A COMPARISON OF THREE DOSIMETRIC PATIENT QUALITY ASSURANCE TOOLS FOR PRECISION RADIOTHERAPY OF HEAD AND NECK CANCER

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ABSTRACT:
Precise and very complex radiotherapy technique Volumetric Modulated Arc Therapy (VMAT) provides uniform and conform dose distribution. Despite that, there is still a possibility that due to precision in the dose calculation of the treatment planning system (TPS) or the errors associated with it, there can be distinctions between dose distributions which are planned and delivered. The gamma index (GI) is the parameter by which is quantified the difference between these dose distributions and this index may depend on the pathology and the area to be treated. The goal of this work is to estimate different parameters of the gamma index (GI) for head and neck cancer treatments. The analysis was based 2%/2 mm, 3%/3 mm criteria. 10 treatment plans were created with the VMAT technique calculated with the TPS Eclipse V.15.6 (Varian Medical Systems, Palo Alto, CA) and measured with the Dolphin (IBA dosimetry, GmbH, Germany), PTW Octavius 4D 1500 (PTW-Freiburg, Freiburg, Germany) and Varian aS1200 electronic portal imaging device-EPID (Varian Medical Systems, Palo Alto, CA) were analyzed. A Varian VitalBeam, linear accelerator with a 6 MV photon beam was used to deliver the dose. The obtained results of the analysis were that a gamma passing rate (%GP) greater than 90% for 2%/2 mm and greater than 95% for 3%/3 mm analysis criteria. The criteria for gamma analysis can be less strict and then the %GP can increase. A significant difference was also observed when the PTV has a greater volume.

Keywords: *VMAT; gamma index (GI); patient quality assurance.*

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1. INTRODUCTION

Radiation therapy is one of the most common and widely used cancer treatment methods. Significant technological and imaging improvements have impacted radiotherapy techniques over the past few decades, increasing their accuracy, flexibility, and efficiency. Three-dimensional conformal radiotherapy (3D CRT) [1], intensity modulated radiation therapy (IMRT) [2], and volumetric modulated arc therapy (VMAT) [3,4,5] are three different techniques of cancer treatment. A techniques IMRT and VMAT demand precise control during radiation delivery and, therefore, in order to determine the distinction between calculated and actual dose distributions, more extensive quality assurance (QA) checks are required. Quality assurance (QA) in radiation therapy aims to minimize the dose deposited in healthy tissue and staff exposure while ensuring adequate patient monitoring to determine the final outcome of treatment. Consists of a series of processes [6]. Due to uncertainty of the target position, patient positioning mistakes, motion organs during therapy, as well as, problems in dose calculation, and errors in plan transfer or beam delivery are all potential risks connected with modern radiotherapy. Therefore, quality assurance should be performed before and/or during patient treatment to provide optimal therapy with minimal damage to normal tissue and minimize errors [7]. In this study, three different dosimetric tools were used to evaluate the quality assurance (QA) results of VMAT plans from ten patients.

2. MATERIALS AND METHODS

VMAT plans for ten patients who underwent radiotherapy were generated at the Centre of Radiation Oncology, the University Clinical Center Kragujevac. All plans were created with Eclipse v.15.6. (Varian Medical Systems, Salt Lake City, UT, USA) radiation planning system using the anisotropic analytical algorithm (AAA). To compare the TPS (treatment planning system) dose with measured doses, the gamma index (GI) method is used. This method integrates, into one parameter, percent dose difference (%Diff) and distance-to-agreement (DTA) [8]. DD (dose difference) is a % directly compares the measured dose at each point to the corresponding calculated dose at that point, DTA (distance to agreement)(mm), tests measure the distance between a point on the measured dose distribution and the nearest point on the calculated distribution with equal dose[9]. There are several criteria for calculating VMAT treatments 1%=1 mm, 2%=2 mm, 3%=2 mm, 2%=3 mm, 3%=3 mm and 5%=3 mm, but 3%=3mm is the most widely used. Acceptance criteria consist of more than 95% of the evaluated points with a global gamma index < 1. Gamma index attempts to combine dose difference and DTA into a single metric that is useable in both areas of dose gradient and homogeneous dose [9]. The comparison of passing rates was made among the three dosimetric tools: Dolphin (IBA dosimetry, GmbH, Germany), PTW Octavius 4D 1500 (PTW-Freiburg, Freiburg, Germany) and EPID QA (Varian aS1200 electronic portal imaging device, Varian Medical Systems, Palo Alto, CA)

EPID QA (electronic portal imaging device quality assurance) detect the radiation transmitted through the patient and treatment couch [10,11]. EPID can be configured in two ways, independent calculation on the patient CT dataset or using the patient/phantom in the beam and the corresponding dose again can be estimated on the patient. EPID QA (Varian aS1200 electronic portal imaging device) was attached to the Varian VitalBeam Linear accelerator (Varian Medical Systems, Palo Alto, CA, USA). For dosimetry mode, the active area of the EPID is 40 x 40 cm^2, with 1190 x 1190 pixels arrays and 0.336mm pixel pitch. Octavius®-4D (PTW-Freiburg, Freiburg, Germany) is a powerful tool for quality assurance (QA) of radiotherapy treatments and can be easily set up [12]. Octavius®-4D use 1405 detectors type plane-parallel vented ionization chambers. The detector size is 4.4 mm x 4.4 mm x 3 mm (0.06 cm^3), the maximum field size is 27cm x 27cm. For analysing data Octavius uses VeriSoft (PTW). A commercially available dosimetry solution, Dolphin-Compass (IBA Dosimetry, Schwarzenbruck, Germany), reconstructs 3D doses of a phantom or patient [13]. The Dolphin uses Compass software to compare 3D dose distributions and Dose Volume Histograms (DVH) between planned and computed doses. The Dolphin is a 2D detector array consisting of 1513 air-vented plain parallel ionization chambers arranged across an area of 40x40cm^2. The detector size is 3.2 mm (Ø) x 2.0 mm (h), (0.016 cm^3), and full treatment fields are 24.3 x 24.3 cm^2.

(a)

(b)

(c)

Fig.1 Machine set up for: (a) EPID QA, (b) Octavius®-4D, (c) Dolphin

3. RESULTS

Using three prescription dose verification tools, gamma analysis was performed on ten selected VMAT plans as shown in Table 1. The criteria applied to the gamma index analysis were 2%/2 mm, and 3%/3 mm. For the 2%/2mm criterion, the mean pass rates for Dolphin, EPID, and Octavius 4D were 93.2% ± 2.6%, 95.1% ± 1.9%, and 91.1% ± 2.8%, respectively. When the criteria was 3%/3 mm, the average pass rates were 99.3%±0.7%, 99.7%±0.3%, and 98.4%±1.3% for Dolphin, EPID, and Octavius 4D, respectively.

Based on the results of all three prescription dose verification tools, the criteria were satisfied. It can be noted that when changing the criteria from 2%/2m to 3%/3mm, the cases satisfying the > 95% pass rate criteria were considerably increased. While, the mean standard deviations of all three tools tended to decrease gradually in the order of EPID, Dolphin and Octavius 4D.

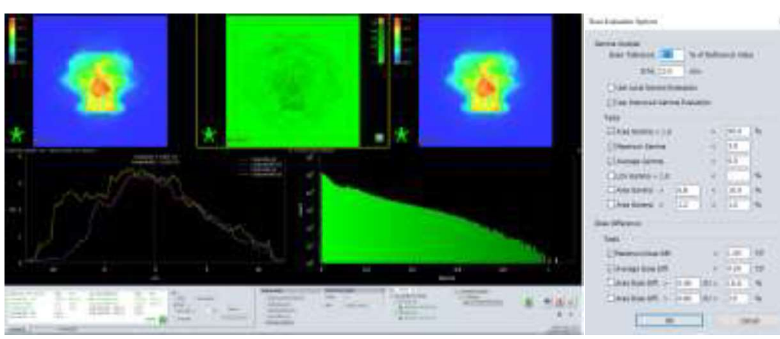

Figure 2. The interface of evaluation gamma analysis 3%/3 mm with potral dosimetry for EPID aSi-1200.

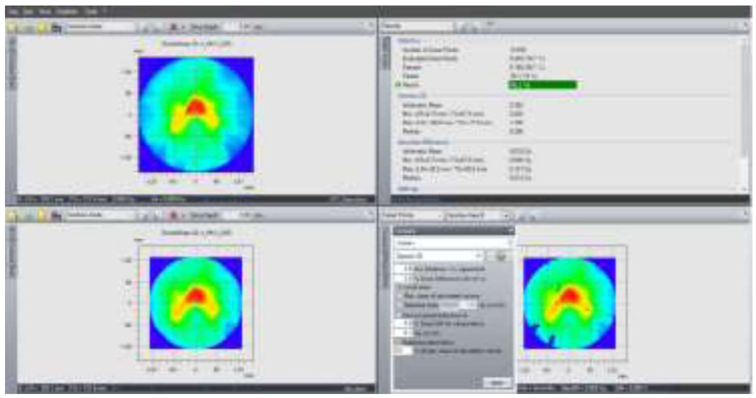

Figure 3. The interface of evaluation gamma analysis 3%/3 mm with VeriSoft for PTW Octavius 4D 1500.

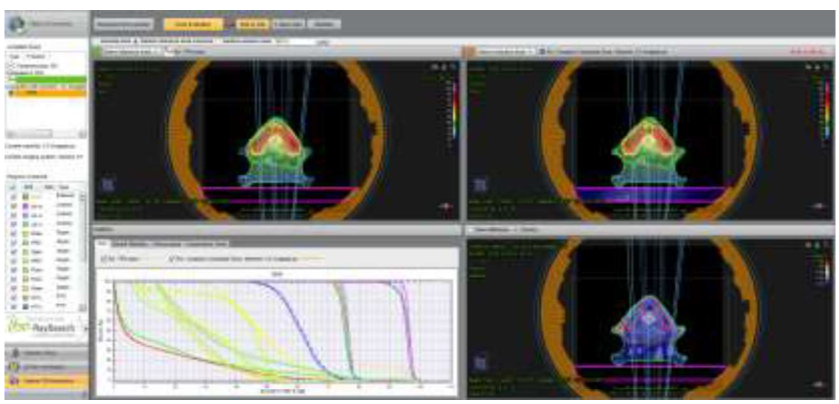

Figure 4. The interface of evaluation gamma analysis 3%/3 mm with Compass for Dolphin – IBA Dosimetry.

Table 1 Gamma analysis results obtained using, EPID, Octavius 4D and Dolphin dosimetry tools.

Patient	*EPID*		*Octavius 4D*		*Dolphin*	
	2%/2 mm [%]	*3%/3 mm [%]*	*2%/2 mm [%]*	*3%/3 mm [%]*	*2%/2 mm [%]*	*3%/3 mm [%]*
1	97,7	100	93,9	99,7	94,7	99,9
2	97,3	100	92,9	99,1	95,4	100
3	92,9	99,5	89,3	97,7	90,6	98,9
4	96,1	99,8	92,6	98,7	93,9	99,6
5	95,8	100	92	99,3	95,3	100
6	94,4	99,4	90,2	97,5	91	98,6
7	92,5	99,4	88,8	97,9	91,7	98,7
8	97	100	93,4	98,9	95,8	99,7
9	94,1	99,5	89,6	98.1	92,5	99
10	93,2	99,4	88,3	97,1	91,1	98,6
Mean	95.1	99.7	91.1	98.4	93.2	99.3

4. CONCLUSION

The gamma evaluation method is typically used to verify the actual dose distribution that will be delivered to the patient when a VMAT treatment is to be performed. QA results are acceptable when they achieve a passing rate higher than 95%, based on a 3% tolerance for dose difference and a 3 mm tolerance for distance to an agreement. In this study, the result of the gamma index obtained by EPID, Octavius 4D and Dolphin was examined. This report provides all three suggested standards are efficient detectors for a patient-specific QA and can be implemented at the clinical level to evaluate the acceptability of VMAT plans, specifically in the busy centre of radiation oncology.

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