5.786	0.670
V30	8.85%	(11.11-7.49)%	1.384	10.38%	(12.75-7.82)%	1.765	0.165
Contralateral breast							
Dmean	5.52 Gy	(6.61-4.71) Gy	0.697	2.49 Gy	(5.53-0.70) Gy	1.894	0.010
Spinal cord							
D max	25.986 Gy	(36.15-23.18) Gy	6.608	18.49 Gy	(22.31-8.47) Gy	5.800	0.093

[Table/Fig-4]: Comparison of the dosimetric parameters for the OARs between TomoHelical and TomoDirect,
Dmean=mean dose; Dmax=maximum dose; V5=volume (%) receiving 5Gy of the prescribe dose or higher; V20= volume (%) receiving 20Gy of the prescribe dose or higher; V30= volume (%) receiving 30Gy of the prescribe dose or higher



[Table/Fig-5]: Treatment time comparison between TH and TD.
TH: TomoHelical; TD: TomoDirect; TT: Treatment time; sec: second; P: Patient

DISCUSSION

Previous studies [8,10,19] on the comparison of TomoHelical and conventional 3-Dimensional Conformal Radiotherapy (3DCRT) or fixed beam IMRT showed that TH provides better conformity, homogeneity, and tissue sparing in postmastectomy radiotherapy treatment as compared to other techniques.

This study showed low-dose regions within the body volume were significantly lower in TD as compared to TH plans. Planning complexity was significantly higher in TD plans, with challenges arising in regulating high dose in tangential regions within and around the PTV volume, with occasional high dose regions appearing even outside of the PTV. TD requires liberal use of planning support structures, pseudovolumes and dose-regulating structures to overcome this issue compared to TH planning. Beam arrangements were selected carefully to ensure optimal coverage of PTV and maximal OAR sparing. Field width, modulation factor, pitch and constraints for PTV and OARs, and other parameters were selected to get the best optimal plan. Teke F et al., found that there is no significant difference in PTV coverage in comparison of TH with TD [19]. In the present study, we found almost similar results, except for Dmax ($p=0.001$). There was no significant difference in the values of CI between the plans (0.96 and 0.95, $p>0.36$). Though in the case of HI, we found a difference (0.118 vs. 0.139) but not statistically significant ($p=0.12$); Similarly, Teke F et al. study showed no significant difference in HI ($p=0.15$) [19]. But Murai T et al., reported that in breast treatment, TD plans had a worse CI than TH (2.21 vs. 4.63) and V95 in TD was better than TH [8]. However, our results showed that TH has a little better V95 coverage than TD.

The ipsilateral lung V5 (volume of lung receiving at least 5 Gy) was well within tolerance in TD (51.47%) and TH (68.95%). On the other hand, V20 (the volume of lung receiving at least 20 Gy) was similar in both plans (TH vs. TD: 22.8 vs. 22.52). As an arc therapy, TH demonstrated increased low-dose areas in the lung (V5) compared to a 3DCRT plan (TD), which may lead to a higher incidence of pulmonary complications resulting from increased low-dose radiation exposure [20].

In a detailed comparison of lung doses for both techniques, we found V5 in all five plans was lower in TD than TH, but V20 in some TD plans was higher than TH. Hence, the planning technique should be chosen carefully based on the anatomy of the patients, as it appears from our observations that TD poses limitations for specific anatomy, like curved or thinned-out chest wall patients, for PMRT, whereas TH can be chosen regardless of the anatomy of the patients [21]. Previous studies [10,22-24] confirmed TH was superior when adding regional nodal irradiation in left-sided breast cancer with a lower mean heart dose as well as a lower V5 and V30 cardiac dose than TD. Teke F et al., reported that TD plans were superior in terms of almost all OAR doses, for example, heart, ipsilateral lung, spinal cord, and contralateral breast ($p<0.05$) [20]. But in the present study, only the low dose area in the ipsilateral lung (V5) and contralateral breast mean dose were significantly lower in the TD plan as compared to the TH plan; the rest of the OARs doses were similar in both techniques. For all patients, the mean contralateral breast dose values in TH were higher than in TD plans. This may be due to rotational beam delivery in TH; the low dose to the contralateral breast may induce second malignancy in long-term survivors [25]. Teke F et al. [19] reported that TD was an appropriate treatment mode for chest wall only irradiation; however, previous studies reported that TH was superior for chest wall with supraclavicular fossa radiotherapy We observed that the TH plan is superior for patients with a chest wall with nodal irradiation (SCF±axilla), a thinned curved chest, bilateral breast irradiation, etc., whereas the TD plan may be offered for uncomplicated, like chest wall only irradiation [26].

Limitation(s)

The study's biggest shortcoming was its tiny sample size, which prevented it from accurately illustrating the results of the analysis. Patients with early-stage cancer and those with right breast cancer were excluded, in addition to the limited sample size. So, it is impossible to examine the dose-volume effect of radiation to the breast or the chest wall alone.

CONCLUSION(S)

TomoHelical and TomoDirect IMRT have almost similar PTV coverage and conformity. Doses to OARs are also similar for both techniques, except for low-dose areas (integral dose), which are more common in the TH plan. So, the technique should be chosen as per the clinical requirements and complexity of the treatment plan. To validate these plans, we need to do a randomized control trial with a greater number of patients.

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