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Comparative Study Between Field-In-Field and Intensity Modulated Radiotherapy Techniques In Treatment Of Breast Cancer

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Abstract-This study is aimed to compare the planning efficiency between three dimensional conformal radiotherapy (3D-CRT), field-in-field forward planned intensity modulated radiotherapy (FIF-FP-IMRT), and inverse planned intensity modulated radiotherapy (IP-IMRT). 20 patients of breast cancer were categorized according to thickness of chest wall, into three groups; small, medium and large. In 3DCRT technique, range of D_2% value was (106-108) % of prescribed dose. In The FiF-FP-IMRT technique, range of D_2% value was (105-107) % of prescribed dose. In IP-IMRT, multiple different beams directions were chosen to create IP-IMRT plans and were inversely optimized, D_2% value ranged from (110-115) % of prescribed dose. 3DCRT, Tangential IP-IMRT and FIF-FP-IMRT plans achieved good sparing of critical organs in all groups. The obtained results showed that, FiF-FP-achieved the best of planning efficiency parameters.

Key Words: Treatment Planning, Radiotherapy, FIF, IMRT, 3DCRT, Breast Cancer

1. Introduction

"Breast cancer is one of the leading causes of cancer death in the less developed countries of the world. This is partly because a shift in lifestyles is causing an increase in incidence and partly because clinical advances to combat the disease are not reaching women living in these regions [1]. Adjuvant radiotherapy given following surgery for primary carcinoma of the breast has been shown to reduce the incidence of loco regional recurrence from 30% to 10.5 % at 20 years and breast cancer deaths by 5.4 % at 20 years. Radiotherapy is the standard treatment after complete local excision of ductal carcinoma in situ (DCIS) and current trials are evaluating its role in low risk patients compared with surgery alone [2].

In the conventional 3DCRT breast irradiation technique, the beam arrangement consists of two opposing tangential glancing portals [3] which allows acceptable coverage of the breast tissue while minimizing the dose to the adjacent critical structures (i.e., ipsilateral lung, contralateral breast, and heart). Physical or dynamic wedges are usually added to these tangential beams in order to compensate for the rapid changes in external contours and to improve the dose uniformity to the entire breast. The risk of contralateral breast cancer has been discussed in recent studies, [4,5] which emphasize the need for reduction of radiation dose to the contralateral breast using physical wedges, avoiding cerroband half beam blocks, and using asymmetric jaws and some form of intensity modulation [4]. Dose-related morbidity due to irradiation of heart tissue has been reported in a few studies earlier [6, 7].

Inversely Planned Intensity Modulated Radiotherapy techniques aiming to produce a uniform dose distribution in the entire target volume while protecting the critical organs have been proposed [8]. To accomplish this, the volumes of interest (Target and critical organs) are normally delineated and a volume-based optimization is performed, balancing the conflicting requirements of the target and critical organs. This approach can produce superior results, when compared to the standard wedged beams [9]. Several single institution studies and two randomized trials for breast cancer have reported that IMRT improves the dose homogeneity and decreases the acute skin toxicity as well as the dose to the contralateral breast compared with conventional tangential techniques with wedges [10].

Forward IMRT for breast irradiation has been previously described by other investigators. It is a very simplified form of IMRT with only a few segments per field, whose shape and weight are optimized by the dosimetrist in order to achieve the best homogenous dose distribution to the target [11]. A dosimetric comparison between multi segmented conformal radiation therapy and 3DCRT with weight-optimized medial and lateral open fields in a large group of unselected patients. The authors concluded that multi segmented conformal radiation therapy provided a better target coverage than 3DCRT with open fields [12]. Preliminary evaluation of acute toxicity of forward IMRT for breast irradiation together with a simple dosimetric comparison of dose distribution within the target in the overall patient population has been recently published [13].

The aim of this work is to compare planning efficiency expressed in dosimetric goals used to develop the Treatment plan between FIF, Forward Planned IMRT and Inverse Planned IMRT to get optimum plan for Breast Cancer Treatment.

2. Materials and Methods

In this study, we reviewed the treatment planning data of twenty patients treated from February 2014 to May 2014 in the Department of Radiotherapy, Ain Shams University Hospitals, Cairo, Egypt.

Table (1) Summary of patient's data for breast treatment

No. of patient	Breast Size Category	Average Breast Volume(cm)	SD (%)	Average Chest Wall Depth(cm)	SD (%)
7	Small	354.30	1.05	2.16	0.003
6	Medium	509.27	1.02	4.02	0.005
7	Large	951.78	4.23	6.68	0.066

All patients were categorized into three groups, (Table 1), according to thickness of chest wall ; a) small chest wall, contains cases that have chest wall thickness ranges from (1-3) cm and its volume ranges from (240 to 500) cc, b) Medium chest wall, contains cases that have chest wall thickness ranges from (3-5) cm and their volume ranges from (500 to 700) cc. and c) large chest wall, contains cases that have chest wall thickness ranges from (5-10) cm and their volume ranges from (700 to 1600) cc. Philips Brilliance big bore CT (85-cm bore) designed for CT imaging for radiation treatment planning can afford patient positioning flexibility. CIVCO's breast and thorax solutions were used for fixation and improve accuracy of the treatment. All groups were planned by 3D conformal, two tangential IMRT and (five,seven,eight,nine) Multiple fields, Inverse Planned, IMRT and finally, Field in Field Forward Planned IMRT techniques . The dose specification was 5000 cGy, prescribed at isocenter point in all techniques, in 25 fractions of 200 cGy per fraction. For all plans applied, superposition algorithm was used for dose calculation in computerized radiation treatment planning system (RTPS) XIO (Version 4.8.03, Elekta, crowely, UK).

Plans of all treatment techniques were compared for evaluation of dosimetric parameters. Details of the beam arrangements and objectives of plans are described below.

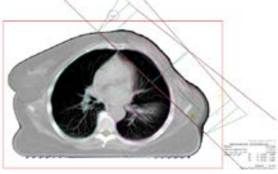
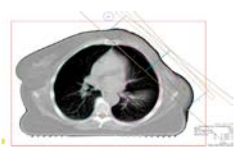
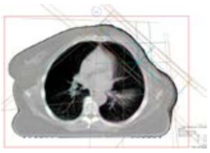


Fig.(1) Arrangement of 3DCRT Technique

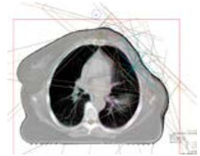
In 3DCRT conventional planning technique, (fig.1) shows the arrangement of fields, the "isocenter" of the treatment machine is positioned at the center point of the midline joining two parallel opposing fields. Physical wedges were then added to both tangential beams in order to improve the dose uniformity to the CTV, and to compensate for the rapid changes in external contours, wedge angles were changed according to separation, thickness and curvature of chest wall to achieve dose homogeneity, dose conformity and minimize volumes of heart and ipsilateral lung that unavoidably get included within the field borders .



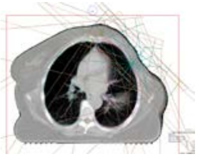
2 Tangs IMRT



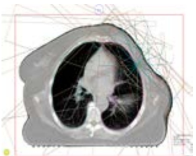
5 Beams IMRT



7 Beams IMRT



8 Beams IMRT

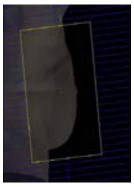


9 Beams IMRT

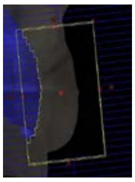
Fig. (2) Arrangements of Inverse Planned, Intensity Modulated Radiotherapy (IP-IMRT)

In Inverse planned, IMRT, (two tangential, five, seven, eight, nine) isocentric photon beams were arranged at equal space from gantry angle 120° to 300°. The "isocenter" of all fields is positioned at the same point for all techniques.

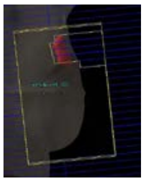
(fig.2) shows arrangement of IP-IMRT with different multiple plans. The inverse planning process was divided into two stages. During the first stage, the optimizer uses inverse planning objectives, anatomy contours, and beamlets to produce the intensity maps and doses. In the second stage, the beamlet intensities are converted to a deliverable form. New beam deliverable doses are recalculated and the dose is then re-optimized using the same objectives as in the first stage, but instead of changing individual beamlet intensities, the beam weights of deliverable beam doses are modulated.



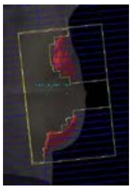
Open Field



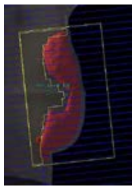
Lung Block



115% Subfield Block



110% Subfield Block



115% Subfield Block

Fig. (3) Steps of Forward Planned, Field In Field, IMRT Technique.

In the FIF technique, an open beam configuration was first calculated and evaluated without any wedges then some subfields per gantry angle are used to produce an optimal breast plan. Generally, there are one lung block and three additional subfields per gantry angle. Lung block is formed by fitting the MLC's to the shape of the lung aids in lateral hot spots. Additional subfields are generated by manually fitting MLC's to "hot" areas

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(hot area of 115% and 110% of prescribed dose). Monitor unit change iteration in the sub fields till reach optimum isodose coverage. Generally, the open beam receives ~ 80% of the dose while the subfields contribute ~20%. This made FP IMRT similar to conventional treatment (fig. 3)

The treatment plans applied were compared objectively using the dose values for CTV and different Organs at Risk (OARs) regions of interest and monitor units in all Techniques .In the CTV, the values of D_{98}% (dose of 98% of CTV), D_2% (Dose of 2% of CTV), mean dose, homogeneity index (HI),

HI = (D2% - D98%) / D50% (1)

and conformity index (CI) were compared for all techniques [14].

CI = V98% of Target Volume (cc) / Total Target Volume (cc) (2)

For Ipsi-lateral lung, the values of max., mean, D_{20}% (dose to 20% lung volume), D_{40}% (dose to 40% of lung volume) and D_{55}% (Dose to 55% of lung volume); for heart, the values of max, mean, D_{35}% (dose to 35% of heart volume) and D_5% (dose to 5% of heart volume); for Contra lateral lung, the values of max. , mean and D_{15}% (dose of 15% of lung volume); for contra lateral breast, the values of max. and mean dose value and for cord; max. doses were evaluated and compared the dose to CTV.

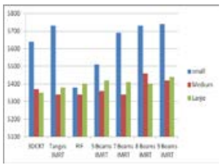
3. Results and Discussion

Column charts for CTV's parameters in all applied plans were shown in fig. (4), FIF technique had D_2% value in range of (106-108) % in medium and large chest wall. All other plans showed values of D_2% in range 110-115% in small chest wall.

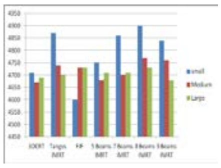
FIF had the lowest dose value of D_{98}%, in small chest wall group, in average of 92% of prescribed dose. Multiple fields IMRT had values of D_{98}% in range of (95-98%) of prescribed dose. Tangs IMRT had better dose coverage in small chest wall more than medium and large.

FIF had the best value of homogeneity between other plans. All multiple IMRT plans had the same homogeneity. 3DCRT in small chest wall group had lower value of homogeneity than its value in medium and large chest wall.

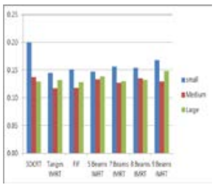
3DCRT and FIF plans had lower conformity than other plans in small chest wall group. Tangs IMRT had the best value in medium chest wall group. All techniques had the same value of conformity which higher than 3DCRT in large chest wall group.



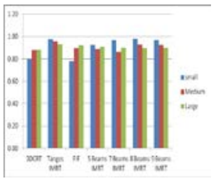
D2% of CTV



D98% of CTV



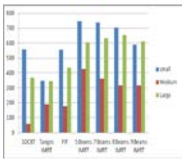
homogeneity index of CTV



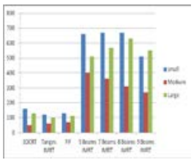
Conformity Index of CTV

Fig. 4 Column Charts for Isodose values of Clinical Target Volume

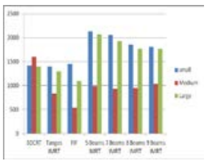
The results of our study matched with other similar studies. Efficiency of FIF technique versus 3DCRT field is clearly brought out by Sasaoka and Futami. The field-in-field technique significantly reduced the maximum dose, the volumes receiving > 107% of the prescription dose and the HI of CTV for dose evaluation compared with 3DCRT technique [15].



Mean Dose values



D35% value



D5% values

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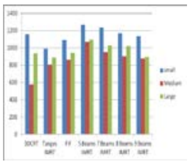
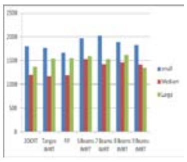
Fig. 5 Column Charts for dose values of Heart

Column charts of dose value parameters of Heart were shown in fig. (5), as mean dose, D_{35}% and D_5% values of heart were evaluated in all applied plans and groups. FIF, Tangs IMRT and 3DCRT plans had the lowest mean dose of heart between other plans in all groups. For D_{35}% and D_5% values, FIF and Tangs IMRT had the lowest value in all groups. For D_5%, All Multiple IMRT fields had lower dose value than 3DCRT plan in medium group only.

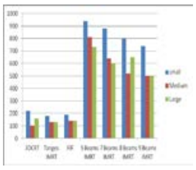
Our results were matched with some previous studies as they concluded that, the dose to heart tended to be lower with IMRT but this difference did not reach any statistical significance. No benefit of IMRT in heart sparing was observed either for small or for large size breast [16]. With the FIF technique, heart volumes receiving 2, 30 and 40 Gy were decreased significantly. Additionally they evaluated the doses in LAD which is an important branch of the left main coronary artery supplying the anterior and antero-lateral walls of the left ventricle and the anterior two-thirds of the septum. The LAD volumes receiving 20, 30 and 40 Gy were reduced significantly with FIF technique. The FIF technique provided lower V30 and V40 values for the entire OAR [17].



Mean Dose values



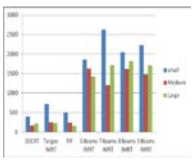
D20% values



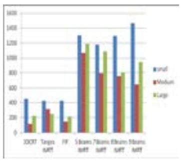
D40% Values

Fig. 6 Column Charts for dose Values of Ipsilateral Lung

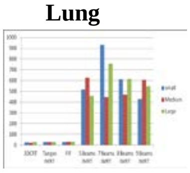
For Ipsi-lateral Lung, Figure (6) shows column charts for dose values of Ipsi-lateral lung in all applied plans and groups. FIF, Tangs IMRT and 3DCRT had the lowest mean dose in large and small chest wall groups. 3DCRT plan had the lowest mean dose in medium chest wall group. For D_{20}% value, 3DCRT and 9 beams IMRT had the best plan in large group. For D_{40}% value 3DCRT, Tangs IMRT and FIF were the best plans in all groups. All evaluation values for the ipsilateral lung were significantly reduced with FIF technique when compared to 3DCRT technique [17]. The FIF technique, compared to 3DCRT, for whole breast RT enables significantly better decreasing the doses received by the ipsi-lateral [18]. In patients with funnel chests, the advantage of lung doses without the reduction of the target dose was reported using an inversely planned IMRT [11]. Tangential beam IMRT of the chest wall compared to 3D-CRT significantly reduces the ipsilateral lung dose-volume (D30% by 43%), similar result has been reported for tangential beam IMRT for the whole breast in early breast cancer patients [19]. The 3D-CRT and FiF- FP-IMRT plans were equivalent in sparing sensitive structures. Although the mean volume of the lungs receiving 20 Gy (V_{20}) was lower for the IP-IMRT technique, both the 3D-CRT and FIF-FP-IMRT plans resulted in a lower mean volume of the lung receiving low dose (5Gy). Moreover, compared with IP-IMRT, the 3D-CRT and FIF-FP-IMRT plans resulted in a significantly smaller mean volume of the lung. In addition, in the IP-IMRT, the value of the mean dose to the ipsi-lateral lung was higher than with the FiF-FP-IMRT and 3D-CRT [20].



Max. Dose of Cont. Lung



Max. Dose of Cont. Breast



Max. Dose values of Cord

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Fig. 7 Dose values of Organs at Risks ; Contralateral Lung,Contralateral Breast and Cord

Column charts for dose evaluation values of contra-lateral lung, contra-lateral breast and cord in all groups were shown in fig. (7). It can be observed that the lowest dose values of these critical organs were with 3DCRT, Tangs IMRT and FIF plans in all groups. FIF technique significantly reduced the evaluation values of the contra-lateral breast [17]. On other hand, IMRT reduces the dose to the contralateral breast 45% compared to conventional tangential wedge techniques [21].

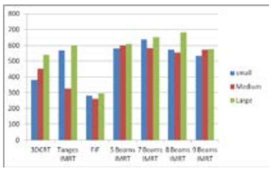

Fig. 8 Total Monitor Units of all Techniques

Our study shows that no significant difference in total monitors unit between 3DCRT and IMRT techniques, and the FIF had the lowest MUs. This can be observed from fig. (8) that represented column charts of total monitor units in all applied plans and groups. Other previous studies agreed with our study. IMRT tangent and six-field hybrid plans both demonstrated total MU 2.5 times greater than that with the FiF tangent or the four field hybrid IMRT plan [22]. MU counts for two IMRT techniques used for breast treatment were compared and found that the counts were approximately 60% more with the IMRT technique using small beamlets than with the FiF technique [23]. The IP-IMRT plans increased the total MUs, thereby increasing the volume of normal tissues exposed to the very low dose. The decrease in the number of monitor units leads to the reduction in leakage dose. The typical planning time for 3DCRT was 20-30 min. For the FiF-FP- IMRT, it took about 15-20 min. In contrast, the IP-IMRT plans required about 50-60 min [20].

4. Conclusion

the IP-IMRT for breast is not justified because of increased planning time, need for more MUs, advanced planning skills, increased D_{max} value in CTV, excess dose to ipsilateral lung, contra-lateral breast, and regions of hot spots. Therefore, compared with the 3D-CRT and IP-IMRT, the FiF-FP-IMRT is a simple and efficient planning technique for breast irradiation. It provides dosimetric advantages, significantly reducing the size of the hot spot and minimally improving the coverage of the target volume. In addition, the FiF-FP-IMRT requires less planning time and is less dependent on the planner's skills. Moreover, implementation of this technique in clinical practice is straight forward, resulting in an overall reduction of doses for OARs.

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