

Dosimetric Evaluation of the Field-in-Field Technique for Large Breast Cancer Irradiation

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The aim of this work is using multi segmented conformal radiotherapy, field in field (FIF) for large breast cancer treatment, the dose coverage of the planning target volume (PTV) and evaluation the radiation load on the organs at risk (OARs). Ten patients with large breasts of mean PTV was $1489 \pm 335 \text{ Cm}^3$ were included. Many parameters were used in the dose evaluations in the PTV OARsvolume including ipsi lateral lung, heart, and the contralateral breast, Dose homogeneity index (DHI) and conformity index (PITV). The FIF technique for all patients improved the homogeneity and conformity of the PTV, where the mean values of maximum dose of the PTV was 107%, the volumes over the prescription dose in irradiated volumes received very low doses. For each dosimetry of the organs at risk, the FIF technique reduced the dose that these organs received. It could be concluded that the FIF technique provided a better dose distribution in the PTV, reduced the doses in the OARs and improved the homogeneity and conformity of the planning volume.

Keywords: linear accelerator (LINAC), FIF technique, Planning target volume, Dose homogeneity index, Breast cancer

Introduction

Most patients in the early-stage breast cancer have been subjected to the breast-conserving treatment consisting of a wide excision and post-operative radiotherapy. Post-operative radiotherapy reduces the risk of local recurrence and results in long-term survival similar to that obtained with mastectomy [1–3]. Post-operative breast tangential radiotherapy is a standard treatment for breast cancer radiotherapy. Women with large breasts are also more likely to have a little bit cosmetic outcome after radiotherapy relative to the women with smaller and medium sized breasts [4, 5].

In recent years, the field-in-field (FIF) technique has become a widely preferred method for administering tangential whole breast radiotherapy and several studies reported that this technique is

useful in reducing hot regions as well as cold regions [6–14].

The optimal method for the FIF technique in the breast tangential radiotherapy has been determined [15]. The prone technique is the most commonly used for large breast as it offers the advantages of eliminating skin folds due to the gravitational effect of the hanging breast, therefore reducing the skin reaction. [5, 16]. The reduction of skin folds is beneficial to the patient since there is no buildup of the dose in the underlying tissue [5]. However, it has many disadvantages Namely, the prone device can be difficult for some patients to mount, depending on their level of physical capability while also being only moderately comfortable.

In this work, the authors used the FIF plan on a large breast size with supine position. An

improved breast TP method has been prepared in an attempt to combine the advantages of three-dimensional conformal radiation therapy (3D-CRT) [17] and intensity-modulated radiation therapy (IMRT), with maintenance of the quality assurance, namely fast TP, short treatment time in 3D-CRT, improved dose homogeneity on the planning target volume (PTV), and reduced doses to the organs at risk (OARs) in IMRT. A radiotherapy plan, using many parameters such as conformity index and dose homogeneity index, has been simulated.

Materials and methods

Patients

Ten patients with early stage breast cancer were enrolled in this planning study. The mean volume of the breast was $1489 \pm 335 \text{ cm}^3$ and the mean chest wall separation was 23.6 cm, where the chest wall separation is the distance between the medial and lateral field borders at the level of the center [18]. Patients with lymph node metastasis or distant metastasis were excluded from the study. The patients were imaged with a CT scanner in treatment position (supine, the ipsi lateral arm up and head turned to the contralateral side). To maintain the treatment position, a breast board was fixed to the CT and treatment table. CT data were acquired with adjacent axial slice spacing of 5 mm, covering the entire chest with normal free breathing. The data obtained from CT were transferred to the treatment planning system (TPS) (Prowess, 5.01). By using this planning system, the ipsi lateral lung, contralateral breast and heart were defined as the OARs. Planning target volume (PTV), heart, and contralateral breast were delineated by the same radiation oncologist. The dose calculation algorithm used was based on the pencil-beam convolution method. Six patients were generated using 6 MV X-rays, four patient were generated using 10 MV at Siemens PRIMUS and PRIMUS^{Plus}. 82-leaf multi leaf collimator, two photon energies of 6MV and 10MV and six electron energies (5Mev, 7Mev, 8Mev, 10Mev, 12Mev and 14Mev) have been applied using Software Version V8.0, Germany. The patients with used 10MV were with breast volume larger than 1300 cm^3 and the separation was larger than 24 cm. The prescription dose was 40 Gy in 15 fractions (266.6 Gy per fraction). The PTVs were restricted to 5 mm and 8mm under the skin surface

for 6MV, 10MV respectively, to exclude the buildup region from the PTVs.

Field-in-Field radiotherapy

All the treatment plans were created using the alternate subfields method ASM for the FIF technique and the starting point was the conventional two tangential plans. Then, additional multi leaf collimators MLC subfields were added. The medial fields were copied as the first subfield. Using MLCs for blocking the dose to the first subfield was 1% to 3% lower than the maximum dose on the beam's eye view. After estimation of the dose, the beam was shifted away from the original field to the first subfield until the dose cloud disappeared. The lateral field was copied as the second subfield. Again, using MLCs for blocking, the dose to the second subfield was 2% to 4% lower than the dose blocked in the first subfield, and the beam weight was shifted. Subfields with Monitor Units (MU) > 4 always used. Forward planning based on the 3D dose distribution and on dose-volume histograms (DVHs) in order to reach the best homogeneity of the dose distribution can optimize the MLC positions and beam weighting. If the maximum dose was over 107% of the prescribed dose, the medial field was copied again as the third subfield. The MLCs were not allowed to block within 1 cm of the reference point. Figure (1) shows the BEVs for two open beams and two subfields. Figure (2) shows the hot areas when using only two open beams before adding segments and these hot areas were removed after adding three subfields (two subfields medial and one lateral sub field).

Dosimetric evaluation

Treatment planning (TP) evaluation tools

There are many tools for qualitative and quantitative evaluation of the TPs.

The visual slice-by slice review of the treatment plans using isodose lines distribution can be used as a qualitative evaluation for the treatment plans where the qualitative evaluation is important to identify the locations of the hot and cold areas in the treatment plans. The quantitative evaluation included the maximum, minimum, mean doses. Dose Volume Histogram (DVH) was generated to evaluate the dose to the different structures in treatment plans. For PTV, the parameters, Dmax, Dmean (the maximum and mean doses in the PTV), V95 %, V105 % and V107 % (the

percentage of volumes receiving at least 95,105 and 107 % of the prescribed dose) were used for plan evaluation. For OARs, the mean and maximum doses, V20Gy, V5Gy for ipsilateral lung, were used for the treatment plan evaluation. V30,V25,V5,V20, Dmean for heart and Dmax, Dmean, V2,V1.2,V0.4 for contralateral breast, were used for the treatment plan evaluation.

Plan quality

Dose volume histogram

All plans were optimized to ensure that 95% of the volume of PTV received 95% of the prescribed dose of 40 Gy.

Dose homogeneity index

Some other indices are required for evaluating the dose distribution within the target and also for assessing the healthy tissue doses. The DHI was used for the evaluating recovered dose distribution within the target dose, where lower DHI defines a target dose with a little change. A DVH was used in the calculation of the DHI.

The homogeneity index was defined using many formulas [19]:

$$DHI = \frac{D_2 - D_{98}}{D_{prescription}} \times 100 \quad (1)$$

Where D98 represents the dose to the 98% of the volume (considered to be the minimum dose) D2 is the dose to the 2% of the target volume (considered to be the maximum dose).

The conformity index

Several different conformity indices have been reported to describe the conformity of the prescription isodose to the target volume. The PITV recommended in the Radiation Therapy Oncology Group (RTOG) radiosurgery guidelines is probably the most frequently quoted [20]. Equation 2 defined the PITV as the ratio of the prescription isodose volume (RI) to the target volume size (TV). The RTOG guidelines define a ratio of 1.0-2.0 as per protocol and ratios in the range of 0.9-1.0 or 2.0-2.5 as minor variations.

$$PITV = \frac{V_{RI}}{TV} \quad (2)$$

Results

Dose Volume Histogram

PTV

The dose volume evaluation for the target with this technique was performed. All patients were optimized to ensure that 95% of the volume of the PTV received 95% of the prescribed dose. The data for all patients are presented in **Table (1)**.

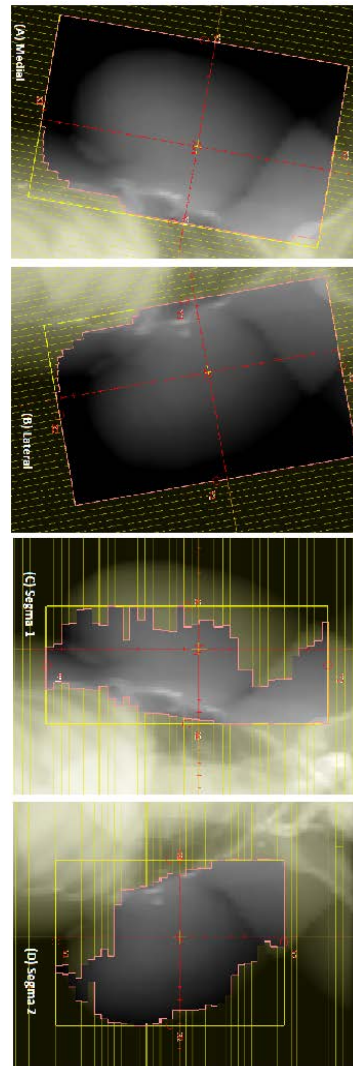


Figure (1) the DRRs for one of ten breast cancer patients with two open beams and two segments beams

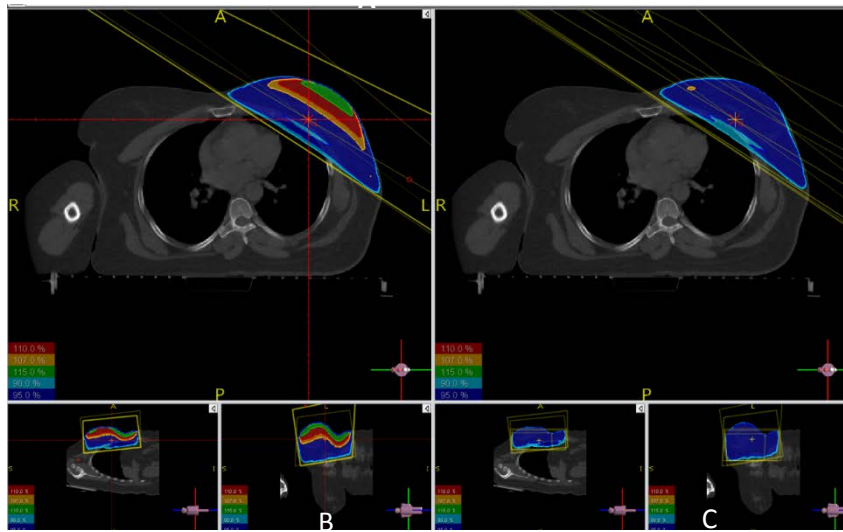


Figure (2) a) Transverse slice , b) Sagittal, c) Coronal for two open beams without segment fields d) Transverse slice e) Sagittal, f) Coronal for two open beams and three segment fields

Table (1): the Maximum, V95, V105, V107, mean dose and dose homogeneity for the FIF plan of ten patients

Patient number	Maximum dose	Mean dose	V9 5%	V1 05	DH I
1	106.7	99.7	96.1	0.4	0.26
2	106.6	99.7	96.5		0.26
3	107.3	99.2	95.8	0.7	0.25
4	107.9	99.6	96	2.3	0.26
5	107.3	99.7	95	0.2	0.28
6	107.4	101	95.1	0.4	0.34
7	106.1	100.8	95	4.4	0.32
8	107.6	100.3	95.1	0.5	0.33
9	106.8	100.8	96.2	4.5	0.32
10	107.2	100.6	95.1	3.9	0.32
Mean ± SD	107.09 ± 0.53	100.14 ± 0.63	95.59 ± 0.59	1.9 ± 1.87	0.29 ± 0.04

For OARs

Table (2) shows mean and standard deviation (±SD) of organs at risk (ipsilateral lung, heart, contralateral breast). The dose volume histogram for PTV and OARs is shown in Figure (3).

Table (2): Mean and Standard Deviation (±SD) of Organs at Risk dose parameters for FIF plan

Structures	Parameters	FIF (Mean ± SD (%))
Ipsilateral lung	D mean	6.18 ± 4.33
	D max	98.22 ± 4.27
	V20Gy	7.73 ± 5.83
	V5Gy	9.9 ± 6.58
Heart	D mean	3.2 ± 1.64
	V30Gy	1.74 ± 1.03
	V25Gy	2.58 ± 1.51
	V5Gy	4.52 ± 2.54
cont lateral breast (CC)	V20Gy	3.46 ± 1.97
	D mean	0.51 ± 0.03
	Dmax	49.79 ± 89.31
	V2Gy	0 ± 0
	V1.2Gy	0.02 ± 0.42
	V0.4Gy	0.21 ± 0.24

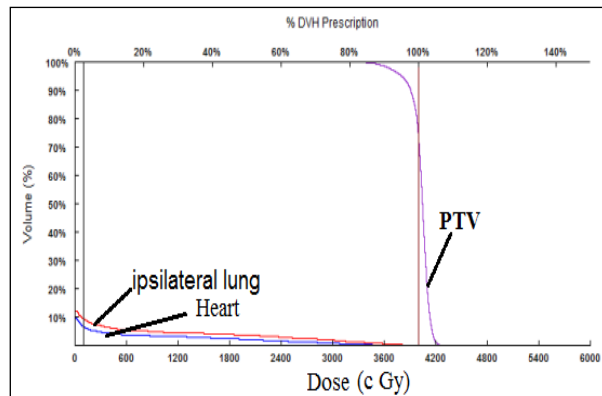


Figure (2) Dose volume histogram for PTV and OARs (ipsilateral lung, and the heart)

Conformity index

The mean value of PITV for all patients was 1.29 with standard deviation 0.1. Figure (3) summarizes the PITV conformity index for all patients.

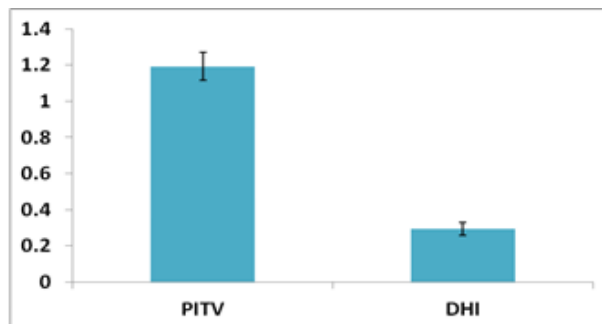


Figure (3): The mean and standard deviation values of PITV for FIF plan of all patients

Discussion

It has been suggested that poor cosmesis and other late adverse effects are related to the dose inhomogeneity, which is associated with a number of factors, including the irregular shape and large size of the breast [20-21]. The PTV coverage was acceptable if 95% of the volume were covered by 95% of the prescribed doses. This was comparable to PTV coverage achieved by the FIF plan. Also, breast reduced the volumes receiving doses over the prescription dose in irradiated volumes and improved the dose homogeneity of PTV. The FIF plan did not only deliver the dose to the intended target, but also spared the doses to critical structure as shown in Table (2). The doses received to all organs were much less than the tolerance dose for all organs, because of the use of MLCs instead of physical wedges which reduced scatter dose to the contralateral breast and other parts of the body [22].

According to RTOG guidelines, ranges of conformity index values have been defined to determine the quality of conformation, because a value of 1 is rarely obtained.

If the conformity index is situated between 1 and 2, the treatment is considered to comply with the treatment plan. As shown in Figure (3), all the values were close to 1 where the mean values was 1.19 ± 0.1 . So the FIF plan improved the conformity for PTV [13].

The FIF plan was performed using two open tangential fields and two or three subfields were added to open beams with identical gantry angles. It may be stated that MS-CRT (FIF plan) is not true IMRT because only two or three intensity levels per beam are used [8]. This small number of the treatment fields shows some advantages to the FIF technique in comparison with the patients that received IMRT which requires much more number of segments. The small number of segments will make small low-dose areas, less monitor units and short treatment time. This is an important because low-dose areas are suspected to induce secondary cancer as late toxicity and smaller number of monitor units implicates less scattered radiation [23, 24]. Additional disadvantages of inverse-planned IMRT are that this technique needs more expensive devices, prolonged treatment-planning times, longer treatment-delivery times, and complicated pretreatment quality assurance (QA) procedures [25].

Recently, investigations of hypo fractionated radiotherapy for whole breast radiotherapy have increased [26]. Because that technique always uses a higher prescription dose per fraction compared with conventional fraction radiotherapy, the dose in homogeneities in the irradiated volumes strongly influence radiation-induced late toxicities. Therefore, the volumes of the treated breast and/or the surrounding normal tissues receiving more than the prescribed dose must be decreased to reduce late toxicities after radiotherapy.

Conclusion

FIF technique for large breast irradiation after breast conserving surgery enables an increase in the dose homogeneity in the PTV. Another benefit of the FIF plan is the disappearance of the scatter dose, which was more prominent in the wedge plan, resulting in fewer contralateral breast doses, possibly causing a reduction in secondary

malignancy in contralateral breasts. In addition, the FIF plan reduces the doses received by other OARs.

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