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Comparison of patient specific quality assurance tests done with using different dosimetric systems for intensity modulated radiotherapy treatment plans

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Abstract

Intensity modulated radiotherapy is the developed technique of 3 dimensional conformal radiation therapy. In this method, irradiated fields can be seperated into many subfields that are called segments. Each segments' radiation dose can be adjusted. Intensity modulated radiotherapy plans have complex segments and high gradient dose regions. Therefore, quality assurance of intensity modulated radiotherapy plans is very important. The aim of this study is to perform quality assurance tests of intensity modulated radiotherapy plans by using different dosimetric systems and compare of results. Intensity modulated radiotherapy treatment plans of thirty patients' quality assurance were tested using Matrixx and Delta4. Then, gamma pass rates that were determined as a result of the gamma analysis done using gamma pass-fail criteria that had values of different dose difference and distance to agreement. In our study, the differences between the mean values of gamma pass rates determined before were statistically examined and there was significant difference between two dosimetric systems.

Keywords: Intensity modulated radiotherapy, Matrixx, Delta4, Gamma analysis

Introduction

Intensity modulated radiotherapy (IMRT) is different from 2 Dimensional (D) conventional and 3D conformal radiotherapy methods and different dosimetric confirmations are needed. In all the centers using this technique in the world, performing dosimetric quality control for patient has become a protocol [1,2] Dosimetric quality control procedures such as Matrixx and Delta4 are being used [3,4]. In this study, the dosimetric quality controls of 30 patients with IMRT were performed using 2D Matrixx and 3D Delta 4 dosimetric systems. The dose maps obtained from the treatment planning system were compared with the dosimetric measurement results. Advantages and disadvantages of the dosimetric systems used have been identified. Thus, it was aimed to establish a quality control program when the dosimetric accuracy of IMRT plans was determined.

Material and Methods

In this study; the dosimetric validation of the treatment plans of 30 patients with different anatomic localized tumors approved for IMRT planning was performed. Treatment plans were prepared using the Monaco treatment planning system with static IMRT (step and shoot) technique [5]. Computer tomography (CT) images of 30 patients, including 10 prostate cancer, 10 head and neck cancer, and 10 brain tumor patients and the plans were clinically approved. Dosimetric quality control procedures were performed using IMRT Matrixx and Scandidos Delta4 phantom [6-8]. The dose maps from the treatment planning system and the absolute dose values were compared. Dose maps; The OmniProI'mRT program for Matrixx, a 2D dosimetric system, was evaluated using the gamma (γ) analysis method over the Scandidos Delta4 program for Delta4, a 3D dosimetric system. The mean gamma analysis of the dosimetric systems was statistically analyzed using a one-way analysis of variance to determine whether there was a significant difference in percentages between the two [9].

Results

In our study, the differences between the mean values of gamma pass rates determined before were statistically examined and there was significant difference between two dosimetric systems (p=0.001).

There wasn't significant difference between two systems in terms of mean values of gamma pass rates that were determined as a result of the gamma analysis performed for 10 patients with brain tumors (p=0,326). However, there were significant differences

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between two systems in terms of mean values of gamma pass rates that were determined as a result of gamma analysis performed for 10 patients with head and neck cancer (p=0,032) and 10 patients with prostate cancer (p=0.008). Also the mean values of gamma pass rates were determined higher for Matrixx system (Table 1).

That was statistically supported that there were significant differences between two systems in terms of mean values of gamma pass rates which were determined as a result of gamma analysis performed using different pass-fail criteria that had values of different dose difference and distance-to-agreement (DTA).

There were significant differences between two systems in terms of mean values of gamma pass rates that were determined as a result of gamma analysis done using pass-fail criteria %2/2mm (p=0.000), %3/2mm (p=0.002), %3/4mm (p=0.002) and %3/5mm (p=0.016) (Table 2,3) (Figure 1,2).

Table 1. Statistical analysis of gamma pass rates obtained after gamma analysis of treatment regions for two dosimetric systems

Treatment Area	Dosimetric system	Average (%)	Standard Deviation
Brain	Matrixx	99,620	0,3795
	Delta4	99,500	0,4163
Head and Neck	Matrixx	98,980	1,0881
	Delta4	97,690	1,8818
Prostate	Matrixx	99,240	1,2002
	Delta4	97,640	1,5643

Table 2 The comparison of gamma pass rates obtained after gamma analysis with criteria with different dose differences and DTA values resulted in quality control measurements of 30 patients with Matrixx

Patient No	%2/2mm (%)	%3/2mm (%)	%3/3mm (%)	%3/4mm (%)	%3/5mm (%)
1	97,7	98,9	99,8	100,0	100,0
2	99,0	99,4	99,9	100,0	100,0
3	96,2	97,5	99,0	99,4	99,5
4	99,0	99,6	99,9	99,9	100,0
5	96,0	97,2	99,2	99,5	99,7
6	98,2	99,1	100,0	100,0	100,0
7	97,1	98,5	99,4	99,7	100,0
8	97,4	98,7	99,8	100,0	100,0
9	97,7	98,5	100,0	100,0	100,0
10	95,6	97,3	99,2	99,5	99,8
11	98,6	99,4	99,9	100,0	100,0
12	**94,4**	98,2	99,6	99,9	100,0
13	**94,5**	96,4	99,0	99,5	99,6
14	95,3	98,1	99,5	99,7	99,8
15	96,1	98,3	99,6	100,0	100,0
16	**93,8**	95,1	96,5	97,2	97,9
17	**94,6**	97,9	99,3	99,5	99,6
18	**92,0**	95,8	98,8	99,1	99,1
19	95,9	98,6	99,9	100,0	100,0
20	**91,6**	96,0	97,7	99,2	99,4
21	97,6	98,8	99,8	99,8	99,9
22	98,7	99,3	99,9	100,0	100,0
23	95,6	96,7	98,6	98,8	99,9
24	98,4	99,0	99,8	99,9	100,0
25	97,4	99,2	99,8	100,0	100,0
26	98,4	99,0	99,7	100,0	100,0
27	96,1	97,7	99,8	100,0	100,0
28	96,7	98,0	99,6	100,0	100,0
29	**94,0**	95,0	96,0	96,8	98,0
30	95,5	98,2	99,4	99,7	99,9

* The lines filled with the grey color belong to the plans that failed gamma analysis.

Table 2 Comparison of gamma pass rates obtained after gamma analysis with criteria with different dose differences and DTA values resulting in quality control measurements of 30 patients with Delta4

Patient No	%2/2mm (%)	%3/2mm (%)	%3/3mm (%)	%3/4mm (%)	%3/5mm (%)
1	**88,6**	96,6	99,1	99,6	99,8
2	100,0	100,0	100,0	100,0	100,0
3	96,9	99,0	99,6	100,0	100,0
4	95,9	98,6	99,8	99,8	99,8
5	98,0	98,7	99,0	100,0	100,0
6	99,4	99,9	100,0	100,0	100,0
7	98,8	99,5	99,6	100,0	100,0
8	98,8	99,1	99,8	100,0	100,0
9	98,6	99,1	99,2	99,5	99,8
10	97,5	97,9	98,9	99,8	99,8
11	**94,0**	98,2	99,6	99,7	99,7
12	**91,7**	97,7	99,3	99,8	99,9
13	**89,9**	**93,6**	96,5	97,4	97,9
14	**88,8**	**91,9**	95,5	96,4	96,6
15	**93,1**	96,3	99,1	99,8	99,9
16	**90,1**	**92,9**	95,5	96,0	99,7
17	**80,1**	**89,3**	95,3	96,6	96,7
18	**82,2**	**93,3**	97,1	98,5	99,0
19	**94,7**	98,0	99,6	99,9	99,9
20	**91,7**	97,6	99,4	99,5	99,7
21	**93,5**	97,5	99,8	99,8	100,0
22	**91,9**	**94,3**	96,6	97,5	98,2
23	**84,7**	**90,6**	95,5	96,8	98,1
24	**87,8**	**92,1**	96,1	97,3	97,9
25	**91,5**	96,2	98,0	98,8	98,9
26	**92,2**	97,1	99,6	100,0	100,0
27	**91,6**	96,9	98,2	99,1	99,4
28	**94,1**	97,3	97,9	98,2	98,8
29	**87,8**	**92,3**	95,8	96,7	97,9
30	**93,3**	98,0	98,9	99,7	100,0

* The lines filled with the grey color belong to the plans that failed gamma analysis.

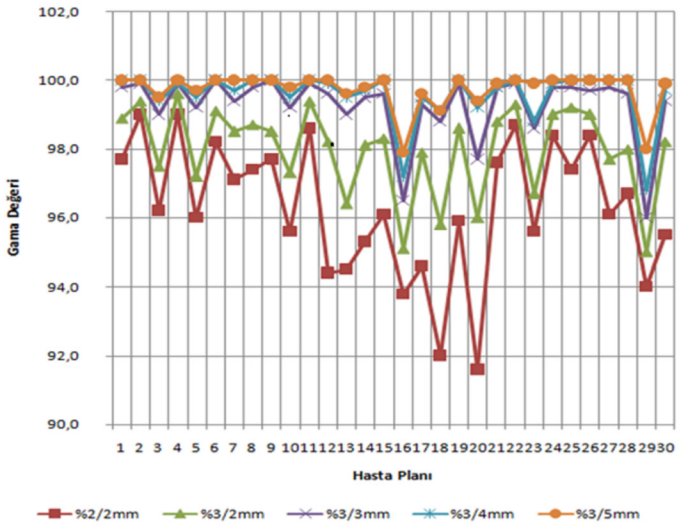

Figure 1. Graphical representation of gamma pass rates obtained using different dose criteria of 30 patients for the matrix

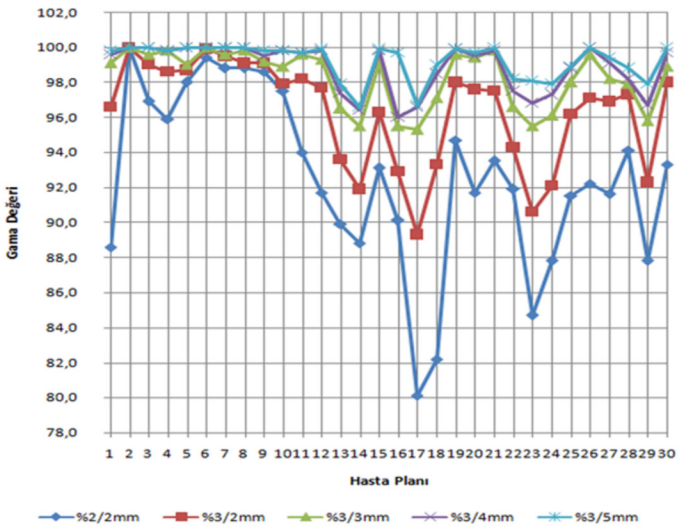

Figure 2. Graphic representation of gamma pass rates obtained using different dose criteria of 30 patients for Delta

It was shown that both Matrixx and Delta4 dosimetric systems were successful in gamma analysis and applicable for the dosimetric verification of the IMRT treatment plans.

Discussion

According to the results obtained from this study, it is revealed that Matrixx being 2D dosimetric method and Delta4 being 3D dosimetric method is applicable for the measurements that are performed in order to in spect the dosimetric accuracy of IMRT treatment plans.

In our study, gamma analysis of 30 patients' IMRT treatment plans using the 'γ evaluation method' which is composite analysis of 3 mm DTA and %3 dose difference (DD) were figured out regarding gamma passing rate (GP%) and also it was observed that the dose distributions are with in acceptable tolerances ($\gamma \leq 1$).

As a consequence of comparison of quality accuracy data with dosimetric methods, it was statistically verified that there was a significant difference in GP % between the methods. Furthermore GP % obtained from Matrixx method that is used to treatment of 30 patients are higher than GP % obtained from Delta4 method that is used to treatment of the same 30 patients. It should be also noted that the main reasons of variance of GP % can be that Matrixx averages there reference doses, Matrixx's gantry and collimator angles were set at 0 degrees to whole area, besides these Matrixx performs dose distribution by collecting the whole field. Accurate reading of Delta4, reading errors for all areas by performing irradiation at all gentle angles, and precise reading in high dose gradient regions, resulting in a large number of unsuccessful gamma analysis points in the whole volume, so that the gamma penetration percentage is lower than the Matrixx percent obtained causes.

Classifying the cases of patients as brain tumor, head and neck cancer and prostate cancer, the dose validation of IMRT pretreatment applied patients with brain tumor, no difference is seen in GP % between the methods, which are Matrixx, and Delta4. Being size of planned area small and having homogeneous dose distribution is the main reason of the similarity of measurements. Since head and neck and prostate cancer patients have wide and high dose gradient range unlike the brain tumor cases, it was founded that quality assurance (QA) measurements acquired by using two dosimetric methods had a meaningful deviations and GP % accomplished from Delta4 method was lower than Matrixx IMRT method.

As a result of gamma analysis by applied varient 3 mm DTA and %3 dose difference, it was supported statistically that there is significant alteration between two methods. Moreover it should be noted that GP % values of IMRT treatment plan prepared to 30 patients was higher in the Matrixx method. The main reason for the difference is that Delta4 is better able to detect points because it performs more accurate reading at smaller DTA values. It should be pointed that with the decrease in DTA value, gamma-passing rate also decreased.

Conclusion

It was indicated that both Matrixx and Delta4 dosimetric methods work out dosimetric verification of IMRT treatment plan.

Competing interests
The authors declare that they have no competing interest.

Financial Disclosure
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