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Research Article

VMAT Tekniği ile Hazırlanan Prostat Radyoterapi Planlarında Farklı Kolimatör Açılarının Etkisi

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Öz

Bu çalışmada, Şişli Hamidiye Etfal Eğitim ve Araştırma Hastanesi Radyasyon Onkolojisi kliniğinde radyoterapi tedavisi alan 10 prostat kanseri hastası için tedavi planlarında farklı kolimatör açıları kullanılarak tümör ve kritik organ dozlarındaki farklılıkların karşılaştırılması amaçlanmıştır. Varian marka Trilogy model lineer hızlandırıcı cihazı ile tedavi edilen 10 prostat kanseri hastasının planları, Eclipse (ver.13.6) tedavi planlama sisteminde çift alan Hacimsel Ayarlı Radyoterapi (VMAT) planlama tekniği kullanılarak değerlendirildi. VMAT tekniğinde kolimatör açıları saat yönünde (CW) ve saat yönünün tersine (CCW) 30°-330° iken tedavi planları yapılıp doz dağılımları elde edildi. Optimizasyon değerleri değiştirilmeden kolimatör açıları VMAT hesaplarında CW ve CCW (15°-345°, 45°-315°, 60°-300°, 75°-285°, 90°-270) olacak şekilde değiştirilerek tekrardan hesaplatılarak kritik organ ve hedef organ doz dağılımları elde edildi ve kolimatör açısının doz dağılımı üzerindeki etkisi incelendi. En iyi doz dağılımını elde ettiğimiz kolimatör açıları VMAT tekniği için belirlendi ve istatistiksel olarak anlamlı olup olmadığı değerlendirildi. İstatistiksel olarak anlamlı olan tedavi planlarının Elektronik Portal Görüntüleme Cihazı (EPID) ile kalite kontrolleri yapıldı ve sonuçlar lineer hızlandırıcıdaki her hasta için doz ölçümleri yapılarak % 3 doz farkı ve 3 mm mesafe farkı kriteri ile karşılaştırıldı. Prostat kanseri hastalarının radyoterapi tedavisi için optimal doz dağılımını sağlayan kolimatör açısının hem istatistiksel olarak hem de yapılan ölçümler sonucunda tutarlı olduğu görülmüştür.

Anahtar Kelimeler: Kolimatör açısı, Hacimsel Ayarlı Radyoterapi, Elektronik portal görüntüleme cihazı, Prostat kanseri

The Effect of Different Colimator Angles in Prostate Radiotherapy Plans with Volumetric Modulated Arc Therapy (VMAT) Technique

Abstract

The aim of this study was to compare the differences in tumor and critical organ doses by using different collimator angles in the treatment plans of 10 prostate cancer patients who received radiotherapy treatment in the Radiation Oncology Clinic of Şişli Hamidiye Etfal Training and Research Hospital. The plans of 10 prostate cancer patients treated with the Varian Trilogy model linear accelerator were evaluated using the double field Volumetric Modulated Arc Therapy (VMAT) planning technique in the Eclipse (ver.13.6) treatment planning system. In VMAT technique, treatment plans were made when the collimator angles were clockwise (CW) and counter clockwise (CCW) 30°-330°. Critical organs and target organs are re-calculated by changing CW and CCW (15°-345°, 45°-315°, 60°-300°, 75°-285°, 90°-270°) in VMAT calculations without changing the optimization values. Dose distributions were obtained and the effect of collimator angle on dose distribution was examined. The collimator angles, which we obtained the best dose distribution, were determined for VMAT technique and evaluated for statistical significance. Quality control of the statistically significant treatment plans was performed with Electronic Portal Imaging Device (EPID) and the results were compared with 3% dose difference and 3 mm distance difference criteria for each patient in linear accelerator. It was found that the collimator

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angle which provides optimal dose distribution for the treatment of prostate cancer patients was consistent both statistically and as a result of measurements.

Keywords: Collimator Angle, Vmat, Epid, Prostate cancer

1. Introduction

Cancer disease is one of the most common health problems in recent years. Prostate cancer has been one of the most common types of cancer in men after lung cancer, with one of the highest mortality rates (after lung and colorectal cancers). The mean age at diagnosis was 72 years; however, with the development of follow-up and screening methods, it is diagnosed at a younger age. The American Cancer Society (ACS) recommends annual prostate specific antigen (PSA) and prostate examinations after the age of 50 years. The incidence of prostate cancer increases with age. Prostate cancer development rate in men under 39 years is 1 / 10,000, 40 to 59 years of age is between 1/103, 60 to 79 years of age is 1/8. In autopsy studies, approximately 30% of men over 50 years of age and 60-70% of men over 80 years of age develop prostate cancer, while 10% of men develop prostate cancer throughout life [1, 2].

Although the factors that cause the occurrence of prostate cancer can not be determined with certainty, some risk factors that are effective in the formation of prostate cancer have been identified. These factors can be listed as heredity, age, race, diet and chemicals. There are three basic diagnostic tools used to diagnose prostate cancer. These include digital rectal examination (DRM), PSA level determination and transrectal ultrasound (TRUS) [3]. Radical treatment options for the treatment of localized prostate cancer; surgery, external radiotherapy and brachytherapy.

Radical prostectomy (RP) is the name given to the surgical treatment of prostate cancer. The prostate and seminal vesicles are removed from the bladder and urethra. Adequate surrounding tissue should be removed to ensure surgical margin negativity. Bilateral lymphatic dissection is often performed. Radiotherapy (RT), applied alone or as part of treatment in 60% of patients diagnosed with cancer, is effective by preventing or destroying the proliferation of cancer cells using ionizing radiation [4-5-6].

The main objective in radiotherapy planning is to minimize the exposure of the surrounding tissues to radiation while providing the necessary dose to the target volume. In this way, it is ensured that the control of the tumor is maintained and the quality of life is not affected [7].

As a result of advances in radiotherapy in recent years, conventional radiotherapy has been replaced by Intensity Modulated Radiotherapy (IMRT) and VMAT techniques. These techniques provide better conformity in the target region and allow the organ at risk receive the minimum dose. With IMRT and VMAT techniques, irradiated radiotherapy areas or arcs-based fixed control points applied at different densities using non-uniform beams can achieve the desired dose distribution within the target volume. A plurality of beam combinations of varying intensity can be optimized to produce higher tumor control and lower normal tissue side effects [5].

The aim of this study is to find the best collimator angle, which is consistent with both the statistical and the measurements, which provides the most appropriate dose distribution for the treatment of radiotherapy of prostate cancer patients.

2. Material Method

Ten prostate cancer patients undergoing radiotherapy (radiation treatment) in Şişli Hamidiye Etfal Training and Research Hospital were included in the study. Patients were treated with VMAT technique using 6 MV photon energy in a Varian Trilogy model linear accelerator. Patients should be hospitalized in the most comfortable and stable position during computed tomography (CT), since they have to lie in the same position each day during the treatment period. To achieve this, immobilization devices are used in tomography of patients; In the supine position, the hands were clamped on the chest, and the bladder was filled using a wedge below the knee, and the tomography images were taken with the rectum empty.

CT section images were transferred to the treatment planning system with DICOM. Before the treatment, CT, Positron Emission Tomography- Computed Tomography (PET-CT) and Magnetic Resonance Imaging (MRG) images obtained from CT sections are transferred to Eclipse (Version 13.6) treatment planning system and treatment volumes and critical organ volumes are drawn and dose definition is made. For the treatment plans prepared by VMAT technique, the dose prescription was given to the patients 78Gy was applied in total. The dose rate was selected as 600 MU. 95% of PTV was given normalization to receive the full dose. Tolerance dose values have been defined on the optimization page to provide the dose values we want to receive planned target volume (PTV) and the allowable dose limits for critical organs. 6500 cGy area of the rectum volume was kept below 17%, 4000 cGy area of the rectum volume was kept below 35%. The 90% isodose line did not cover more than half of the rectum in any of the axial sections and the 50% isodose line did not cover the entire rectum in any of the axial sections. 6500 cGy area of the bladder volume was kept below 25%, 4000 cGy area volume was kept below 50% and femoral head doses were below 10% of 5000 cGy area volume and 1500 cGy area volume of Penis bulb dose was 90% optimization parameters were determined.

During optimization, priority values indicating the order of priority to be given while trying to provide the specified dose values for PTV and critical organs were entered on the optimization page. In VMAT technique, treatment plans were made when the collimator angles were clockwise CW and counter clockwise CCW 30 ° -330 °. Critical organs and target organs are re-calculated by changing CW and CCW (15°-345°, 45°-315°, 60°-300°, 75°-285°, 90°-270°) in VMAT calculations without changing the optimization values.

dose distributions were obtained. Before treatment, images taken with electronic portal imaging devices or manual port films are compared with anatomical references in images from the treatment planning system (TPS). Corrections are made automatically or manually if necessary. In addition, the treatment area with kilovoltage (kV) or Cone Beam Computed Tomography (CBCT) is verified and set-up errors are minimized.
The dose values of the target volume and critical organs take from the dose-volume histograms of the treatment plans, MINITAB program were used and the t-test was used for the matched data in table 1. The relevant p values (significance) are given in the table 2, 3, 4, 5, 6.

In the treatment of VMAT prostate patients, tumor volume and dose volume histograms for critical organs were evaluated and the best collimator angle was selected. The statistical significance of this collimator angle was tested and the consistency of the treatment plans made in this collimator angle on the applicability of the linear accelerator was checked. The 3% dose difference was subjected to a 3 mm distance difference test to see to what extent the results overlap.

CT images of 10 selected prostate cancer patients were screened at the 3 mm cross-sectional intervals and transferred to the treatment planning system. Target structures using these CT images were contouring for gross tumor volume (GTV) and cilinical target volum (CTV), PTV, and critical organs. As shown in figure 1 and figure 2, treatment plans were developed using Rapid Arc (ARC) tecnique and the collimator angles without changing the optimization parameters. The plans of the treated patients were evaluated with the Varian Trilogy linear accelerator in the Eclipse (ver. 15. 3) treatment planning system.

In this study, the treatment planning of 10 prostate cancer patients with radiotherapy treatment was calculated by dual-field VMAT techniques while the collimator angle was 30°-330° and optimum dose distribution was obtained. The treatment plans were recalculated and the effect of the collimator angle on the dose distribution was examined. It was investigated whether the collimator angle we obtained the best dose distribution was statistically significant. Statistically significant treatment plans were performed with EPID and the results were compared with 3% dose difference and 3 mm distance difference criterion by performing dose measurements for each patient in the linear accelerator. Patients were treated with Image Guided Radiotherapy (IGRT) by online correction with CT every day.

3. Results and Discussion

When planning with double-area VMAT technique, when 60°-300° and 75°-285° collimator angles were given, it was obtained that PTV covered better than the other angles considering 95% dose coverage. In the bladder doses of critical organ doses, while the collimator angles were 15°-345°, some dose drops were observed, while for rectal doses, the dose of collimator angles was 75°-285°. However, all dose reductions were below 0.5% and within Quantec dose limits. The results obtained from the double-area VMAT technique at 75°-285° collimator angles were obtained by using the Epid measurement system quality control program. When the index (3% dose difference, 3 mm distance difference) were considered, the calculation and measurement results of each plan critical and target organs were compared. For PTV. index pass rate was found to be 98.9 % ± 0.7. If 75°-285° collimator angles were selected in the double-area VMAT technique for prostate cancer patients, treatment plans were calculated and the results were obtained as a result of calculations and measurements that would contribute to critical organ doses and target volume doses.

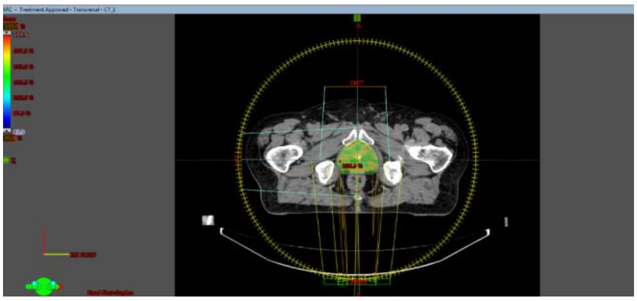

Figure 1. Treatment areas of planned prostat cancer patient with VMAT technique.

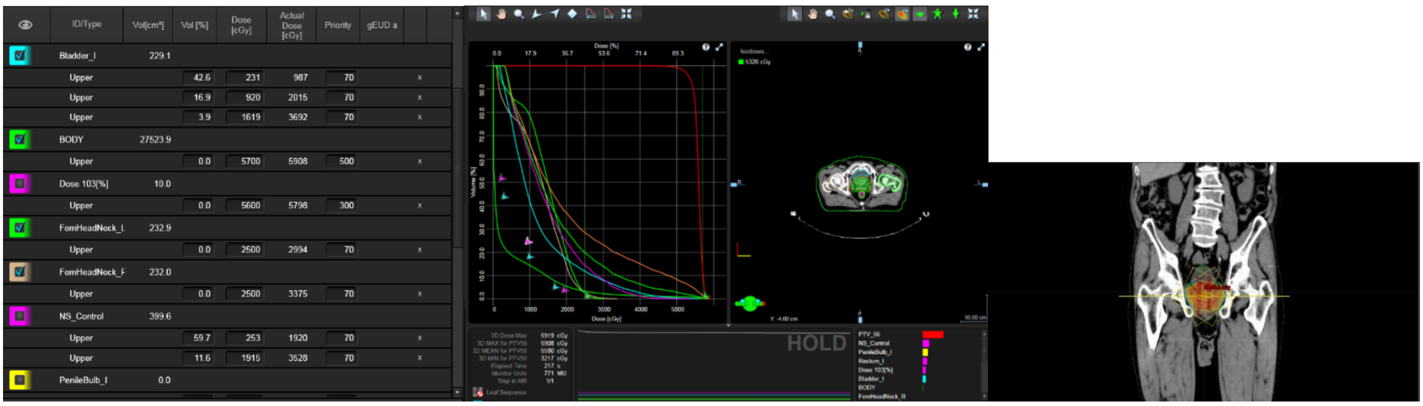

Figure 2. Optimization window and dose volume histogram

Results of the target volume doses, intact organ doses and t-test results of the 10 patients with prostate cancer who were treated with Varian Trilogy model linear accelerator in the Radiation Oncology Department of Şişli Hamidiye Etfal Training and Research Hospital by changing the collimator angles with the double-area VMAT method, and the results of the t-test for the matched data it is available.

Table 1. Dose covering 95% of 10 PTV by double-field VMAT technique, 40 Gy area percentage of bladder, 65 Gy area percentage of bladder, 40 Gy area percentage of rectum, 65 Gy area percentage of rectum.

	30°-330° Collimator angle is used	**15-°345° Collimator angle is used**	**45°-315° Collimator angle is used**	**60°-300° Collimator angle is used**	**75°-285° Collimator angle is used**	**90°-270° Collimator angle is used**
The amount of dose that covers 95% of PTV with VMAT (cGy)	7825,2±251	7833,1±230	7878,7±270	7882±220	7883,4±225	7860,2±260
40 Gy area percentage of bladder	20,37%±6,7	20,30%±6,5	20,45%±6,7	20,47%±6,9	20,57%±6,9	20,77%±6,8
65 Gy area percentage of bladder	9,90%±4,5	9,93%±4,3	10,6%±4,4	10,25%±4,5	11,2%±4,5	10,15%±4,3
40 Gy area percentage of rectum	22,10%±7,4	22,6%±7,1	22,18%±7,3	22,70%±7,3	21,5%±4,1	21,7%±7,1
65 Gy area percentage of rectum	8,62%±4	8,57%±3,9	8,73%±4	9,2%±4,1	9,1%±4,1	9,6%±4,1

Table 2. The t-test for matched data is the result of the statistical significance test of 95% of PTV relative to 30 ° -330 ° collimator angle of collimator angles by double-field VMAT technique.

Dose Amount Covering 95% of PTV with Dual Area VMAT				
Collimator Angles	Average of 10 patients	Collimator Angles	Average of 10 patients	P value
30° - 330°	7825,2±251	15° - 345°	7833,1±230	0,213
30° - 330°	7825,2±251	45° - 315°	7872,7±270	0,007
30° - 330°	7825,2±251	60° - 300°	7882±220	0,004
30° - 330°	7825,2±251	75° - 285°	7883,4±225	0,003
30° - 330°	7825,2±251	90° - 270°	7850,2±260	0,154

Table 3. Statistical significance test results of t-test for matched data of 40 Gy area percentage of bladder according to 30 ° -330 ° collimator angle of collimator angles by double-field VMAT technique.

40 Gy Field Percentage of Double Field Bladder				
Collimator Angles	Average of 10 patients	Collimator Angles	Average of 10 patients	P value
30° - 330°	20,37%±6,7	15° - 345°	20,30%±6,5	0,564
30° - 330°	20,37%±6,7	45° - 315°	20,45%±6,7	0,768
30° - 330°	20,37%±6,7	60° - 300°	20,47%±6,9	0,12
30° - 330°	20,37%±6,7	75° - 285°	20,57%±6,9	0,19
30° - 330°	20,37%±6,7	90° - 270°	20,77%±6,8	0,087

Table 4. Statistical significance test results of t-test for matched data of 65 Gy area percentage of bladder according to 30°-330° collimator angle of collimator angles with double-field VMAT technique.

65 Gy Field Percentage of Double Field Bladder				
Collimator Angles	Average of 10 patients	Collimator Angles	Average of 10 patients	P value
30° - 330°	9,90%±4,5	15° - 345°	9,93%±4,3	0,146
30° - 330°	9,90%±4,5	45° - 315°	10,6%±4,4	0,047
30° - 330°	9,90%±4,5	60° - 300°	10,25%±4,5	0,531
30° - 330°	9,90%±4,5	75° - 285°	11,2%±4,5	0,018
30° - 330°	9,90%±4,5	90° - 270°	10,15%±4,3	0,573

Table 5. Statistical significance test results of t-test for matched data of 40 Gy area percentage of rectum according to 30 ° -330 ° collimator angle of collimator angles by double-field VMAT technique.

40 Gy Field Percentage of Double Field Rectum				
Collimator Angles	Average of 10 patients	Collimator Angles	Average of 10 patients	P value
30° - 330°	22,10%±7,4	15° - 345°	22,6%±7,1	0,659
30° - 330°	22,10%±7,4	45° - 315°	22,18%±7,3	0,268
30° - 330°	22,10%±7,4	60° - 300°	22,70%±7,3	0,793
30° - 330°	22,10%±7,4	75° - 285°	21,5%±4,1	0,623
30° - 330°	22,10%±7,4	90° - 270°	21,7%±7,1	0,822

Table 6. Statistical significance test results of t-test for matched data of 65 Gy area percentage of rectum according to 30 ° -330 ° collimator angle of collimator angles by double-field VMAT technique.

65 Gy Field Percentage of Double Field Rectum				
Collimator Angles	Average of 10 patients	Collimator Angles	Average of 10 patients	P value
30° - 330°	8,62%±4	15° - 345°	8,57%±3,9	0,332
30° - 330°	8,62%±4	45° - 315°	8,73%±4	0,219
30° - 330°	8,62%±4	60° - 300°	9,2%±4,1	0,004
30° - 330°	8,62%±4	75° - 285°	9,1%±4,1	0,042
30° - 330°	8,62%±4	90° - 270°	9,6%±4,1	0,068

4. Conclusions

This work explores the impact of different collimator angles on a dosimetric scoring function. Collimator angle selection could play a vital role in improving the plan quality of VMAT for treating patients with prostate cancer. This study found that MLC rotation affects VMAT plan complexity and PTV dosimetric distribution.

This study identified the optimum collimator angles for optimizing dosimetric distribution for planning target volume (PTV), sparing of organs at risk (OARs), and plan complexity. The findings of this study could help planners to select appropriate collimator angles to obtain optimum results [8, 9].

If treatment plans are calculated by selecting collimator angles of 75°-285° in double-field VMAT technique for prostate cancer patients, the results were calculated as a result of calculations and measurements that will contribute to critical organ doses and target volume doses. When t-test was applied for the matched data for the double-field VMAT technique, the dose including 95% of the PTV volume was obtained as p = 0.003 for the collimator angles of 75 ° -285 ° with respect to the collimator angle of 30 ° -330 °, a statistically significant result obtained.

Kim et al. reported that the collimator angle γ index value. In the collimator angles we determined, it was obtained as a result of the measurements in which the index value was within the acceptance limits in the treatment of dual-area VMAT. With the obtained dual-field VMAT technique, we obtained the measurements at 75 ° -285° collimator angles γ index (3% dose difference, 3 mm distance) measurement results were taken into consideration [10].

Isa et al. were found to have a better coverage of PTV than the other angles when 95% dose coverage was taken into consideration when patients were given collimator angles of 60°-300° and 75°-285° when planning with dual field VMAT technique It was observed that the angle of the collimator providing optimal dose distributions for radiotherapy treatment of prostate cancer patients was consistent both statistically and as a result of the measurements made [11].

The results of our study could serve as a guide for collimator angle selection with regard to PTV dosimetric distribution, plan complexity, and the sparing of OARs in prostate VMAT planning.

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