e-ISSN: 0975-1556, p-ISSN:2820-2643

Available online on www.ijpcr.com

International Journal of Pharmaceutical and Clinical Research 2023; 15(5); 2253-2259

Original Research Article

Comparison of Dosimetric Parameters between Two Treatment Planning Methods of IMRT in Breast Cancer Patients

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Received: 26-02-2023 / Revised: 24-03-2023 / Accepted: 30-04-2023

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Conflict of interest: Nil

Abstract

Introduction: Intensity modulated radiotherapy (IMRT) is now becoming standard of practise in breast cancer. In IMRT plans, the beam arrangement preferred is to ensure optimal dose delivery to the clinical target volume (CTV). In planning the beams may be preselected by the physicist known as Preselected Beam Optimization (PSBO) or may be selected by the treatment planning system known as Beam Angle Optimization (BAO). Both the methods aim to achieve prescription to planning target volume (PTV) with maximal sparing of organs at risk (OARs). The present study aims to compare the dosimetric parameters between the Beam angle optimization with preselected beam angle orientation (PSBO) in breast cancer patients.

Materials and Methods: Present study was conducted in the department of Radiation Oncology. Twenty patients of post mastectomy breast cancer planned by PSBO were randomly selected. A new plan was created for each patient with BAO method. Dosimetric parameters of PTV (V 47.5, HI and CI) and OAR (heart, lung, oesophagus, spinal cord and contralateral breast) were compared.

Results: The PTV dosimetric parameters of BAO showed were better in comparison to PSBO in V47.5 (96.5 % v/s 94.6%), the Homogeneity Index (0.08 vs 0.10). Other PTV dosimetric parameters showed no statistically significant difference. The PSBO plans had a lower value of Mean dose of heart (10.3 vs 15.5), PRV Spine was (12 vs 22), V5 of contralateral lung (7.6 vs 35.2) and dose to contralateral breast (2.6 vs 4.0). The monitor units calculated were lower in PSBO plans (1027 vs 1177) (p value = 0.003).

Conclusion: In the present study some of the PTV parameters had a significant difference in BAO whereas the PSBO plans achieved better dose distribution to OARs, long term follow up is needed to validate its clinical implications.

Keywords: Breast Cancer, IMRT, Dosimetric Parameters, PSBO, BAO.

Introduction

Radiotherapy is an important treatment modality in management of breast cancers. With advent of newer techniques of delivery of radiotherapy, Intensity modulated radiotherapy (IMRT) is now becoming standard care of practice. In IMRT plans, the beam arrangement preferred to ensure optimal dose delivery to the clinical target volume (CTV) of breast cancer patients is by multiple tangential beam pairs. In planning the beams may be preselected by the physicist known as Preselected Beam Optimization (PSBO) or may be selected by the treatment planning system known as Beam Angle Optimization (BAO). Both the treatment planning methods aim to achieve prescription to planning target volume (PTV) with maximal sparing of organs at risk (OARs). The quality of plans is defined by appropriate choice of the number, orientation of beams and incorporation of scatter dose. The optimum number of beams and their orientation depend on a complex combination of a number of factors including anatomy, tolerances of normal tissues, tissue architecture, and prescription dose. The beam angle selection (BAS) in intensity-modulated radiation therapy depends on finding the best combination of several beams in a discrete set of beams [1]. However, for creating conformal dose distributions optimum beam intensity is also needed.

There are software algorithms for treatment plans which can be generated in a much shorter time with the help of Artificial intelligence (AI). The present study aims to compare the dosimetric parameters between two treatment planning methods – PSBO and BAO by IMRT planning in breast cancer patients.

Materials and Methods

Study Setting: Department of Radiation Oncology, Shri Ram Murti Institute of Medical Sciences

Study Design: Observational study

Study population: For the present study 20 patients of Breast Cancer (post-mastectomy) which were planned by PSBO were randomly selected. A new plan for each patient was created with BAO method.

Target volume delineation and Organs at Risk:

CT scan for radiotherapy planning was done on axial CT slice thickness of 3 mm. Target volume delineation was done as per the recommendations of International Commission on Radiation Units and Measurements Reports (ICRU) Report 50, 1993; ICRU Report 62, 1999[2,3] OARs like heart, ipsilateral lung, contralateral lung, oesophagus, spinal cord, contralateral breast were also delineated.

Dose Prescription: These patients were planned to a dose of 50 Gy in 25 fractions to the PTV. The ideal planning objective was to achieve a minimum dose of 95% and a maximum dose of 107% of the prescribed dose.

Radiotherapy planning and prescription

1. The planning and contouring were done using Varian Eclipse version 13.6 Treatment Planning System (TPS), and calculation was done using Anisotropic Analytical Algorithm (AAA).
2. In the Preselected beam orientation, the beam angles are chosen by a medical physicist. The selection of beams depends upon the OARs adjacent to PTV, after which the optimisation was done giving upper and lower objectives to PTV, upper objectives to serial organs and mean objectives to parallel organs.

For the present study, the treatment plans using PSBO which had already been executed had to be compared with the new plans using BAO. For this, another new plan was generated by BAO, using the same Target Volume delineation, prescription and Radiotherapy planning objectives.

Dosimetric parameters to be compared in both plannings:

PTV dosimetric parameters:

1. V47.5, Dmax, Dmean, D2, D50, D98, p Conformity index (pCI), Homogeneity index (HI)
2. Homogeneity index (HI) -

   $HI = (D_{2\%} - D_{98\%}),$
   $D_{50\%}$

   where $D_{2\%}$, $D_{50\%}$, $D_{98\%}$ are the absolute dose delivered to 2%, 50% and 98% of PTV, HI of zero indicated a homogenous distribution.

- Conformity Index (CI) – Conformity Index is a measure of degree of conformity of the absorbed dose distribution to the PTV. For the evaluation of CI, Paddick's conformity Index was used[5]

  $pCI = (TV^2{}_{PIV})$
  $(TV \times PIV)$

Where TV_{PIV}, TV and PIV are the prescribed isodose volume over the target volume, Target Volume, Target Volume and Prescription isodose volume respectively.

OAR dosimetric parameters:

1. Heart: D_{mean} <26 Gy
   V_{25} <10 Gy
2. Ipsilateral lung: V_{20} < 20%
   V_{50} = 0
3. Contralateral lung: V_5 < 20%
   V_{10} = 0
4. Esophagus: V_{35} < 50%
   V_{50} < 40%
5. PRV Spinal Cord: D_{max} < 50 Gy
6. Contralateral Breast**:** Dmean < 4 Gy

The doses to PTV and OARs were analysed from Cumulative Dose–volume histograms (DVHs), as recommended in ICRU Report 83, 2010.[4]

Statistics

Statistical significance was calculated using unpaired 't' test. A p-value of <0.05 was considered as statistically significant.

Results

The PTV Dosimetric parameters and OARs were compared between PSBO and BAO generated plans, the results of which have been shown in Table-1 and Table-2

Table 1: Dosimetric parameters of the PTV in two techniques (Mean ± SD)

Parameters	Preselected Beam Orientation (Mean± SD)	Beam Angle Optimisation (Mean± SD)	P - value
V47.5	94.61 ± 2.34	96.50±2.06	0**.01**
Dmax	53.94± 1.06	53.869±1.05	0.82
Dmean	49.75± 0.504	49.85±0.60	0.54
D2	51.63± 0.83	51.39± 0.82	0.37
D50	49.96± 0.53	50.05± 0.53	0.61
D98	46.29± 1.63	46.89± 1.26	1.78
Homogeneity index	0.101± 0.02	0.08± 0.02	**0.02**
Conformity index	0.765± 0.09	0.79 ± 0.09	0.99
MUs	1024.35± 259.8	1177.7± 184.01	**0.03**
No. of fields	6.15 ±0.81	6.65± 1.34	0.16

Table 2: Dosimetric parameters of the OARs in two techniques (Mean ± SD)

Parameters		**Preselected Beam Orientation (Mean ± SD)**	**Beam Angle Optimisat Ion (Mean ± SD)**	**P – value**
Heart	Dmean	10.34±7.17	15.45±6.73	0.02
	V25	14.52±15.55	16.35±13.62	0.69
PRV Spine	Dmax	11.95±11.57	22.06±11.90	0.009
Ipsilateral lung	V20	33.55±10.71	36.61±12.37	0.40
	V50	1.584±2.38	0.709±1.050	0.14
Contralateral lung	V5	7.578±14.36	35.19±32.83	0.001
	V10	3.39±11.26	10.10±22.08	0.236
Contralateral breast	Dmean	2.56±1.09	4.01±2.31	0.017
Esophagus	V35	3.46±6.38	5.49±9.37	0.43
	V50	0.47±1.00	1.06±3.31	0.454

The PTV dosimeteric Parameters of BAO showed a better dose distribution in comparison to PSBO (96.5 v/s 94.6) which was statistically significant (p value = 0.01). The Homogeneity Index was better in BAO plans (0.08 vs 0.10) which was also statistically significant (p value = 0.02), whereas monitor units calculated were lower in PSBO plans (1027 vs 1177) which was also statistically significant (p value = 0.03). Other PTV dosimetric parameters showed no statistically significant difference.

The PSBO plans had a lower value of Mean dose of heart (10.3 vs 15.45) which was also statistically significant. (p value = 0.02). The difference in PRV Spine was much more, wherein PSBO had lower Dmax (12 vs 22) which was highly statistically significant (p value = 0.009) though both plans achieved the prescribed dose constraints.

The V5 of contralateral lung had a very low value in comparison to BAO (7.6 vs 35.2), (p value = 0.001). Similarly, the contralateral breast also had a lower D mean in PSBO plans (2.6 vs 4.0) (p value= 0.017). There was no statistically significant difference found in dosimetry of the other OARs.

Discussion

Dosimetric parameters had significant difference between two planning methods – PSBO and BAO in terms of PTV and OARS. PSBO produced plans with better OAR sparing in Heart, Contralateral lung, Spinal cord and contralateral breast, while PTV parameters such as V47.5 and Homogeneity index were superior of BAO plans.

A study by Joszef [6] *et al*, evaluated automated beam placement technique for whole breast radiotherapy (WBRT) using tangential beams for 36 patients with left breast cancer. The results demonstrated a significant decrease of the V95% of the CTV1 (99.6–98.8, p 1⁄4 0.002). In another study by Wang [7] *et al*, forty patients were retrospectively planned and automatically generated plans were compared with manually generated plans.

In contrast to Joszef [6] *et al*, the results showed that the automatic plans had overall comparable plan quality to manually generated plan, with mean target $V_{95\%}$ was 91.0% for the automatic plans and 88.5% for manually generated plans. Similarly Sheng [8] *et al* in a study of total of 40 WBRT plans from a single institution, showed almost similar results to Wang [7] *et al*. In this study, dose distribution was qualitatively compared between clinical plans generated manually and automatically generated plans which revealed that there was no statistical significance observed in any dosimetric endpoints between the two plan groups.

The results of our study are in contrast to the various studies mentioned before. The PTV dosimetric parameters of BAO showed a better dose distribution in comparison to PSBO (96.5 v/s 94.6) which was statistically significant (p-value = 0.01). The Homogeneity Index was also superior in BAO plans (0.08 vs 0.10) which was also statistically significant (p-value = 0.02), whereas Joszef [6] *et al*, demonstrated that both manual and automatically generated plans were comparable in homogeneity similar to Sheng [8] *et al*, which demonstrated the overall dose homogeneity was comparable between the manual and auto-plans. The better PTV dosimetry in BAO plans in our study, may be attributed to more spent time by medical physicists in optimisation and reoptimization to produce plans for delivering better plan quality.

The dosimetric parameters of Heart as OAR, Wang [7] *et al*, found that heart mean dose was comparable (2.2% vs 2.0% p value = 0.416) between the manually and auto generated plans. On the contrary, a study by Sheng [8] *et al*, showed statistically significant difference (1.6 % vs 1.5 %, p value = 0.001) in heart mean dose between the two plans. In our study also, we found statistically significant difference in heart mean dose.

There was increase in heart mean dose in BAO in comparison to PSBO plans (15.5 Gy vs 10.4, p value = 0.02). Bakx [10] *et al*, showed contrast results to our study where the dose to the heart was reduced in the newly optimized plans with a mean reduction of 0.4 Gy, which was statistically significant. With advancements in radiotherapy techniques, it is important to reduce dose to the heart the minimum. The survival in the breast cancer patients is increasing, therefore minimising dose to the heart can minimize cardiac morbidities in long term follow up [12].

The dosimetric parameters of lung as OAR have been studied by various authors. Joszef [6] *et al*, found significant improvements in the ipsilateral lung V10 (55.2 to 40.7 cm^3, p value = 0.0013) in automated plans. Similarly, Wang [7] *et al* found the mean ipsilateral lung V_{20Gy} was lower for the automatic plans (15.2% vs 17.9%). These results are in contrast to the study by Bakx [10]. *et al,* and the present study. Bakx [10] *et al*, studied the effect of automatic beam angle optimization in forty patients in left sided, node negative breast cancers. The mean ipsilateral lung V_{20Gy} was found to be lower for the manually generated plans, which in concordance to our study where V20 for Ipsilateral lung were lower for PSBO plans (34%vs 37%) but not statistically significant (p value = 0.40)

One of the key highlights of the current study is regarding contralateral lung dose which has not been discussed in most of the studies in literature. V5 of Contralateral lung was decreased in both (2.6 vs 4Gy) but significantly lower (p value = 0.001) in PSBO plans. It has an important clinical implication in view that lung is one of the most sensitive tissues to ionizing radiation, which may lead to radiation pneumonitis (RP) and radiation fibrosis (RF) in 5–20% of patients and may lead to dyspnea, lung fibrosis, and impaired quality of life [13].

A study by Bakx [10] *et al*, showed that the dose to contralateral breast in both plans was below 1 Gy (range 0.1 to 0.9 Gy). In contrast, our study demonstrated a statistically significant increase in D mean of contralateral breast in BAO plans (4 vs 2.5, p-value = 0.017), when compared with PSBO plans the beam arrangement affects both the dose to the OARs and treatment volume parameters in dosimetry and MUs delivered. Higher MUs delivered contribute to a larger scattered dose, dose to surrounding tissues such as the contralateral breast or lung increase by creating low dose regions increasing the risk of secondary cancers. This risk needs to be accounted for given the long-term survival of breast cancer, especially in younger patients.

In a study by Purdie [11], 157 of 158 plans (99%) were deemed clinically acceptable, and 138 of 158 plans (87%) were deemed clinically improved or equal to the corresponding clinical plan when reviewed in a randomized, double-blinded study by one experienced breast radiation oncologist. Their study showed no increases in the MUs to deliver the plans. In contrast to the present study showed, statistically significant increase in no. of MUs in the BAO plans (1177 vs 1024, p value 0.02) The increase in MU means more secondary radiation dose and, therefore, a higher risk of developing secondary cancers [14].

Penninkhof [9] *et al*, proposed that the plan quality was no longer skill or time dependent. The automatic plan generation of 121 plans took on average 30 minutes. It was concluded that automation of the IMRT planning thus contributes to standard of care. The study further concluded that the well-informed selection of angles and isocentre offers an extra possibility of individualizing treatment. This added conclusion is especially important for patients to minimise dose to the heart, contralateral lung and contralateral. The PSBO plans gives the freedom of individualising beam arrangement which can further decrease doses to OARs, maintaining the integrity of acceptance of plan.

Conclusion

The treatment plans produced by both PSBO or BAO methodology were clinically acceptable. The PTV parameters such as V47.5, Homogeneity Index were significantly improved in BAO plans where as PSBO plans had better OAR sparing. Long term follow up is needed to validate the clinical implications of the advantage of PSBO plans in OAR sparing.

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