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Breast Dosimetry : A Phantom study between Tangential Wedge Fields and Multiple Open field-in-field 3D Conformal Forward Planning

G.F. Acquah*[1], P.O. Kyeremeh[1], C.O. Doudoo[2], P. Ahiagbenyo[2], C. Edusa[3] and K. Beecham[3]

*[1]Department of Radiation Medical Physics, Sweden Ghana Medical Centre, Accra, Ghana
[2]Department of Radiotherapy, Sweden Ghana Medical Centre, Accra, Ghana
[3]Department of Radiation Oncology, Sweden Ghana Medical Centre, Accra, Ghana

ABSTRACT

Whole breast irradiation frequently leads to acute and long term toxicities which many studies [1-3] has shown to be associated with dose inhomogeneity (hot spots). A 3D conformal forward planning technique was studied to improve dose uniformity and potentially reduce toxicity for breast irradiation using segmented field-in field (FIF).
A Rando Alderson female anthropomorphic phantom was CT scanned, planned with two conventional tangential wedge fields and then planned with the FIF technique. A 3D dose distribution for the tangential wedge fields (i.e. motorized wedges on the medial and lateral tangential) were obtained by selecting the best possible wedge combinations and photon energies, with the goal of reducing the hot spots in the breast below 110 percent of the prescribed dose. The 3D conformal forward plan employed using the multiple FIF was to achieve an optimal dose distribution and desired homogeneity through a complex manual fluence map optimization process.
The FIF plan resulted in smaller "hot spots" far below 110% with a maximum dose of 102.8%, while maintaining greater coverage of the treatment volume. The dose homogeneity index was 1.00 of the treatment volume when using FIF as compared to 1.03 with standard wedges. The use of 3D forward planning with FIF technique for tangential breast radiotherapy is an efficient and effective method for achieving uniform dose throughout the breast. It is dosimetrically superior to the treatment technique that employs only wedges.
Keywords: Breast cancer, inhomogeneity, Conventional wedges, Field-in-field, Forward planning.

I. INTRODUCTION

Breast cancer is the second most common cancer in the world and most frequent cancer among women in Africa. It is also the most frequent cause of cancer death in women in less developed countries [4]. The majority of new cases are predicted to occur among women less than 65 years, but the average age of diagnosis among African women tends to be younger as seen in the Caucasian population [5]. Results from randomized clinical trials in early stage breast cancer have shown improved local control in whole breast radiotherapy after breast conserving surgery (BCS) [6]. Most early stage breast cancer patients receive radiotherapy as part of their treatment. However, treatment related toxicity such as moist desquamation, breast discomfort, development of chronic breast edema and especially cardiotoxicity increase the risk of death and survival benefit [7].

Treatment planning and irradiation vary in different institutions, but, in general, the problem of dose delivered to the target and its toxicity remains complex. In Breast radiotherapy, fields are usually tangential which encompass the breast, and, in some cases, matched to a supraclavicular field. The planning target volume (PTV) usually has an irregular shape and generally difficult to achieve homogeneous isodose distribution. Wedges are used to improve these inhomogeneities. However, this increases the dose to the ventral and dorsal parts of the breast and very often lot of target volume is underdosed i.e. there are regions in the target volume with doses much less than 95% and also very unsymmetrical. For such reasons, the techniques of segmented fields were studied to try and improve the isodose distribution to the PTV whiles decreasing doses or hot spots in the irradiated tissues outside of the PTV.

Per recommendations of the International Commission on Radiation Units and Measurement (ICRU) report 50, an optimal plan must have an acceptable heterogeneity within the PTV of 95% to 107% isodose levels relative to the prescribed dose [8]. Conventional tangential field irradiation leads to inhomogeneous dose distribution inside the PTV, where the low dose volumes within the target will result in the reduction of the tumor control probability and high dose volumes result in increased late normal tissue toxicity. In cases where inhomogeneity and dose uniformity are of serious concern, especially in large breast, planning using the FIF technique will reduce inhomogeneity dose regions within the volume.

In order to improve dose uniformity, the FIF plan technique has been introduced at our center. With the availability of a Linac with multileaf collimators (MLCs) and a 3D computerized treatment planning system (TPS), this technique was made possible. In this study, dosimetric comparison are made of 3DCRT tangential wedge plans and forward planning FIF plans for the treatment of breast cancer using a female Rando Alderson anthropomorphic phantom as shown in Fig.1.

II. METHODS AND MATERIAL

For this study, a female Rando Alderson anthropomorphic phantom was simulated on a CT simulator (Siemens Somatom 16 slices), immobilized on an inclined breast board on a flat couch according to departmental protocols. The CT data was acquired with axial scans with slice thickness of 3mm, covering the entire chest. The data obtained from the CT were transferred to the TPS (Oncentra MasterPlan, version 4.3; Nucletron, an Elekta company) to generate a 3D reconstruction. The clinical target volume (CTV), PTV, heart and lung are delineated by the radiation oncologist. A wire placed on the midline at the sternum of the patient during simulation defines the boundaries of the contralateral breast. The target volumes were defined and the dose prescribed according to ICRU Report 50 recommendation. Accordingly, the target volume should be covered by 95% isodose line of the prescribed dose. The PTV definition for the breast and organs at risk (OAR) was done according to the breast cancer atlas for radiation therapy planning consensus definitions of the Radiation Therapy Oncology Group (RTOG) [9].

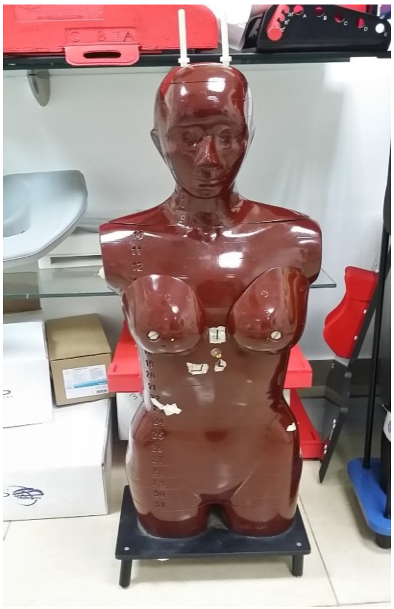

Figure 1. An anthropomorphic female Rando phantom

The conventional technique uses two tangential wedged fields, mostly 6MV photon beams to plan and treat breast cancer patients. According to this, the gantry angles are chosen in such a way that the contralateral breast should be out of the fields and less than 2cm and 3cm of heart volume and lung volume respectively are encompassed in the irradiated volume. The wedge angles were selected using all possible wedge combinations, with the goal of reducing the hot spots in the breast below 110% of the prescribed dose. Wedges were placed on the 3D-CT dataset using the isocentric technique to obtain dose homogeneity inside the breast.

The FIF uses a 3D forward plan with two tangential open fields and multiple FIF to achieve an optimal dose distribution and desired homogeneity through complex manual fluence map optimization as shown in Fig. 2. This technique consists of the following procedures. First, optimization of the isodose distribution as much as possible on a two tangential open fields.

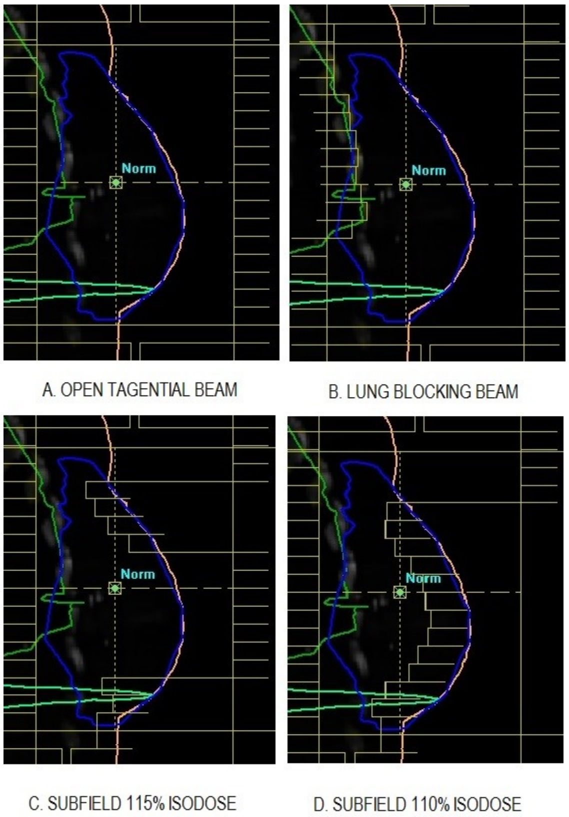

Figure 2. Manual fluence map optimization process

Isodose lines were displayed on the 3D viewer interphase to see which parts of the target volume are overdosed. Four subfields per gantry angle are used to produce an optimal breast plan with no wedges, generally a lung blocking field and three additional subfields per angle. The lung block is formed by fitting MLCs to the shape of the lung to aid in reducing lateral hot spots. The additional subfields are generated by manually fitting the MLCs to hot areas, i.e. 115%, 110% and 105% isodose lines. The open beam portions generally contributes about 80% of the beam weighting whiles the subfields contributes the remaining 20% weighting. Initial weighting factors for all subfields are put as 0 in order not to disturb isodose distribution. In Beam Eye View (BEV) and with the help of MLCs, the volume which receives more than 100% of the prescribed dose is blocked in steps of 5% increments. Monitor Units (MUs) are calculated and isodose distribution inspected. Per departmental protocol, effect is made in achieving not less than 7 MUs for segmented fields.

MLCs can also be used in shielding the heart during left breast irradiation. Maximum dose in PTV accepted should be 107% and the isodose distribution should be symmetrical in all axial planes regarding the medial and lateral breast side. A maximum of 10 treatment beams including 8 segmented beams were required with the majority of the dose delivered via the main open beam. The addition of the lung block segments was of significant benefit for cases with a greater proportion of lung within the irradiated volume. The treatment dose for each plan was 50Gy/25fractions. The plans were normalized to the isocenter to cover the PTV with 95% isodose. Dose volume histograms (DVHs) and dose volume information of the PTV, lung, and where applicable the heart, were calculated for both plans. Five different set of plans were done by two Medical Physicists/Dose planners/Dosimetrists independently using both techniques.

Dose changes in PTV with the tangential wedge plans and FIF plans were compared using the dose homogeneity index (DHI) as defined below:

$$DHI = \frac{D2 - D98}{D_{presriptio\,n}} \times 100$$

D2 is the dose to 2% of the target volume as displayed on the DVH, representing maximum dose. D98 is the dose to 98% of the target volume as displayed on the DVH, representing minimum dose. PTV doses were compared on the basis of maximum dose, minimum dose and the mean dose as well as the percentage of target volumes receiving at least 95% of the prescribed dose (V95) of 50Gy. Doses to the OAR were also compared as well as the presence of dose inhomogeneity (hot spots).

III. RESULTS AND DISCUSSION

Supraclavicular node involvements were not considered for this study. All dose specification points were normalized to the isocenter of the PTV to make for an unbiased comparism.

The total PTV volume was 510.75 cm^3. For wedged plans, the average V95% was 474.30 ± 18.13cm^3 and 493.49 ± 13.16cm^3 for the FIF plans. There was no significant difference in terms of the PTV volumes that received 95% of the prescribed dose. The hot spots volumes were significantly higher in the wedged plan than in the FIF plan (with an average hot spot of 112.6% vs. 101.9% respectively. The FIF technique allowed for a more homogenous dose distribution when compared to the wedged plan as shown in Fig. 3. The DHI values were 1.00 ± 0.004 and 1.03 ± 0.01 for the FIF and wedge plans respectively. The maximum dose to the PTV was also significantly reduced with the FIF technique, a dose of 57.85 ± 1.32Gy for wedged plan and 55.13 ± 0.46Gy for the FIF plan.

The average lung V20Gy values for tangential wedge and FIF plans were 19.82 ± 4.81% and 14.37 ± 1.86% respectively. The average heart V30Gy values for tangential wedge and FIF plans were 6.61 ± 0.049% and 4.52 ± 0.007% respectively.

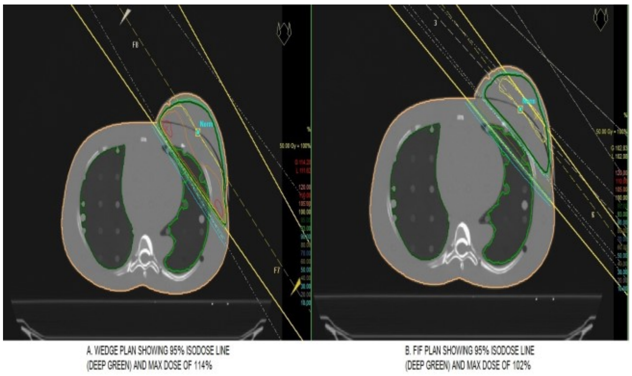

Figure 3. Dose homogeneity comparism

Inverse planning techniques are mostly easier than 3D conformal forward planning since automatic fluence optimization can be performed by the TPS to obtain optimal dose distribution to avoid nearby OARs. For cases such as breast cancer plans, we might be able to derive a good 3D plan as in IMRT plan if the plan would naturally not require too much intensity modulations. To achieve greater dose homogeneity, wedges were not the best to use as it increased the hot spots and maximum dose values to PTV and OARs. The use of segmented fields however was proven to be of great value in terms of better dose uniformity and reduction of hot spots. Statistical analysis as tabulated in table 1 shows that dose homogeneity increased by 3% while OARs dose values decreased negligibly when the FIF plan was employed in treating breast cancer.

Table 1. Dosimetry comparative analysis for wedge and FIF plans

Average ± S.D	Wedge Plan	FIF Plan
DHI	1.03±0.01	1.00±0.004
V95% (ccm)	474.30±18.13	493.49±13.16
Lung V20Gy (%)	19.82±4.81	14.37±1.86
Heart V30Gy (%)	6.61±0.049	4.52±0.007

IV.CONCLUSION

In this study, two different treatment planning techniques for tangential breast irradiation were dosimetrically compared using an anthropomorphic female Rando phantom. The FIF technique was superior to wedged technique in terms of dose homogeneity and absorbed dose in irradiated tissues outside the PTV (hot spots). Field in field technique, or segmented field technique, using multiple static multileaf collimators, can be considered as IMRT technique obtained with forward planning. This technique can be successfully used for improving dose homogeneity distribution. The planning and treatment of segmented field technique are more time consuming but it rewards with a much better isodose distribution and dose homogeneity in the target volume. Its use for tangential breast radiotherapy is an efficient and effective method for achieving uniform dose distribution throughout the breast. It is dosimetrically superior to the treatment technique that employs only wedges. Adopting this FIF planning technique in clinical setting will provide a better breast irradiation with high dose homogeneity and reduction of dose to OARs. Further dosimetric studies with real patients will be carried out as well as doses to the contralateral breast with both planning techniques.

V. ACKNOWLEDGMENT

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