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Research Article

Investigation of Three Different Treatment Planning Systems Using Intensity Modulated Radiotherapy Treatment Technique in Low-Grade Prostate Cancer: Dosimetric Comparison

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ABSTRACT

Objective: The aim of this study is to compare the dosimetric differences of 3 different treatment planning systems and to examine the quality of the plan in low grade prostate cancer.

Method: 50 randomly selected low grade prostate cancer treatment plans using 3 different Treatment Planning Systems (TPS), Eclipse V13.6 (varian medical systems, Palo Alto USA), Prowess Panther V5.2 (Prowess Inc. Concord, CA, USA) and Raystation V2.4.8. (laboratories AB, Stockholm, Sweden) treatment planning systems. IMRT plans were made with Multi-Static Segment (MSS) Intensity Modulated Radiotherapy (IMRT) and Dynamic Multi-Leaf Collimator (DMLC) technique in 7 fields with 78 Gy conventional treatment radiation dose in 39 fractions with an increase of 50-51 degrees. PTV target volume and critical organ doses, Monitor Units (MU), PTV conformity index and homogeneity index values were examined.

Conclusion: Comparable dose distribution was achieved with IMRT plans created with the same planning Computed Tomography (CT) data in three different planning systems, and Dose Volume Histogram (DVH) data suitable for clinical use were obtained. When the homogeneity values were examined, there was a significant difference in favor of Raystation TPS ($p<0.05$). The prescribed dose that best covered the PTV volume was obtained with the Eclipse treatment planning station ($p<0.05$). In terms of critical organ doses, all planning systems met the desired criteria and there was no significant difference between criticle organ doses ($p>0.05$). More monitor units were obtained with Eclipse TPS than raystation and prowess TPS.

Keywords: IMRT; Prostate cancer; Treatment planning systems; Raystation; Eclipse; Prowess; Homogeneity index; Conformity index; Monitor unit

INTRODUCTION

Prostate cancer is the second most common neoplastic disease. One of the treatment methods for prostate cancer is radiotherapy. With advances in radiotherapy, the target volume can be effectively treated while protecting healthy tissues. While applying this treatment technique, different treatment planning systems and treatment planning methods can be used [1]. Different treatment techniques are used in the treatment of early grade prostate cancer. Intensity modulated radiotherapy is one of the most commonly used treatment methods [2].

With IMRT, a more homogeneous dose distribution can be achieved in irregular tumour shapes. With Multi-Leaf Collimators (MLC), dose adjustment at the target volume can be made with sharper lines [3].

In traditional IMRT planning, fluense profiles are optimized to achieve the desired dose distribution. These profiles are adjusted with the MLC to achieve the appropriate plan quality. This is

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called a 2 step process. This may result in more segments and MUs. Different treatment planning system algorithms can calculate the dose distribution within the tissue. The accuracy of the calculated dose depends on the approximations and assumptions made by the algorithms. Volume definitions, implementation of the plan, simulation, MU calculation and transfer to the treatment device are performed by treatment planning stations [4].

DMPO (Direct Machine Parameter Optimization) MLC settings are made in the optimization process. Raystation optimization is done with Ray Optimizer and optimization core NPSOL. NPSOL is a sequential quadratic programming algorithm. It can achieve linear and non-linear boundaries [5,6]. Treatment planning stations with many different algorithms are commercially available for IMRT plans. The success of planning depends on the hardware and software of the computer as well as the experience of the planner [7].

Prowess Panther treatment planning system uses "Fast Photon (FF)" and "Collapsed Cone Convulution Superposition (CCC)" algorithms for dose calculation [8]. The CCC algorithm is completely based on 3D heterogeneity correction. The FF algorithm, on the other hand, calculates from measured data without heterogeneity verification [9].

The Analytical Anisotropic Algorithm (AAA) is implemented by the Eclipse treatment planning system. AAA uses the 3 Dimensional (3D) pencil beam convulution-superposition algorithm as a dose calculation model. Basic physical parameters based on Monte Carlo were added to clinical data. Beam modifying accessories (such as block, wedge, etc.) are taken into account in dose calculation [10].

In this study, 50 randomly selected low grade prostate cancer IMRT treatment plans were constructed using Eclipse, Raystation, and Prowess TPS. Dosimetric parameters such as conformity index, homogeneity index, monitor unit, target volume and critical organ DVH parameters of 3 different treatment planning systems were analyzed statistically. Student t test was used for statistical analysis of the datas. A p value of <0.05 was considered statistically significant.

MATERIALS AND METHODS

Fifty low grade prostate cancer patients were selected for plan comparison. Simulation was performed on a Siemens Somatom Definition AS (Siemens healthcare, Erlangen, Germany) Computerized Tomography (CT) device with a slice thickness of 3 mm. The pelvis of the patients was immobilized using foot and knee stabilizers (combifix). In order to ensure the geometric reproducibility of the treatment position during each treatment, the simulation was taken with an empty rectum and after 45 minutes of drinking 1 liter of water.

For PTV, a total dose of 78 Gy was defined in 39 fractions. 7 field IMRT plans were created for each patient using Eclipse, Prowess, and Ray Station TPS. TPS dose calculations were optimized by keeping the 2.5 mm grid resolution constant and taking the RTOG 0126 values as a reference. Homogeneity Index (HI), Conformity Index (CI), D_{Max} (Gy), D_{Mean} (Gy), D_{Min} (Gy), MU and critical organ doses were compared with each other [11].

Clinical Target Volume (CTV) was deliniated with seminal vesicles. The Planned Target Volume (PTV) was created by giving a margin of 0.7 cm posterior to the CTV and 1 cm from the other directions. Using 6 MV photon energy, 2 Gy in each fraction (every day/5 days/week) was given a total dose of 78 Gy. The right and left femoral heads, bladder, rectum, intestine were drawn as the organs at risk [12].

Plans were normalized so that 95% of the PTV encompasses the prescribed dose. RTOG 0126 criteria were taken as reference in critical organ evaluation [13]. PTV D98, D95, D50, D2 values, conformity and homogeneity index values, critical organ dose values were recorded for comparison [14]. Mean dose for rectum, V50, V60, V65, V70, V75, V80, mean dose for bladder, V65, V70, V75, V80 values were compared. At each planning station, the plan optimization parameters were determined according to the planning needs. Pseudo volumes were used if deemed necessary to achieve the plan criteria.

The gantry angles used in IMRT treatment plans were determined as 0°/50°/100°/150°/210°, 260°/310° [15]. In prowess and raystation TPS, MSS IMRT plans were created as 63 segments-70 segments in total, and in Eclipse TPS, plans were created with the DMLC technique.

RESULTS

A comparative analysis was performed for doses administered to target and at-risk organs. The following formulas were used to calculate the Conformity (CI) and Homogeneity (HI) index values of the plans.

Homogeneity index:

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

Where,

D50=Dose received by 50% of the volume.

D98=Dose received by 98% of target volume.

D2=Dose received by 2% of the target volume.

The closer the homogeneity index value is to zero, the more homogeneous the plan is.

Paddick conformity index:

CIPaddick=(TVPI/PI) × (TVPI/ TV)=TVPI2/(PI × TV),

According to the conformity index defined by Paddick et al.: TVPI is the prescribed isodose volume received by the target volume, PI is the prescribed isodose volume, and TV is the target volume. According to this definition, the ideal situation is TVPI=PI=TV. We also used the Paddick conformity index in our study.

The most homogeneous dose distribution in PTV was obtained with Raystation TPS (Figure 1). When the homogeneity values of the plans made with all planning stations are compared with each other statistically, there is no significant difference between the eclipse and prowess TPS homogeneity index values. Compared to raystation TPS, the difference between eclipse and prowess was calculated as 1.36 E-16 and 1.01E-15, respectively (p<0.05).

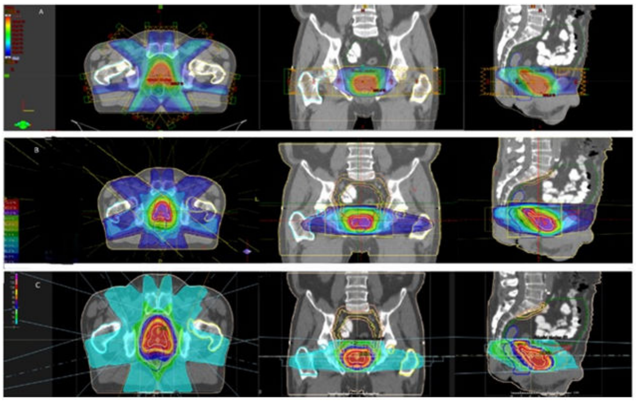

Figure 1: Shows the dose distribution obtained at the same cross-section at Raystation, Eclips and Prowess stations.

When the conformity index values were examined, it was determined that the prescription dose covered the target volume better with the Eclipse treatment planning station (Figure 2). The p values between eclipse-raystation, eclipse-prowess, raystation-prowess were obtained as 1.89E-8, 0.0027 and 0.056, respectively.

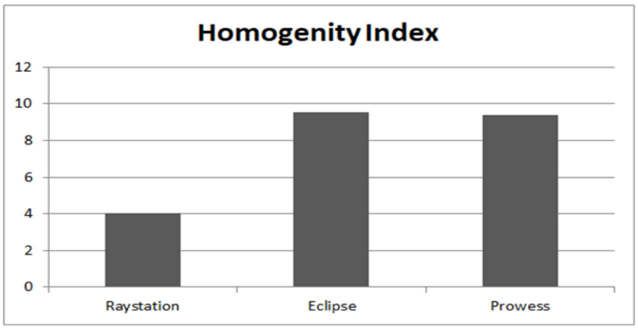

Figure 2: The most homogeneous dose distribution in PTV was obtained with Raystation TPS.

When the PTV minimum, maximum and mean dose values are examined, the values obtained with Raystation have a more desirable DVH slope, as seen in Figure 3. A significant difference was obtained when the minimum, maximum and average doses were compared with Raystation TPS and other planning stations (p<0.05). There is no significant difference between Eclipse and Prowess TPS in maximum PTV dose values. The minimum, maximum and mean values closest to the prescription dose were obtained with Raystation TPS in accordance with the homogeneity index value (Table 1).

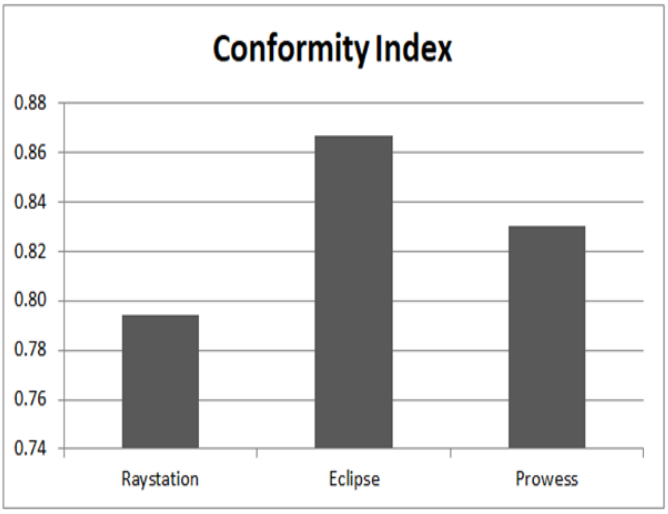

Figure 3: When the conformity index values were examined, it was determined that, the prescription dose covered the target volume better with the Eclipse treatment planning station.

Table 1: Dosimetric analysis values for PTV.

	Raystation	Eclipse	prowess	Raystation-Eclipse	Eclipse-Prowes	Raystation-Prowes
	7 Alan	7 Alan	7 Alan			
PTV Max	8036,35	8567,36	8596,8	4,03E-22	0,362939	8,24E21
PTV Min	7629,35	6990,04	7267,61	8,67E-20	0,014	0,001
PTV Mean	7908,5	8211,48	8166,48	8,53E-20	0,04	1,17E-14
CI	0,79	0,87	0,82	1,89E-08	0,0027	0,056
HI	4,02	9,54	9,4	1,36E-16	0,717	1,01E-15
Normalized MU values	1,68	2,22	1,59	1,55E-07	6,28E-09	0,12

Optimizations were performed to match critical organ doses to RTOG criteria. Figures 4-5 show dose volume histograms for the rectum, bladder, right and left femoral heads and intestines obtained at the planning stations. Clinically appropriate doses for critical organs were obtained with planning systems and statistically no significant difference was observed between the data. In addition, when the DVH graph was examined with eclipse TPS, visually lower doses were obtained.

In the study, elekta synergy platform (Elekta AB, Stockholm, Sweden), varian trilogy (Varian medical systems, Palo Alto, CA, USA) and siemens oncor(Siemens medical systems, Concord, CA) devices were modeled in Raystation, Eclipse and Prowess treatment planning stations. For the Monitor Unit (MU) evaluation, the MU values required to dose 2 Gy at 10 cm depth at SSD 100 cm were accepted as reference. The total monitor unit required for treatment was evaluated by normalizing with the reference MU [15]. Eclipse MU values were significantly higher than other TPS (p<0.05), MUs were found to be compatible between raystation and prowess (p>0.05). The difference is thought to be due to MSS and DMLC irradiation techniques.

DISCUSSION

Fogliata, et al., studied the breast IMRT plan. In their study, they compared 10 different planning stations and algorithms. They stated that all planning stations in a heterogeneous residential area such as breast give an acceptable plan [16]. IMRT creates the appropriate dose distribution in concave shaped tumors. Fogliata, et al., compared the head and neck plans using 3 different planning systems on: Helax-TMS, Cadplan-Helios, CMS-Focus. Each planning system needs additional planning parameters to obtain the appropriate dose distribution within itself. In their study, they stated that the planning stations had equal and acceptable dose distributions [17]. In the estro project carried out in 2005, IMRT plans were compared with 8 different planning systems over the same tomography images between radiotherapy centers. Although the 11 IMRT plans they used for comparison differed in MU values, all met their planning goals and produced clinically acceptable plans [18]. Fiorino, et al. compared the tomotherapy treatment plan with IMRT plans for head and neck cancers in the Helios/Eclipse treatment planning systems. With tomotherapy treatment planning, they obtained more effective treatment plans in terms of PTV and critical organ doses compared to conventional IMRT plans [19]. Oliver, et al., compared the plans of tomotherapy, IMRT, and rapidark. They showed that plans made with Rapidarc are dosimetrically superior to plans made with IMRT. Yie Chen, et al., compared tomotherapy, Pinnacle and Raystation planning stations for lung cancer and obtained clinically acceptable plans. They stated that their tomotherapy plan is dosimetrically superior to the other two treatment planning systems. With Raystation MCO, hot spot elimination in PTV can be performed in a shorter time. This shortens the planning time as much as possible. In our study, when the target volume was examined in addition to the acceptable critical organ doses, a statistically significant homogeneous dose distribution was obtained with Raystation .

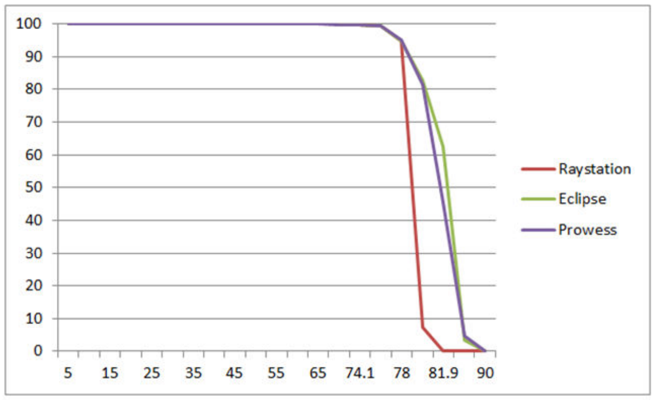

Figure 4: When the PTV minimum, maximum and mean dose values are examined, the values obtained with Raystation have a more desirable DVH slope.

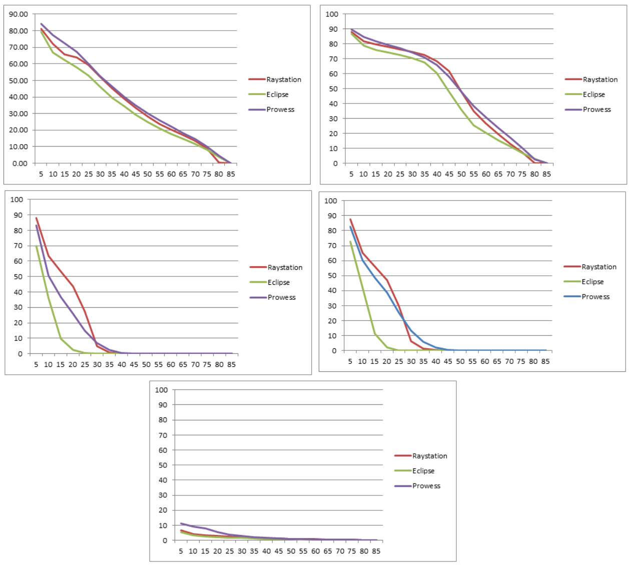

Figure 5: Dose volume histograms for the rectum, bladder, right and left femoral heads and intestines obtained at the planning stations.

CONCLUSION

Comparable dose distribution was achieved with IMRT plans created using the same CT data in three different treatment planning systems, and DVH data suitable for clinical use were obtained. Homogeneity index values were significantly different in favor of Raystation TPS (p<0.05). While Raystation TPS provided the most homogeneous dose at the target volume, the dose prescribed with Eclipse TPS better covered the target volume. In terms of critical organ doses, all planning systems met the desired criteria and there was no significant difference between organ doses (p>0.05). More monitor units were obtained with Eclipse TPS than Raystation and Prowess TPS.

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