Dosimetry Analysis of 3D CRT and IMRT Techniques on Small and Large Breast Cancer Volume

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DOSIMETRY ANALYSIS OF 3D CRT AND IMRT TECHNIQUES ON SMALL AND LARGE BREAST CANCER VOLUME

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Abstract— The aim of the study was to compare dosimetric parameters of planning target volume (PTV) and organs at risk (lungs) between 3D-conformal radiation therapy (3D CRT) and intensity-modulated radiation therapy (IMRT) in breast cancer, also to find correlation between volume and these parameters. A total of 60 patients with left/right breast cancer received radiotherapy, 30 by 3D CRT and 30 by IMRT, with a dose of 50 Gy in 25 sessions. Plans were compared according to dose-volume histogram (DVH) analysis in terms of PTV homogeneity (HI) and conformity (CI) indices as well as lungs dose, also integral dose (ID). IMRT had the higher CI than 3D CRT, and the lower HI than 3D CRT. But IMRT had the higher ID than 3D CRT. So, IMRT had the better HI and CI than 3D CRT in breast cancer treatment. In other hand, there are negatif correlation between volume and CI in 3D CRT. But no signifficant correlation in IMRT. And there are no correlations between volume and HI in both techniques. Also there are signifficant positif correlation between volume and ID in both techniques.
Keywords— breast volume;3D CRT; IMRT; HI; CI; ID;

I. INTRODUCTION

Breast cancer is the most common cancer diagnosed in women around the world, with an estimated 1.67 million new cases by 2012 [1]. Currently, radiotherapy plays an important role in the treatment of breast cancer [2]-[5]. Radiotherapy uses high-energy X-rays to kill cancer cells. Breast-conserving surgary followed by radiotherapy is a standard treatment for cancer early stage breast [6]. Planning radiotherapy develops over the years to improve conformal treatment plan and avoid the nearest normal tissue using 3D Conformal Radiotherapy (3D CRT) and Intensity Modulated Radiotherapy (IMRT) [7]. 3D CRT treatment planning is used manually. That is, the planner selects all radiation parameters, such as the amount of irradiation, the direction of irradiation, the shape, weighting, and so forth. On IMRT, the planner must decide before the dose distribution he wants and the computer calculates the intensity of irradiation to be generated, to approximate the distribution of the desired dose [8].

Radiotherapy aims to provide a uniform distribution of doses to the target volume and minimize the dose to surrounding organs. The dose distribution can be evaluated using a dose volume histogram (DVH) and isodic strip. DVH contains information about the dose given on the partial volume (absolute or relative) of the target or OAR. [9]. Dose distribution of treatment plans can be analyzed using conformity index (CI) and homogenity index (HI) [10]. Furthermore, an integral doses (ID) also need to be analyzed, because a large ID on normal tissue increases the risk of secondary tumors [11]. Radiotherapy for breast cancer provides many benefits, but this treatment still has a number of disadvantages, such as the occurrence of acute effects on the skin and increased risk of arm dysfunction. Long-term effects can cause carcinogenic and heart or lung damage [12]. So, the most efficient way to avoid such effects is to choose radiation techniques that can minimize exposure to internal organs. Selection of radiotherapy techniques on breast cancer has been only considering the potitioning factor of patients at the time of treatment. Whereas there is one more thing to consider, namely the volume of the breast, because the volume of the breast affects the dose distribution [13]. There is a decrease in the dose of breast volume from the surface to the deeper part [14].

Some studies about 3D CRT and IMRT have been conducted. 3D CRT and IMRT have a good coverage target on the breast wall of breast cancer patients [15]. Another study said that IMRT techniques are better used in cases of lung carcinoma than 3D CRT [16]. But 3D CRT techniques provide better conformity than IMRT in cases of early-stage breast cancer [17]. Nevertheles, the choice of techniques between IMRT and 3D CRT depends on the patient case [8]. Based on several studies that have been done, there is no discussion about the comparison of dosimetry between 3D CRT and IMRT techniques in cases of breast cancer with a certain volume/stage. There is also no discussion of the effect of breast volume on dosimetry parameters between the two techniques. So it can be known which technique is more appropriate given in certain breast cancer patients.

II. MATERIAL AND METHODE

The radiotherapy treatment data of 60 patients with left or right breast cancer previously treated with 3DCRT (30 patients) and IMRT (30 patients) at the Ken Saras Hospital were selected. Computed tomography (CT) scans from all patients previously treated were selected for this dosimetric study. All patients received a prescribed dose of 50 Gy to the left or right breast in 25 fractions. An Elekta Compac 201165 Linear accelerator Monaco 5.11 software was used in this study. Patients with 3D CRT and IMRT techniques both used 6 MV photon energy. The sample consisted of 10 small, 10 medium, and 10 large breasted women based on breast volume. A breast was considered small if the breast planning target volume for breast (PTVbreast) was <500 cm^3, medium if the breast PTV was 500-800 cm^3, and a large breast if the PTVbreast was >800 cm^3. Contouring of target volumes and OARs was completed on an Monaco 5.11 treatment planning system. All contours, followed a set of contouring guidelines designed for the purpose of this study. The CTV were delineated by a radiation oncologist, and all other contours were performed by researcher and a medical physicist.

Dose information was collected to evaluate PTV coverage and doses to OARs. Dose homogeneity index (HI), dose conformity index (CI) and integral doses (ID) were reported for PTV coverage comparisons. CI is the target volume ratio by reference dose and Volume Planning Target Volume (PTV) [16]. To find the CI used equation (1).

$$CI = \frac{VT_{presc}}{V_{PTV}} \quad (1)$$

with VT_{presc} being the target volume by the reference dose, V_{PTV} is the PTV volume. The CI value is from 0 to 1, where the greater the CI value indicates better conformity [18], [19]. HI indicates the ratio between the maximum and minimum doses on the target volume. Lower values indicate better homogeneity [20]. HI is obtained from equation (2).

$$HI = \frac{D_2 - D_{98}}{D_{prescription}} \times 100\ \% \quad (2)$$

with D_2 and D_{98} (accepted dose volume of 2% and 98%) is the minimum and maximum dose. $D_{prescription}$ is a prescription dose. ID can describe energy deposition throughout the body and as a physical quantity that represents physical aggression and the risk of complications due to radiation therapy. ID was calculated by DVH or a result of the average dose and radiation volume [21]. ID is given in equation (3).

$$ID = V \times \rho \times D \quad (3)$$

with V, D, and ρ representing volume, average dose, and density of organ. In this study, a density of ρ = 1 g / cm3 would be used for all patients.

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A repeated measures independent sample t-tests were used for statistical analysis. Differences between the 2 modalities were considered significant if p < 0,05. HI and CI was calculated using the formula recommended in ICRU Report 83, with a result closer to zero indicating greater homogeneity, and a result closer to 1 indicating greater conformity [18].

III. RESULT AND DISCUSSION

In this study, the dosimetric outcomes of different plans in treating the left/right breast were investigated. The dosimetric comparisons of the treatment volume for the two planning techniques are shown in Table 1.

TABLE 1 - SUMMARY OF DOSIMETRIC VALUES OF THE TREATMENT VOLUMES FOR THE 3D CRT AND IMRT PLANNING TECHNIQUES

Parameters	Techniques 3D CRT	IMRT	p value 3D CRT vs IMRT
CI	0,870±0,056	0,947±0,030	0,000
HI	0,206±0,050	0,159±0,046	0,000
ID	3311735±1579961	3823841±1840527	0,040
$D_{average}$	4987,217 ± 51,37315	5139,383 ± 326,4162	
D_{max}	5530,667 ± 134,6253	5879,24 ± 493,9989	
D_{min}	2482,423 ± 567,1737	3596,463 ± 1056,171	
D_{lung}	1456,06 ± 613,6665	1384,787 ± 954,5288	

Based on the research results on Table 1, the conformity index (CI) on IMRT technique has a higher mean value than the 3D CRT technique. This suggests that IMRT techniques on radiation of breast cancer have better conformity than the 3D CRT technique because the average value of CI is closer to 1. The high conformity in IMRT techniques occurs because in IMRT planning there is a ring that serves as a barrier inside and outside 2 cm from the PTV contour, so that PTV will receive the dosage according to the prescriptions given. In addition, in the IMRT planning the dose profile occurs uniformly so that the radiation beam will be modulated and the weighting of each segment will be different. Smaller HI values in IMRT techniques show better homogeneity. The homogeneity of the IMRT technique occurs because of optimization in the Treatment Planning System (TPS) that forces the doses received by the patient to be the same in each direction of the rays. The Integral Dose (ID) of the IMRT technique is greater than the 3D CRT. This is because the use of multiple beams in IMRT techniques. The existence of multiple beams can cause normal surrounding tissues to get exposed to irradiation, coupled with longer irradiation times.

IMRT techniques have higher average doses than 3DCRT. The maximum and minimum dose of IMRT techniques is also higher than that of 3DCRT. However, the dose exposed to the lung organ is higher with the 3DCRT technique than the IMRT technique. So, IMRT techniques are better than CRT 3D techniques for breast cancer in terms of CI and HI.

DVH results for both techniques can be seen in Fig1.

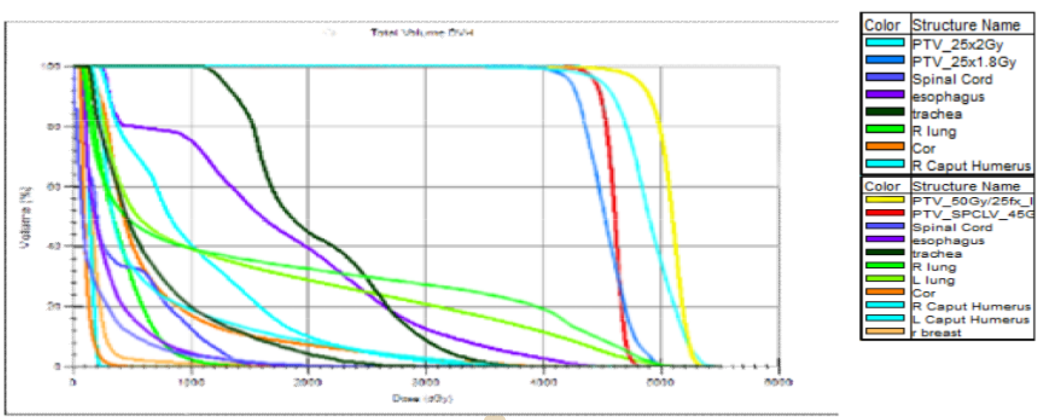

Fig 1. DVH results for 3D CRT and IMRT techniques

In the figure of the DVH of the IMRT technique, the curve lines are steeper than those in the 3D CRT technique. This suggests that IMRT techniques provide better homogeneity than 3D CRT techniques in cases of breast cancer. While the lines on 3D CRT techniques are more gentle. These results are in accordance with the results of HI measurements that have been performed.

The correlation of volume and dosimetric parameters (CI, HI, and ID) is in the Table 2.

TABLE II- SUMMARY OF CORRELATION BETWEEN VOLUME AND DOSIMETRIC PARAMETERS FOR THE 3D CRT AND IMRT

Parameters	Techniques							
	3D CRT				3D CRT		IMRT	
	Small	Medium	Large	r Value	Small	Medium	Large	r Value
CI	0,892346	0,873311	0,826313	-0,442	0,951126	0,948854	0,941914	- (p>0,05)
HI	0,186903	0,21876	0,218605	-(p>0,05)	0,161762	0,157022	0,170711	- (p>0,05)
ID	1980872	3225511	5654203	0,935	1868120	3320169	5881862	0,644

In Table 2, there are negatif correlation between volume and CI in 3D CRT. The larger the volume, the lower the CI value. But there are no volume and CI correlation in IMRT (p>0,05). HI for 3D CRT and IMRT had no correlation with volume (p>0,05). This result is consistent with previous studies, whereas HI does not depend on the shape, size, and complexity of the tumor [22]. And for ID, there are signifficant positif correlation between volume and ID. The larger the volume, the greater the ID value. In this study, the results obtained that the size of the breast has little effect regardless of the modalities used. This may occur due to small sample size or inclusion of booster (additional irradiation). The location of the booster can affect homogeneity and dose to Organ At Risk (OAR) regardless of the size of the patient's breast volume.

IV. CONCLUSIONS

This study compared 3D CRT and IMRT to treat the whole left/right breast cancer, with the aim of determining which modality provided the best target coverage while minimizing doses to the OARs. The influence of patient breast size on dosimetry was also assessed. Of the 2 modalities investigated, the results indicate that IMRT is the better planning technique than 3D CRT. IMRT offered significantly superior doses to the PTVs compared with 3D-CRT and while also producing significantly lower doses to the lung. There was very little difference in dosimetry between patients of different breast size regardless of the modality. But there is a relationship between CI and volume on 3D CRT technique. The larger the volume, the smaller the CI. But there is no relationship of volume with HI.

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