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Dose Verification With Different Ion Chambers For FFF Energy Plans

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ABSTRACT

Verification of patient plan is very important in stereotactic treatments. VMAT plans were prepared with 6MV-FFF or 10MV-FFF energies for 25 intracranial and extracranial stereotactic patients. Absolute dose was measured for dose verification in each plans. Iba CC01, Iba CC04, Iba CC13 ion chambers placed at a depth of 5cm in solid phantom (RW3). Also we scanned this phantom with ion chambers by Siemens Biograph mCT. QA plans were prepared by transferring twenty five patient plans to phantom assemblies for three ion chambers. All plans were performed separately for three ion chambers at Elekta Versa HD linear accelerator. Statistical analysis of results were made by Wilcoxon signed-rank test. Difference between dose values were determined %1.84±3.4 (p: 0.001) with Iba CC13 ion chamber, %1.80±3.4 (p: 0.002) with Iba CC04 ion chamber and %0.29±4.6 (p: 0.667) with Iba CC01 ion chamber. In stereotactic treatments, dosimetric uncertainty increases in small fields. We determined more accurate results with small sized detectors. Because the inner electrode of the CC01 ion chamber is steel, it leads to perturbation and this effect is further increased in FFF energies. The differences between TPS calculations and CC01, CC04, CC13 ion chambers measurements were determined to be less than 2% on average. Considering both the perturbation effect and the volume effect, the CC04 ion chamber should be used for SRT / SBRT point dose verification.

KEYWORDS;*Patient QA, Ion Chambers SRT/SBRT QA*

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I. INTRODUCTION

The success of the treatment in radiotherapy depends on the accuracy of the implemented radiation dose. Intensity Modulated Radiotherapy (IMRT) and Volumetric Arc Therapy (VMAT) techniques are used to obtain a dose-adjusted dose distribution with small segments [1]. It is implemented by linear accelerator based Stereotactic Radiotherapy (SRT) and Stereotactic Body Radiotherapy (SBRT) treatments using IMRT/VMAT techniques. Flattening Filter Free and non-coplanar beams provide high dose rate and high dose gradients. In SRT/SBRT high dose gradients and healthy tissue protection are provided at maximum level and irradiated with high radiation doses. Conformal dose distribution in the tumor and sharp dose change outside of the target are obtained by using non-coplanar plane and small beams [2,3].

Conventional linear accelerator design incorporates a conical flattening filter (FF) in the beam line to create a beam with a uniform intensity at a specified depth in a patient. In small fields, the dose rate of a flattening filter is limited. Modern linear accelerator have introduced flattening filter free beams, which offer the clinical benefit of a shorter treatment times with higher dose rate. It causes differences in ion recombination with high dose rates in FFF rays [4,5].

Verification of plan is crucial in stereotactic treatments. Verification of plans can be made by 1D, 2D and 3D systems. Point dose verification can be made in Quality Assurence (QA) with 1D. The one-dimensional QA is the comparison of the dose measured in ion centers with the calculated dose at the center of the plan. One-dimensional point dose verification; ion chambers, films and thermoluminescent dosimeter (TLD) dosimetry systems are used [6].

The aim of our work was compare QAs of stereotactic plans for different ion chambers. For quality assurence in SRT / SBRT plans using FFF energy and small areas, the suitability of CC13, CC04 and CC01 ion chambers was investigated.

II. MATERIALS AND METHOD

25 SRT / SBRT patients, 6MV-FFF or 10MV-FFF energy in the non-coplanar plane was prepared using VMAT fields. SRT / SBRT treatments were planned in such a way that the dose drop outside of the target was sharp and the target volume had a dose change of 20-25%. In this way, the target is irradiated with the

prescribed dose, maximum protection is provided in healthy tissue around the target. However, since the dose change is very high in and outside the target volume, it is difficult to detect the dose and dose distribution.

To perform point dose verification, a QA phantom was created by placing the ion chamber at a depth of 5 cm of RW3 solid water equivalent phantoms. The plans were transferred to the QA phantom without changing the collimator and gantry and couch angles. And Monte Carlo was calculated by the dose calculation algorithm The plans were re-calculated without changing any parameters on the slab phantom CT images.

Point dose measurements were measured at 5 cm depth for Iba® (Schwarzenbruck, Germany) CC01, CC04 and CC13 ion chambers at Source skin distance 100 cm. All plans were irradiated in phantom settings which have prepared in Elekta® Versa HD (Elekta Oncology Systems, Crawley, UK) linear accelerator.

Wilcoxon signed-rank test and the results were analyzed statistically. The Wilcoxon signed rank test was used to examine the differences between treatment planning system (TPS) and measurement. A probability value less than 0.05 was considered significantly.

	Full Guarded	**High Uniform Spatial Resolution**	**Cavity Volume (cm3)**	**Cavity Lenght (mm)**	**Cavity Radius (mm)**	**Wall material**	**Wall thickness (g/cm2)**	**Central electrode material**
CC01	X	X	0.01	3.6	1	C552	0.088	Steel
CC04	X	X	0.04	3.6	2	C552	0.07	C552
CC13	X		0.13	5.8	3	C552	0.07	C552

Table 1. Properties of ion chambers

III. RESULT

Dose difference between TPS and Iba CC13 ion chamber was obtained %1,.84±3.4 (p:0.001), with Iba CC04 ion chamber was obtained %1.80±3.4 (p:0.002) and Iba CC01 was obtained %0.29±4.6 (p:0.667).

Patient No		**CC13 Measurement**	**TPS**	**Different %**	**CC04 Measurement**	**TPS**	**Different %**	**CC01 Measurement**	**TPS**	**Different %**
1	**6MV-FFF**	742,0	741,0	0,1	742,0	736,0	0,8	664,0	763,0	-14,9
2	**6MV-FFF**	1286,0	1227,0	4,8	1288,0	1275,0	1,0	1275,0	1194,0	6,4
3	**10MV-FFF**	1370,0	1330,0	3,0	1375,0	1315,0	4,6	1343,0	1244,0	7,4
4	**6MV-FFF**	573,0	550,0	4,2	593,0	550,0	7,8	547,0	527,0	3,7
5	**10MV-FFF**	804,0	775,0	3,7	827,0	800,0	3,4	764,0	731,0	4,3
6	**6MV-FFF**	698,0	685,0	1,9	696,0	679,0	2,5	667,0	678,0	-1,6
7	**6MV-FFF**	1316,0	1282,0	2,7	1318,0	1282,0	2,8	1295,0	1279,0	1,2
8	**10MV-FFF**	1324,0	1301,0	1,8	1328,0	1295,0	2,5	1308,0	1297,0	0,8
9	**6MV-FFF**	1145,0	1096,0	4,5	1130,0	1100,0	2,7	1101,0	1081,0	1,8
10	**10MV-FFF**	1212,0	1200,0	1,0	1217,0	1194,0	1,9	1171,0	1194,0	-2,0
11	**6MV-FFF**	1883,0	1807,0	4,2	1851,0	1880,0	-1,5	1841,0	1773,0	3,7
12	**10MV-FFF**	2059,0	1940,0	6,1	2076,0	1988,0	4,4	2082,0	1964,0	5,7
13	**6MV-FFF**	140,0	148,0	-5,4	141,0	145,0	-2,8	144,0	151,0	-4,9
14	**10MV-FFF**	66,0	74,0	-10,8	68,0	75,0	-9,3	75,0	76,0	-1,3
15	**6MV-FFF**	1189,0	1168,0	1,8	1207,0	1150,0	5,0	1182,0	1159,0	1,9
16	**10MV-FFF**	1217,0	1188,0	2,4	1238,0	1190,0	4,0	1228,0	1184,0	3,6
17	**6MV-FFF**	2487,0	2491,0	-0,2	2606,0	2526,0	3,2	2572,0	2589,0	-0,7
18	**6MV-FFF**	1810,0	1820,0	-0,5	1744,0	1831,0	-4,8	1755,0	1907,0	-8,7
19	**6MV-FFF**	2316,0	2310,0	0,3	2294,0	2266,0	1,2	2186,0	2223,0	-1,7
20	**10MV-FFF**	2486,0	2423,0	2,6	2463,0	2460,0	0,1	2382,0	2413,0	-1,3
21	**6MV-FFF**	1380,0	1404,0	-1,7	1408,0	1407,0	0,1	1380,0	1423,0	-3,1

22	**10MV-FFF**	1390,0	1389,0	0,1	1398,0	1358,0	2,9	1366,0	1376,0	-0,7
23	**6MV-FFF**	566,0	555,0	2,0	575,0	561,0	2,5	561,0	566,0	-0,9
24	**10MV-FFF**	718,0	700,0	2,6	739,0	704,0	5,0	712,0	702,0	1,4
25	**6MV-FFF**	1740,0	1734,0	0,3	1772,0	1757,0	0,9	1761,0	1777,0	-0,9
Average		**1276,7**	**1253,5**	**1,8**	**1283,8**	**1261,0**	**1,8**	**1254,5**	**1250,8**	**0,3**
STD		**647,1**	**637,2**	**3,4**	**649,4**	**644,9**	**3,4**	**642,6**	**644,7**	**4,7**
P		**0.001**			**0.002**			**0.667**		

Table 2. Patient QA results with CC13, CC04 and CC01 ion chambers

Small fields were used in stereotactic implementations and dosimetric uncertainty increased in small fields. Therefore more accurate results were obtained with small sized detectors. An average QA results were determined lower than 2% for each ion chambers. The best average results were determined by CC01 ion chamber but not statistically significant. CC04 and CC13 showed lower differences between TPS and measurements in all patient QA results.

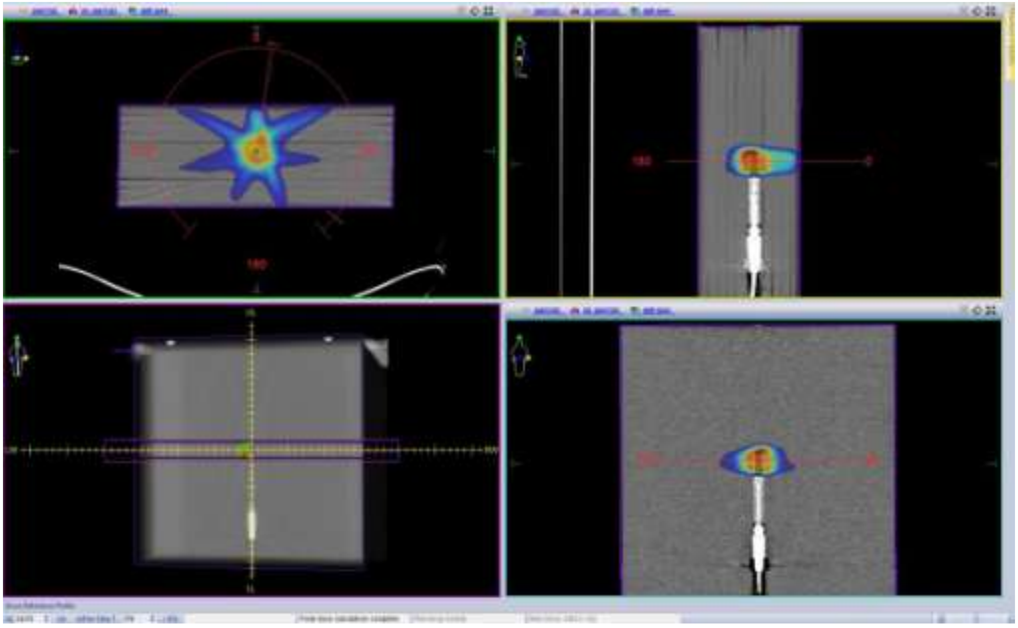

Figure 1. Calculating dose in Monaco TPS

IV. CONCLUSION

QA results were determined similar with CC04 and CC13 ion chambers. Although better results were obtained by CC01, standard deviation value were determined higher. There were obtained statistically significant differences CC04 and CC13 measurements.

Gurjar et al. an average difference were determined 0.65±0.38 by comparing 15 IMRT plans and CC13 ion chamber at slab phantom. In stereotactic treatments high dose gradient plans are perfomed to further reduce the dose around the target, and therefore a non-homogeneous dose distribution occurs within the target. Since there is a non-homogeneous dose distribution in the target, this leads to uncertainty in absolute dose measurements [7].

Fraser et al. were made point dose measurements for QA plans of 50 patients by using ion chamber which has three different volumes with dynamic and step and shoot IMRT techniques in their studies. They have used 0.015 cc Pinpoint, 0.6 cc Farmer and 0.13 cc types of ion chambers. They were determined respectively 5.27%, 3.5% and 3.99% difference between calculated and measured point dose values with 0.015 cc Pinpoint, 0.6 cc and 0.13 cc ion chambers in dynamic IMRT QA plans [8].

An accurate dose delivery is very important to reach successful treatment. Also, specific VMAT plans of the patient needs quality assurance. There are many dosimetric techniques to check accuracy of treatment. Verifying dose at reference point of the plan is important step in dosimetric control technique. Process of verifying point dose should be made before treatment to fix errors. In line with this purpose, QA of 25 (SRS/SBRT) VMAT treatment plans were performed by different ion chambers [9,10,11].

Pulliam et al. In a 6-year period, the 13003 IMRT-VMAT treatment plan performed the absolute dose measurement using Iba CC04 ion chamber and EDR2 film. In plan verifications, they evaluated 5% dose difference-3 mm distance to agreement for films and 3% dose difference criteria for CC04 ion chambers. When all of the 13003 treatment plans were considered; 97.7% of ion chamber measurements and 99.3% of gamma index analysis (EDR2) were valid [12].

Small fields and FFF beams are used for high dose gradient and high dose rate in SRT/SBRT treatments. Detector’s response of ion chambers depends on several factors. For instance; CC13 ion chamber’s resolution and volume are not suitable for small field measurement. Also, CC01 ion chamber’s inner central electrode is steel so this property is bringing uncertainty because of perturbation effect. Especially in FFF energies this perturbation effect is increased even at high dose rates. When we compared three ion chambers, we determined more accurate dose measurement with CC04 ion chambers for SRS/SBRT treatments.

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