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Dosimetric Comparison of 3-Dimensional Conformal and Intensity-Modulated Radiotherapy Planning Techniques in Breast Cancer

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ABSTRACT

Considering the high rates of long-term survival in breast cancer patients, it is crucial to determine the most appropriate RT technique in order to prevent RT-related heart and lung damage and other complications that may adversely affect quality of life. In this study, we aimed to detect the superior radiotherapy technique in patients with breast cancer in terms of the target volumes and the organ at risk (OAR). We included 20 breast cancer patients who were applied modified radical mastectomy. Two different treatment plans (IMRT and 3DCRT) were prepared for each patient. Chest wall, supraclavicular, axillary and/or mammaria interna lymphatic regions were contoured as clinical target volüme (CTV). For planning target volüme (PTV), 0.5 cm was added to CTV (post margin; 0.3 cm). The doses of the target volumes and the OAR volumes (contralateral breast, heart, ipsilateral lung), the homogeneity index (HI) were compared. For the heart, the contralateral breast, the ipsilateral lung, Dmean and V25, Dmean and Dmax, D5 and D20 were evaluated, respectively. In addition, D2, D98, D95 ve Dmean were investigated for the PTV. Mann Whitney test was used for statistical analysis and $p < 0.05$ was considered significant. IMRT technique was superior to the 3DCRT in terms of the PTV, the OAR volumes and the HI. However, irradiated contralateral breast volume was less in the 3DCRT technique.

Keywords: Radiotherapy, Breast cancer, 3DCRT, IMRT, Homogeneity index

ÖZET

Meme Kanserinde 3 Boyutlu Konformal ve Yoğunluk Ayarlı Radyoterapi Planlama Tekniklerinin Dozimetrik Olarak Karşılaştırılması

Meme kanseri hastalarında uzun süreli yüksek sağkalım oranları göz önüne alındığında, radyoterapi (RT) ile ilişkili kalp ve akciğer hasarını ve yaşam kalitesini olumsuz yönde etkileyebilecek diğer komplikasyonları önlemek için en uygun RT tekniğini belirlemek çok önemlidir. Çalışmamızda, meme kanseri tanılı hastalarda, hedef hacimler ve risk altındaki organlar açısından üstün olan RT tekniğini belirlemeyi amaçladık. Modifiye radikal mastektomi uygulanan 20 meme kanseri tanılı hastayı dahil ettik. Tarafımızca her hasta için 2 farklı tedavi planı (3BKRT ve YART) çalışıldı. Göğüs duvarı, supraklavikular, aksiller ve/veya mammaria interna lenfatik bölgeler klinik hedef hacim (CTV) olarak konturlandı. Planlanan hedef hacim (PTV), CTV'ye 0.5 cm marj (posterior marj 0.3 cm) verilerek oluşturuldu. Hedef hacimlerin ve normal doku hacimlerinin (kontralateral meme, kalp, ipsilateral akciğer) aldığı dozlar ile homojenite indeksleri (HI) karşılaştırıldı. Kalp, karşı meme ve aynı taraf akciğer için sırasıyla; Dmean ve V25, Dmean ve Dmax, D5 ve D20 değerlendirildi. Ek olarak, PTV için D2, D98, D95 ve Dmean değerleri incelendi. İstatistiksel analiz için Mann Whitney testi kullanıldı ve $p < 0.05$ değeri anlamlı kabul edildi. YART tekniği, PTV, normal doku hacimleri ve HI açısından 3BKRT'den daha üstündür. Bununla birlikte, ışınlanmış karşı meme hacmi 3BKRT tekniğinde daha azdır.

Anahtar Kelimeler: Radyoterapi, Meme kanseri, 3BKRT, YART, Homojenite indeksi

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INTRODUCTION

Breast cancer is the most common type of cancer in women and is among the leading causes of cancer-3 related deaths.[1] It is mainly treated by surgery, chemotherapy, radiotherapy, targeted therapy and endocrine therapy. The determination of RT necessity and the area to be irradiated is based on the stage of the disease, histopathology and the applied surgical technique. Nowadays, adjuvant RT is recognized to provide both local- regional control and an overall survival advantage.[1,2,3] The aim of RT is to ensure that the target area receives the desired dose homogeneously while protecting the OAR.[4] Considering the high rates of long-term survival in these patients, it is crucial to determine the most appropriate RT technique in order to prevent RT-related heart and lung damage and other complications that may adversely affect the quality of life. Before conformal RT techniques were developed, survival advantage with RT in breast cancer patients was not clearly demonstrated, and these patients were determined to suffer mortality due to cardiac toxicity.[5] Today, owing to the developments in RT techniques, 2-dimensional RT (2DRT) has been replaced with 3-dimensional conformal radiotherapy (3DCRT) and intensity-modulated radiotherapy (IMRT) planning techniques. In this study, OAR and treatment volumes that were contoured by the physician on computed tomography (CT) sections (simulation images) of 20 patients with operated breast cancer were used. Two separate treatment planning techniques (3DCRT and IMRT) were studied for each patient and the doses of OAR and the target volumes were compared in the treatment planning system.

PATIENTS AND METHODS

Study Group

In the scope of this study, the simulation images and materials of 20 patients (12 left, 8 right breast cancer) who had undergone mastectomy for breast cancer and had been treated at Akdeniz University Faculty of Medicine, Radiation Oncology clinic between January 2017 and December 2017, were used. These images were studied through 2 different RT treatment planning techniques and dosimetric results were compared.

GE Light Speed RT Computed Tomography Device

In our study, a General Electric (GE) Lightspeed RT Computerized Tomography device was used to obtain CT images of patients diagnosed with breast cancer who were scheduled to receive RT treatment. The gantry width was at 80 cm and contained a multi-segment viewing feature. The increments between slices were 2.5mm

Precise Treatment Planning System

The Precise 2.15 system is the standard treatment planning system of Elekta Synergy Platform linear accelerator device. The operating system is Linux based. Data was transferred through DICOM RT and the network system used is known as the IMPAC system. For dose calculation, the Precise treatment planning system utilizes the 'Full Area integration' algorithm for photons, the 'Hogstrom's Pencil Beam' algorithm for the electrons, and the 'Aperture Based Inverse Planning' algorithm for the IMRT.

Patient Simulation

During the simulation process of breast cancer patients in our clinic, we used a "breast board".

Contouring of the CT Images

The contouring of simulation images sent to the contouring workstation was performed by the researching physician. CTV was created by contouring the target volumes (such as the chest wall and lymphatics which needed to be irradiated). OAR (heart, lung, conralateral breast) were contoured in all sections. All patients were planned to chest wall with inclusion of mastectomy scar. Supraclacicular fossa (Scf), Level 1, Level 2, Level 3 were irradiated in 17 patients, mammmaria interna (MI) was included in 15 of them. In 3 patients, only the chest wall irradiated due to the fact that they were staged as N0. PTV was formed by allowing a margin of 0.5 cm (0.3 cm in the posterior direction to reduce the lung dose) to the CTV in every direction. Following the completion of the contouring process, the data were sent to the TPS.

Figure 1. Planning according to the 3DCRT

Treatment Dosage and Planning

RT was delivered to a total dose of 50 Gy in 2 Gy fraction doses daily. Doses of the target volumes and OAR volumes (contralateral breast, heart, ipsilateral lung) and HI were compared between the two groups.

Planning with the 3DCRT Technique

The 3DCRT technique was used for planning in 20 breast cancer patients who underwent mastectomy (Figure 1). During the planning period, the SCF, Mammaria Interna, Level 1, Level 2, Level 3 and chest wall doses were between 95%-107% and mean dose was 50 Gy (in 3 patients only the chest wall received beams due to the fact that they were staged as N0). An angle of 345° was used for the SCF field at the planning stage. An angle of 290°-310° was determined for the chest wall area in the inner tangent, and an angle range of 110°-130° was used in the outer tangential. Planning with the IMRT technique

IMRT technique was also planned in the same patient group (Figure 2). The planning process and the doses were performed similar to the 3DCRT technique. The plans were made using 5 fields.

Dosimetric Evaluation of Plans

The QUANTEC (Quantitave Analyses of Normal Tissue Effects in the Clinic) dosimetric planning evaluation protocol was primarily used for the evaluation of each plan. An angle of 345° was determined for the SCF area. The angles for the chest wall area were set at 115° and 315° and were selected according to the patient's anatomy.

Dose Homogeneity Index (HI)

HI was calculated according to definition proposed by the International Commission on Radiation Units and Measurements (ICRU) Report-83; HI = (D2-D98)/D50 HI value closer to zero indicates a more homogeneous dose distribution within the PTV. Therefore, the ideal HI value is zero.

The ethical approval was obtained from Akdeniz University Clinical Research Ethical Committee.

RESULTS

The mean age of patients was 52.25 years. The characteristics of patients included in the study are shown in Table 1. The dosimetric values of heart tissue were interpreted by Dmean and V25 values

Figure 2. Planning according to the IMRT technique

in DVH. In the 3DCRT technique, Dmean was 506.35±80.04 and V25 was 6.71±1.68, whereas Dmean was 655.70±105.06 and V25 was 8.66±2.11 in the IMRT (Table 2). The results were interpreted by the values of Dmean and Dmax in DVH for the contralateral breast. Dmean was 1.26±0.14 and Dmax was 30.58±2.93 in the 3DCRT technique, while Dmean was 1.89±0.21 and Dmax was 32.92±4.08 in the IMRT technique (Table 2). For ipsilateral lung were assessed the values of V5 and V20 in DVH. In the 3DCRT technique values were as follows: V5=42.99±1.37 and V20=31.02±1.05, while results in the IMRT technique were: V5=50.07±1. 54 and V20=34.31±1.14 (Table 2). For PTV, we evaluated D2, D98, D95 and Dmean doses. D2: Minimum dose which receives 2% of the target volume (maximum dose). D98: The minimum dose that 98% of the target volume receives, (minimum dose). D95: 95% of the dose received by the target volume. Dmean: The mean dose received by the target volume. In the 3DCRT technique, the following results were found: D2 = 5445.5±28.30, D98 = 4643.28±18.96, D95 = 4739.8 ± 1.38 and the Dmean = 5037.4±4.46. As for the IMRT tech-

Table 1. Table 1. The characteristics of the patients included in the study

Patient Characteristics	Values
Age (Mean)	52.25 (range: 35-67)
Site	
Left	12 (60%)
Right	8 (40%)
Stage	
T1	4 (20%)
T2	12 (60%)
T3	1(5%)
T4	2 (10%)
Tdcis	1 (5%)
Lymph Node Involvement	
N1	9 (%45)
N2	6 (%30)
N3	2 (%10)
N0	3 (%15)
Chemotherapy	
Neo-adjuvant	6 (%30)
Adjuvant	13 (%65)
No chemo	1 (%5)
Extra-Capsular Spread	
Present	8 (%40)
Not Present	12 (%60)

nique, results were: D2 = 5327.6±15.19, D98 = 4731.7±12.01, D95 = 4573.3±238.3 and Dmean = 5030.25 ±2.67 (Table 2). HI of two techniques were compared in Table 2 and figure 3.

DISCUSSION

Radiotherapy is one of the most important steps in the treatment of breast cancer. Owing to the recent technological developments, RT techniques have seen significant advances. Nowadays, the 2-dimensional conventional RT planning technique has been replaced with conformal RT techniques. 3DCRT and IMRT are among the commonly used conformal treatment planning techniques. In this study, a total of 20 modified radical mastectomy patients in the Akdeniz University Faculty of Medicine received treatment at the radiation oncology clinic employing both the 3DCRT and IMRT techniques for each patient, with the planning being studied and dosimetrically compared for various parameters. A total of 20 patients underwent statistical evaluation. The results were evaluated and summarized on graphs and tables. The ideal RT treatment technique should reduce the maximum dose applied (D2), while ensuring that the desired dosage within the PTV is delivered as homogeneously as possible. In the literature, D95 and/or D98 dose values are also evaluated along with D2 for evaluation of techniques.[6,7] In our study, we compared the D2, D95, D98 and Dmean dose values with dose values received within the PTV. In the IMRT, while the maximum dose (D2) was lower , D95, D98 and Dmean dose values were higher. That is, the desired dose values on the target volume were provided more appropriately by IMRT technique. Moreover, we calculated the HI value

Table 2. Comparison of some values with the 3DCRT and IMRT techniques

	3DCRT	IMRT	p
Heart			
Dmean (cGy)	506.35±80.04	655.70±105.06	0.213
V25 (%)	6.71±1.68	8.66±2.11	0.571
Contralateral breast			
Dmean (Gy)	1.26±0.14	1.89±0.21	< 0.017
Dmax (Gy)	32.92±4.08	30.58±2.93	0.570
Lung			
V5 (%)	42.99±1.37	50.07±1.54	< 0.002
V20 (%)	31.02±1.05	34.31±1.14	< 0.042
PTV			
D2 (cGy)	5445.5±28.30	53.27±15.19	< 0.001
D98 (cGy)	4643.28±18.96	4731.7±12.01	< 0.001
D95 (cGy)	4573.3±238.3	4739.8±14.38	< 0.002
HI 0.1583±0.087	0.1182±0.051	< 0.001	

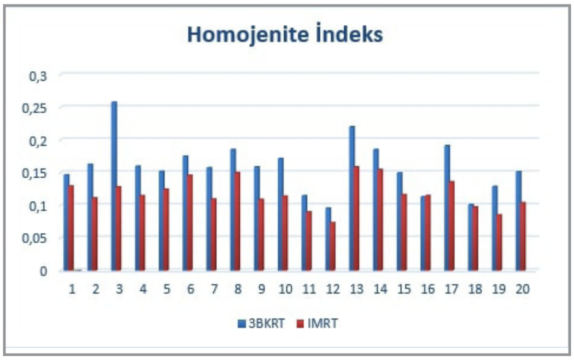

Figure 3. HI comparisons of 3DCRT and IMRT plans

for the PTV in our study. We know that the closer the value is to zero, the more homogeneous the planning will be. In our study, the IMRT technique was superior from the point of view of HI. This is consistent with the literature.[6-8] The heart may be exposed to high RT doses, especially in patients with left breast cancer. Therefore, in these cases, protection of the heart becomes an important factor in RT planning without compromising the dose delivered to the target volume. This can be consistently performed by utilizing planning techniques. In recent years, "deep breathing techniques" have been recommended for protection of the heart and have been shown to lower the dose delivered to the heart.[8] Our results showed that mean dose to the heart and V25 in patients with left breast cancer were higher in the IMRT planning compared to the 3DCRT technique. We can see variable results about this issue in the literature. In some studies, 3DCRT was claimed to be superior, while some showed IMRT to be superior in the dose delivered to the heart.[8] Another OAR that is important to consider in breast cancer radiotherapy is the ipsilateral lung tissue. A recent prospective study reported that the incidence of RT- induced pneumonia was 13% in breast cancer patients.[9] In the study of Rastogi et al. 107 patients randomized.[10] The results showed that in terms of V5 the 3DCRT technique was superior, while the IMRT technique was superior in terms of V20. In a different study, there was no statistically significant difference between the two techniques in V20, while the 3DCRT technique was found to be more advantageous in terms of V5.[8] In our study, 3DCRT was clearly superior in terms of V5 and V20 values of the lung. We associated the alteration in findings particularly with the number of patients included in these studies. In the study of Ma et al. there were 10 patients, while in our study there were 20 patients.[7] It is feasible to guess that different results may be yielded by including a higher number of patients. Moreover, we also believe that these results may be attributed to the fact that MI was also included in the area of treatment in some patients. In patients who have a diagnosis of breast cancer, it is important to consider secondary cancers that may develop in the future in connection to the dose of radiation that the contralateral breast receives during RT applications. In a phantom study performed according to the conventional 3-field RT technique, the measured contralateral breast mean dose was reported to be at 106.3 -205 cGy.[11] In two studies performed according to the IMRT technique higher values (362cGy, 475cGy) were observed.[12,13] Al-Rahbi et al.compared 3 techniques (3DCRT, FIF, reverse-IMRT) in terms of V0.6, V1, V2 and V5 values observed in the contralateral breast volumes.[14] They reported that the FIF technique was superior to other techniques. In another study, contralateral breast doses of 3 different techniques were assessed, and it was found that the Dmean dose was lower in the 3DCRT-FF technique (compared to 5F-IMRT and 2PVMAT).[8] In the current study, the Dmean and Dmax values of the contralateral breast were found to be higher in the IMRT technique.

Conclusion

In our study, 3DCRT and IMRT techniques in patients with breast cancer were compared dosimetrically. In accordance with the literature, we have observed that the IMRT technique can better protect the organs at risk while providing a more homogeneous dose distribution to target volumes. However, an important disadvantage we observed was the high doses occurring in the contralateral breast in the IMRT technique. As a result, while the radiotherapy technique to be applied is being determined, the patient's general condition, the fixation apparatus to be used, and the patient's anatomy should be taken into consideration as well as the advantages and disadvantages of each technique.

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