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Examination of Dosimetric Verification of Prowess Panther Treatment Planning System Using Monte Carlo Method For Small Fields

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ABSTRACT

Treatment planning systems (TPS) have an important role in the implementation of radiotherapy treatment. Quality control of TPS is extremely important in terms of treatment reliability. In this study, it was aimed to make quality control of TPS by comparing the data obtained from the PROWESS Panther TPS with the results of the Monte Carlo simulation for small fields.

In this study, TPS used in the radiation oncology department was examined. For MC simulation, BEAMnrc and DOSXYZnrc codes were used in modeling and dose measurement of linear accelerator device. Gamma analysis method was used to compare measurement results.

When we examine the gamma analysis for PDDs in the study, the gamma values obtained in the 3x3 cm^2, 4x4 cm^2 and 5x5 cm^2 field sizes for the 3% and 3mm criterion provide this criterion for each measurement point. The fact that each dose point in the measurement field is less than 0.1 gamma value indicates that the dose profiles obtained in PROWESS Panther TPS are in good agreement with the MC results.

The doses calculated by PROWESS Panther TPS were found within the reference limits. It can be concluded that the dose calculated by PROWESS Panther TPS in homogeneous environments is within acceptable limits for use in radiotherapy. Studies should also be carried out in non-homogeneous environments such as lung, bone and soft tissue in order to obtain more accurate results about PROWESS Panther TPS.

Keywords: Radiation Oncology, Radiation, Treatment Planning Systems, PROWESS Panther, Monte Carlo Simulation

Introduction

The dose values generated in the treatment planning system (TPS) are calculated according to the measurement values obtained from the linear accelerator (Linac) device. In TPSs, the stages of determining the target volume and critical organs, making the appropriate treatment planning for the patient and transferring the plan to the treatment device are carried out. The correct prediction of the radiation dose created by the Linac device in an environment by TPS directly contributes to the success of radiotherapy. Errors due to TPS can cause fatal accidents. Considering the procedures performed during radiotherapy treatment, TPS quality control is of great importance for the reliability of the treatment.

The contribution of the algorithm used in TPS's to this success is also high. The accuracy of the calculated dose depends on the approximations and assumptions made by the algorithms. The algorithms used in TPS are categorized based on measurements (1-2). The general approach used to examine the accuracy of the TPS is to compare the TPS results with the accurate method. Today, the most appropriate method used for accurate calculation of radiation dose is Monte Carlo (MC) (1-3-4-5). PROWESS Panther (6-7) is a TPS program used today. This treatment planning system shows all the platforms it has in a single interface. The range of modules include: External Beam; (Direct Aperture Optimization) DAO IMRT; Jaws-Only IMRT; (Computerized Tomography) CT Simulation and Brachytherapy. It uses "Fast Photon" and "Collapsed Cone Convolution Superposition" as dose calculation algorithm (6).

The aim of this study is to compare the radiation dose calculated with PROWESS Panther TPS and MC method in a

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homogeneous environment and small radiation areas and to examine the accuracy of the PROWESS Panther TPS.

Material and Methods

In this study, BEAMnrc and DOSXYZnrc (8-9) codes were utilized to model the Siemens Artiste Linac device with 6 MV photon energy used in the radiation oncology department of the Van Yüzüncü Yıl University and calculate the radiation dose in the homogeneous phantom, respectively.

Previous studies were benefited to model the Siemens Artiste Linac device and calculate the radiation dose (10-11-12).

Firstly, the head part of Siemens Artiste Linac was simulated by using the BEAMnrc code. In the BEAMnrc, Linac head components comprise the exit window, target, primary collimator, flattening filter, monitor chamber, Y Jaws and X MLC, respectively. The number of histories is $6x10^8$ particles in simulation. The electron range rejection was used to speed the simulation process and to improve the most accurate simulation for bremsstrahlung photons created by the particle. The phase space files were obtained for the field sizes of 2x2 cm^2, 3x3 cm^2, 4x4 cm^2 and 5x5 cm^2 at SSD (source-skin distance) 100 cm, respectively.

Secondly, the phase space files obtained by BEAMnrc were used to calculate radiation dose in DOSXYZnrc. In DOSXYZnrc, the voxel size is 0.2x0.2x0.2 cm^3 for virtual phantom. $3x10^8$ histories were run for each calculation. Percent deep dose (PDD) and dose profile values were obtained for 2x2 cm^2, 3x3 cm^2, 4x4 cm^2 and 5x5 cm^2 field sizes in a homogeneous environment. The PDD curves and dose profile values were calculated along the central axis and at 10 cm dose depth, respectively. A statistical uncertainty of less than 0.2% was achieved. In all simulations in BEAMnrc and DOSXYZnrc, the electron cut-off energy (ECUT) is set to 0.7 MeV and the photon cut-off energy (PCUT) is set to 0.01 MeV. The radiation dose obtained from DOSXYZnrc on the virtual phantom for a 5x5 cm^2 field is shown in Figure 1 as an example.

By creating a virtual phantom in PROWESS Panther TPS, radiation doses on the phantom for 2x2 cm^2, 3x3 cm^2, 4x4 cm^2 and 5x5 cm^2 field sizes were calculated at SSD 100 cm. PDD values and dose profile values at 10 cm were obtained with the help of point dose measurement on PROWESS Panther TPS. Since the Collapse Cone (CC) algorithm is used more frequently in 3-dimensional conformal radiotherapy and intensity-modulated radiotherapy (IMRT), all radiation doses calculated in TPS were obtained using the CC algorithm. The gamma index method was used to analyze the results. The 3 mm criterion for the position and 3% criterion for the calculated dose were defined as gamma parameters.

Results

In order to check the accuracy of the MC simulation, in addition to the field sizes to be examined in the study, a field size of 10x10 cm^2 also was modeled. The dose results obtained in the area of 10x10 cm^2 showed a good agreement with the dose results measured in the water phantom. In addition, the approval of the MC simulation has also been shown in previous studies (10-12).

PDD values were obtained by measuring the doses generated by PROWESS Panther TPS and MC simulation on the central axis of the homogeneous phantom then PDD values were normalized to the maximum dose. PTW MEPHYSTO mc^2 was utilized to calculate the result of Gamma analysis of PDD values obtained for 2x2 cm^2, 3x3 cm^2, 4x4 cm^2 and 5x5 cm^2 field sizes (13). Figure 2 demonstrates the result of the gamma analysis.

Dose profile values measured at 10 cm depth were also checked to examine the accuracy of the PROWESS Panther TPS. The dose values measured in a 0.2 cm^3 voxel defined in DOSXYZnrc were compared with the dose values measured by the point dose in PROWESS Panther TPS. Gamma analysis method was used to determine the comparison correctly. The gamma analysis values calculated for dose profiles are shown in Figure 3.

Discussion

Loss of lateral electronic equilibrium is more common in small field sizes. The algorithms that some treatment planning systems have cannot take into account this loss of balance (14). Therefore, it is of great importance to control the dose calculated by the TPS in

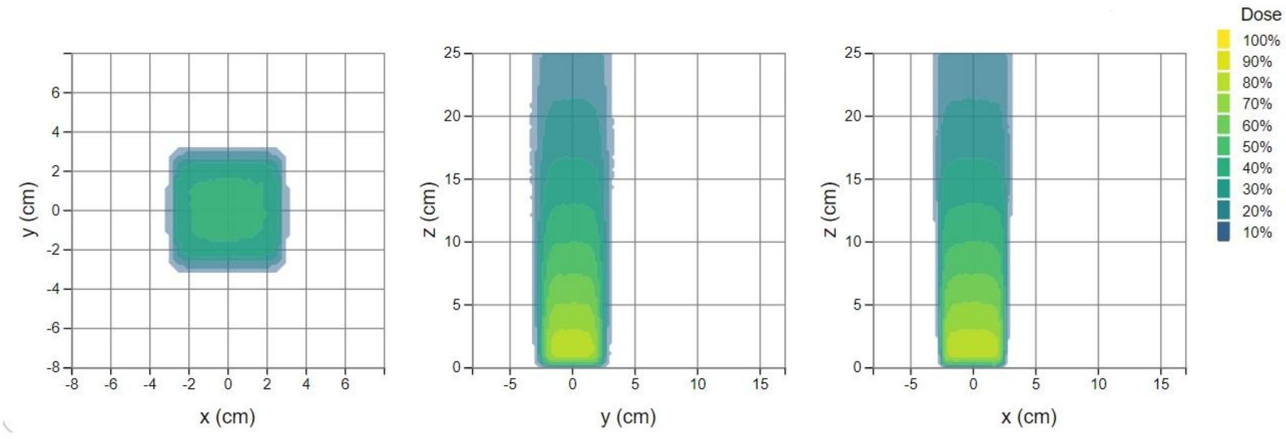

Fig. 1. For 5x5 cm², radiation distribution obtained on the phantom as a result of MC simulation

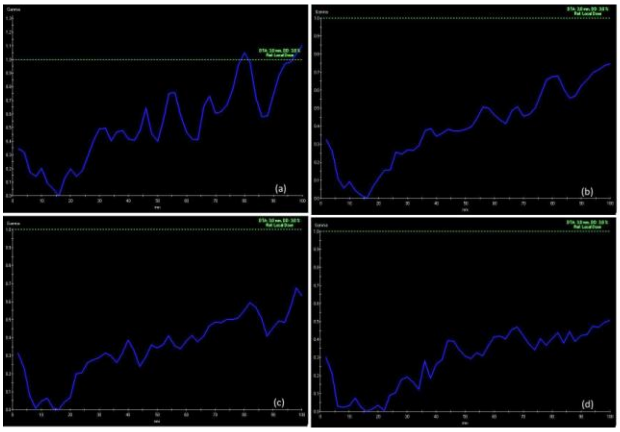

Fig. 2. Gamma analysis results obtained as a result of PROWESS Panther TPS and MC comparison for PDD. (a) for 2x2 cm² (b) for 3x3 cm² (c) for 4x4 cm² (d) for 5x5 cm²

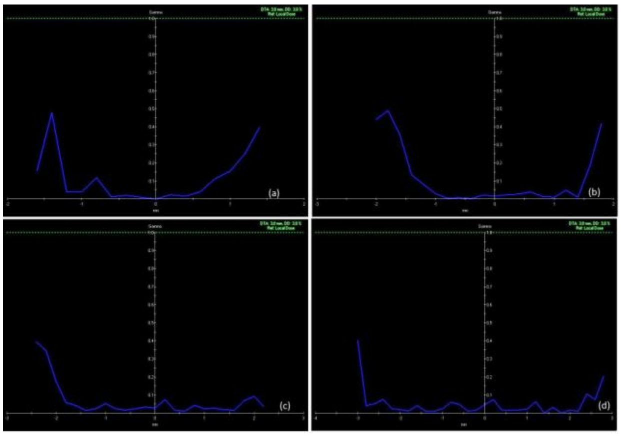

Fig. 3. Gamma analysis results calculated for dose profile. (a) for 2x2 cm² (b) for 3x3 cm² (c) for 4x4 cm² (d) for 5x5 cm²

small fields. In addition, there are important studies on this subject in the literature (15-16-17-18-19). When we examine the gamma analysis for PDDs in the study, the gamma values obtained in the 3x3 cm², 4x4 cm² and 5x5 cm² field sizes for the 3% and 3mm criterion provide this criterion for each measurement point. For the 2x2 cm² field size, as the depth increases, the similarity decreases and the measurement points beyond 8 cm remain above gamma analysis criteria. As can be seen clearly from Figure 2, the larger the fields, the better the gamma analysis result obtained. In addition, as seen in Figure 2, the measured results for each field near the maximum dose depth are similar. Even if the gamma values increase at deep points, the ones remain below 1.

If we examine the dose profile results, as can be seen from Figure 3, all measurement points for each field size meet the criteria. Although the mismatch towards the edges of the field is an expected result, the values obtained even in these regions remain below the gamma criteria. The fact that each dose point in the measurement field is less than 0.1 gamma value indicates that the dose profiles obtained in PROWESS Panther TPS are in good agreement with the MC results.

The correct calculation of the dose given to the patient in radiotherapy treatments by the treatment planning systems ensures that the radiotherapy is correctly applied. The correct calculation of the dose given to the patient makes it simpler to control the side effects that may occur in the patient. It also increases the quality of the treatment and ensures more accurate protection of the critical organs. Therefore, quality control of treatment planning systems used in radiotherapy is of great importance. The radiation dose calculated by the algorithms of treatment planning systems in any environment should be controlled by comparing it with experimental methods or measurements. In our study, we checked the dose calculated by the PROWESS Panther TPS system for small fields in a homogeneous environment. When the data obtained as a result of comparing the doses measured by TPS with the MC method were examined, the doses calculated by PROWESS Panther TPS were found within the reference limits. It can be concluded that the dose calculated by PROWESS Panther TPS in homogeneous environments is within acceptable limits for use in radiotherapy. Since only the doses formed in a homogeneous environment were examined in our study, studies should also be carried out in non-homogeneous environments such as lung, bone and soft tissue in order to obtain more accurate results about PROWESS Panther TPS.

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