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CLINICAL COMMISSIONING AND DOSIMETRIC VERIFICATION OF THE RAYSTATION TREATMENT PLANNING SYSTEM[†]

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Background: The software used by treatment planning systems (TPS) plays an important role for treatments using radiation. The accuracy of the calculated dose in radiation treatments depends on the assumptions made by the TPS. In this study, we summarize our methods and results regarding clinical commissioning of the basic functions needed for photon therapy. Materials and Method: Measurements were obtained for the 6 and 15 MV photon energies obtained from the Siemens Artiste linear accelerator device. Important data such as percent deep dose, profile and output measurements were taken in the water phantom and transferred to the RayStation Treatment Planning System. Results: When the absolute dose values calculated by the RayStation TPS are compared with the water phantom data, the differences obtained are less than 3%. When the 2-dimensional quality control of asymmetrical areas and patients with IMRT plan was controlled by gamma analysis method, the gamma rate was more than 95%. Conclusion: One of the most important quality control tests is TPS acceptance tests, which must be performed before clinical use. In this study, in which we checked the basic dose measurement and patient planning, it was seen that the RayStation TPS can be used in patient treatment for clinical use. The doses calculated by the RayStation TPS were found to be reliable and within the expected accuracy range. These results are sufficient for the application of 3-dimensional conformal radiotherapy (3D-CRT) and IMRT technique.

Keywords: RayStation, Commissioning, Dosimetric Verification
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The software used by treatment planning systems (TPS) plays an important role for treatments using radiation [1]. The accuracy of the calculated dose in radiation treatments depends on the assumptions made by the TPS. In TPS, operations such as defining the target volume, making the treatment plan, determining the treatment areas, and calculating the appropriate Monitor Unit (MU) value are performed. Considering what has been done, it is extremely important to carry out quality controls before TPSs are put into use for clinical use [2,3,4].

The International Atomic Energy Agency (IAEA) has published a report on the quality control of TPSs [5]. In addition, IAEA has also prepared a technical document file numbered TECDOC 1583, which includes practical tests for dosimetric calculations [6]. Reports published by the Association of Physicist in Medicine (AAPM) are also available in the literature [7,8].

RayStation (RaySearch Labs, Stockholm/Sweden) is a good example of advanced TPS. Raysearch laboratories have an important place in the world in the field of advanced software and are the creators of the RayStation TPS for radiation therapy [9]. Studies for the commissioning of TPS models are available in the literature [10,11,12,13].

RayStation is a treatment planning system that has just started to be used in our country. It started to be used in our clinic in 2021. We aimed to check the accuracy of the radiation dose calculations of the RayStation TPS before it is used in the clinic. In this study, we summarize our methods and results regarding clinical commissioning of the basic functions needed for photon therapy.

MATERIALS AND METHODS

In the study, Somatom Sensation 4 (Siemens, Erlangen) device was used for computed tomography images. Measurements were obtained for the 6 and 15 MV photon energies obtained from the Siemens Artiste linear accelerator (Linac) device. IBA Bule Phantom-2 (IBA dosimetry, Schwarzenbruck, Germany) water phantom device was used in the study. The compact ion chambers used in the water phantom are CC04 (13808) (IBA dosimetry, Schwarzenbruck, Germany). All absolute measurements were obtained with DOSE 1 (IBA dosimetry, Schwarzenbruck, Germany) electrometer. PTW OCTAVIUS was used for 2D quality control measurements (PTW, Freiburg, Germany).

For 6 and 15 MV photons, Percent deep dose (PDD) measurements were obtained in field sizes of 2x2 cm^2-40x40 cm^2, on the central axis and at 100 cm source to skin distance (SSD). In addition, profile measurements were taken at maximum dose depth (dmax), 5 cm, 10 cm and 20 cm depths and inplane-crossplane directions.

For 2x2 cm^2-40x40 cm^2 fields, 100 MU irradiation was made at SSD=100 cm, 10 cm depth, and Output measurements were taken for both photon energies and normalized to 10x10 cm^2.

The MLC transmission factor was calculated by irradiating the multi-leaf collimators (MLC) in the closed state while the jaws were open at maximum width.

After all data were transferred to the TPS system, dose measurements at different depths for asymmetrical areas were taken in a water phantom and compared with the doses calculated by the RayStation TPS. In addition, dose

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distribution results obtained in patients planned for Intensity Modulated Radiotherapy (IMRT) and in different asymmetrical areas in TPS were compared with the dose distribution calculated by RayStation's QA module using gamma analysis test. For the gamma index, dose confirmation distance and dose difference criteria were chosen as 3 mm and 3%, respectively[1,14]. Absorbed dose measurements were made according to the IAEA TRS-398 protocol [15].

RESULTS

The 6 MV and 15 MV photon beam data required for the RayStation TPS were measured with the water phantom. Then, the measured beam data was transferred to the RayStation system by normalizing the maximum dose. Figure 1 and Figure 2 show the PDD and profile results measured in the water phantom.

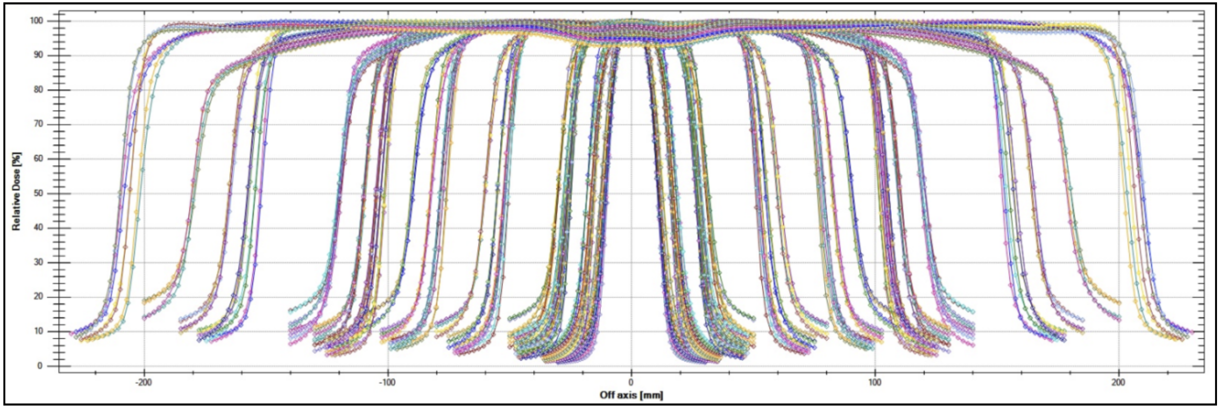

Figure 1. Profile results obtained in the water phantom.

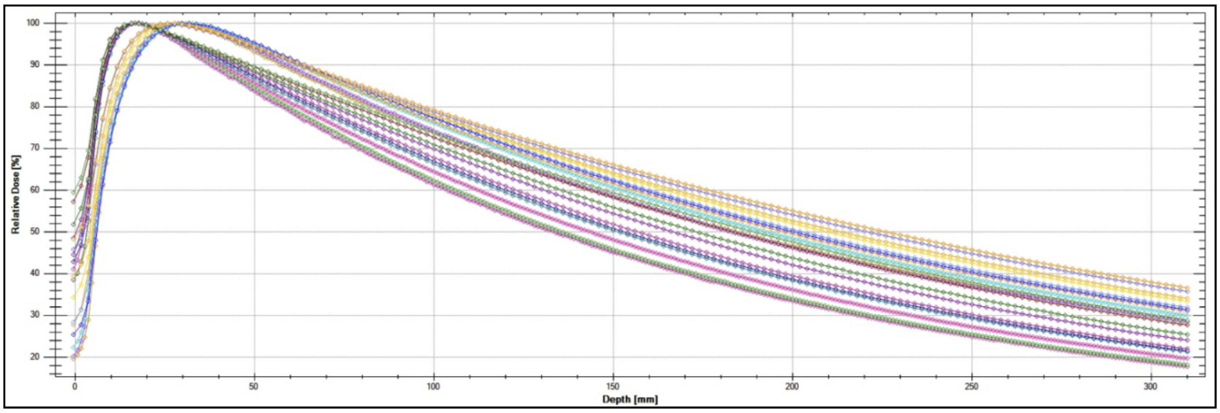

Figure 2. PDD results obtained in the water phantom.

Output values obtained for different fields at a depth of 10 cm and the results normalized to 10x10 cm^2 are shown in Table 1 and Table 2.

Table 1. For 6 MV photon energy, the dose values obtained as a result of 100 MU irradiation in different areas, at a depth of 10 cm, and the ratios normalized to 10x10 cm^2.

Field Size (cm^2)	Detector Model	6 MV				
		1st Measurement (pC)	2nd Measurement (pC)	3rd Measurement (pC)	Average	Ratio
2x2	**CC04**	1661,3	1661,3	1661,3	1661,3	0, 783928
3x3	**CC04**	1764	1764	1764	1764	0, 83239
4x4	**CC04**	1835,8	1835,8	1835,8	1835,8	0, 86627
5x5	**CC04**	1893,6	1893,6	1893,45	1893,55	0, 893521
7x7	**CC04**	2000,1	2000,2	2001,2	2000,5	0, 943988
10x10	**CC04**	2118,2	2119,2	2120,2	2119,2	1
10x20	**CC04**	2220,5	2217,3	2220	2219,267	1, 047219
12x12	**CC04**	2177,1	2176,4	2177,4	2176,967	1, 027259
15x15	**CC04**	2246,9	2244,6	2244,5	2245,333	1, 059519
20x20	**CC04**	2332,7	2331,3	2333	2332,333	1, 100573
20x10	**CC04**	2192,7	2192,7	2193,2	2192,867	1, 034762
25x25	**CC04**	2398,9	2396,1	2395,1	2396,7	1, 130946
30x30	**CC04**	2446	2442,3	2441,3	2443,2	1, 152888
40x40	**CC04**	2497	2498,4	2495,3	2496,9	1, 178228

Table 2. For 15 MV photon energy, the dose values obtained as a result of 100 MU irradiation in different areas, at a depth of 10 cm, and the ratios normalized to 10x10 cm^2.

Field Size (cm^2)	Detector Model	15 MV				
		1st Measurement (pC)	2nd Measurement (pC)	3rd Measurement (pC)	Average	Ratio
2x2	**CC04**	1916,5	1916,5	1916,5	1916,5	0,779086
3x3	**CC04**	2109	2109	2109	2109	0,85734
4x4	**CC04**	2203,5	2203,5	2203,5	2203,5	0,895756
5x5	**CC04**	2272,1	2272,5	2272,2	2272,267	0,923711
7x7	**CC04**	2363,5	2366,6	2364	2364,7	0,961286
10x10	**CC04**	2460	2459,5	2460,3	2459,933	1
10x20	**CC04**	2538,7	2537,4	2538,6	2538,233	1,03183
12x12	**CC04**	2501,7	2501,7	2504,8	2502,733	1,017399
15x15	**CC04**	2555,3	2554,1	2554	2554,467	1,038429
20x20	**CC04**	2617,2	2616,8	2617,7	2617,233	1,063945
20x10	**CC04**	2509,2	2511,8	2511,7	2510,9	1,020719
25x25	**CC04**	2661,9	2661,4	2660,8	2661,367	1,081886
30x30	**CC04**	2696	2698,6	2696,6	2697,067	1,096398
40x40	**CC04**	2734,5	2734,8	2734,4	2734,567	1,111643

After taking measurements in accordance with the IAEA TRS-398 protocol and determining the desired factors in the protocol, absolute dose measurements were taken in different areas and at different points and compared with the dose values obtained in the RayStation system. the differences in percentages are shown in Table 3 and Table 4.

Table 3. For 6 MV photon energy, absolute dose values obtained in RayStation and water phantom as a result of 100 MU irradiation in different areas and at different points.

Field Size (cm^2)	Points X,Y,Z (cm)	RayStation TPS (cGy)	Water Phantom (cGy)	Difference (%)
3x3	(0,1,5)	72,1	70,85	1,73
10x10	(3,-3,8)	73,5	73,96	0,63
15x15	(0,0,5)	89,6	90,16	0,62
20x20	(-3,7,10)	73,4	73,76	0,50
30x30	(5,12,7)	87,4	88,92	1,73
3x5	(0,0,5)	77,4	78,12	0,93
10x5	(0,0,7)	73,4	73,93	0,72
10x20	(1,1,9)	73,9	73,83	0,10
30x15	(5,-3,11)	70,2	71,01	1,16
20x9	(3,0,6)	84	85,18	1,41
30x40	(2,-5,5)	95	96,88	1,9
5x40	(0,-1,9)	69,7	69,77	0,10

Table 4. For 15 MV photon energy, absolute dose values obtained in RayStation and water phantom as a result of 100 MU irradiation in different areas and at different points.

Field Size (cm^2)	Points X,Y,Z (cm)	RayStation TPS (cGy)	Water Phantom (cGy)	Difference (%)
4x4	(0,1,5)	83,5	84,52	1,22
7x7	(1,0,8)	79,3	79,97	0,84
10x10	(3,-3,6)	90,5	91,13	0,70
15x15	(0,0,7)	89,8	90,01	0,23
20x20	(-3,7,7)	91,7	91,93	0,26
30x30	(0,0,5)	100	100,50	0,50
	(5,12,9)	84,9	85,81	1,07
40x40	(0,0,5)	100	100,92	0,92
4x7	(0,0,5)	88,8	89,59	0,89
10x5	(0,0,4)	93,5	93,92	0,45
10x20	(1,1,7)	88	88,82	0,93
30x15	(5,-3,5)	99,5	100,50	1,01
20x9	(3,0,10)	78,6	78,59	0,02
30x40	(2,-5,5)	102,5	103,84	1,31
5x40	(0,-1,12)	69,4	69,70	0,43

Before starting the gamma analysis measurements, a calibration factor for the 2D-array was obtained by irradiating 100 MU in a 10x10 cm^2 area. Comparison of 2-dimensional measurement results was made in 4 different ways.

The images of the 2D-Array, whose computerized tomography was taken, were sent to the RayStation system. In the RayStation system, 20x20 cm^2 area was opened on the 2D-Array images and 100 MU irradiation was made. Then, the MLCs were closed by 2 cm and 100 MU irradiation was performed again. This process was repeated 5 times. The Figure 3 demonstrates gamma analysis results from the comparison between measurement maps and calculated plan maps.

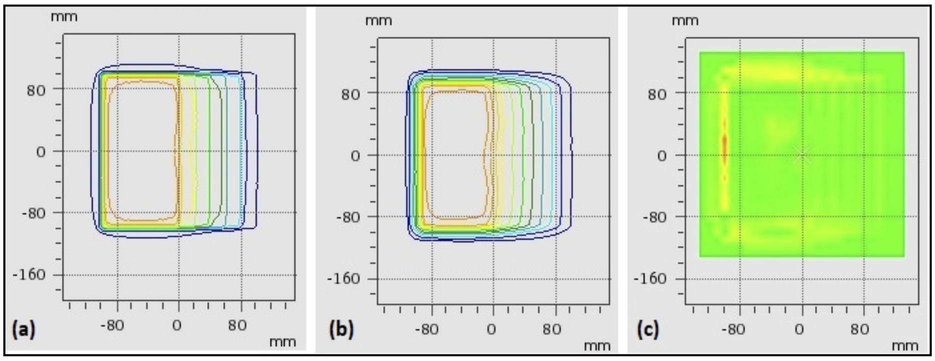

Figure 3. (a) Dose distribution calculated by RayStation; (b) Dose distribution measured by PTW OCTAVIUS; (c) Gamma Index results.

Then, with the help of MLCs, an irregular area was created on the RayStation and this area was controlled in 2 dimensions. The field created on the RayStation TPS and gamma analysis results are shown in Figures 4 and 5, respectively.

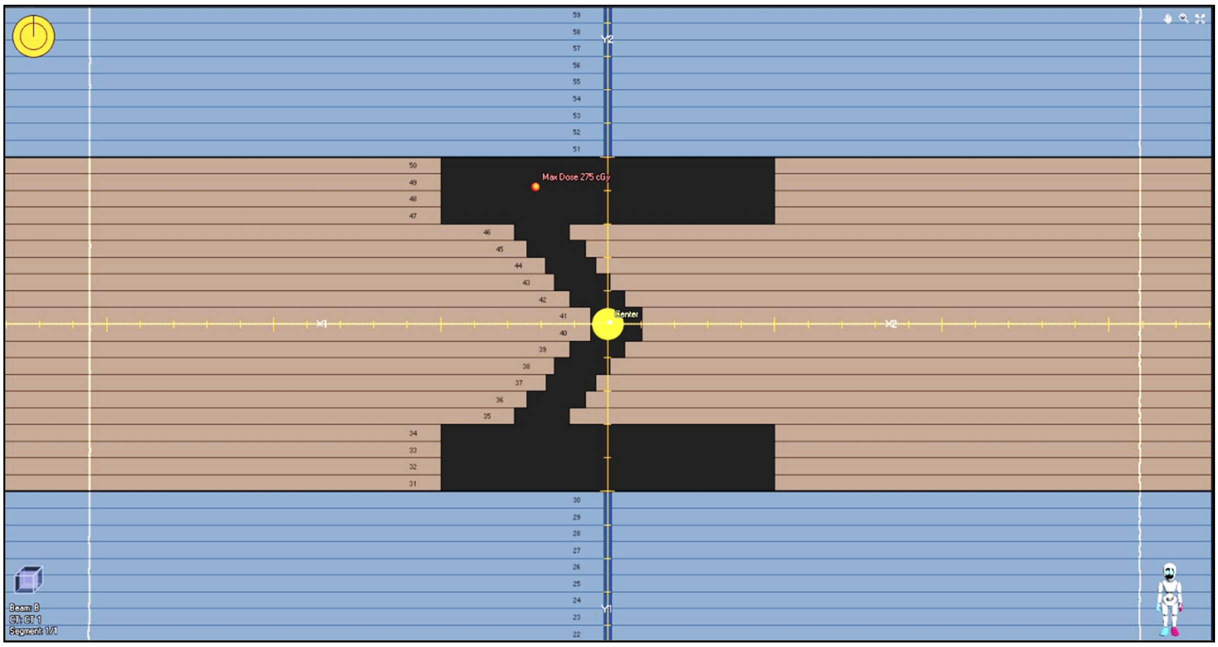

Figure 4. The irregular area created with the help of MLCs in the TPS system.

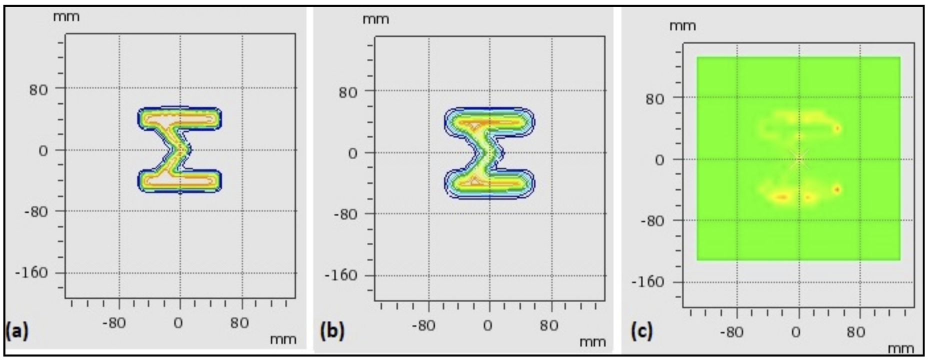

Figure 5. (a) Dose distribution calculated by RayStation; (b) Dose distribution measured by PTW OCTAVIUS; (c) Gamma Index results.

In order to see the effect of MLC leakage and Tongue and Groove effect on planning, MLCs were closed by leaving a gap in the +x direction and 100 MU irradiation was made. Then, the MLCs in the -x direction were closed by leaving a gap and 100 MU irradiation was made. The dose distribution obtained as a result of the irradiation was compared with the gamma analysis method. The fields of MLC created on the RayStation TPS and gamma analysis results are shown in Figures 6 and 7, respectively.

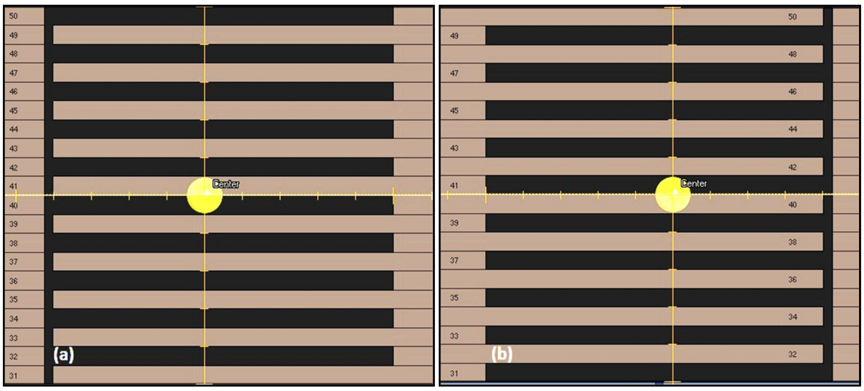

Figure 6. For MLC leakage and Tongue and Groove effect, the fields created with the help of MLCs in the TPS system. (a) The MLC's are in the +x direction. (b) The MLC's are in the -x direction.

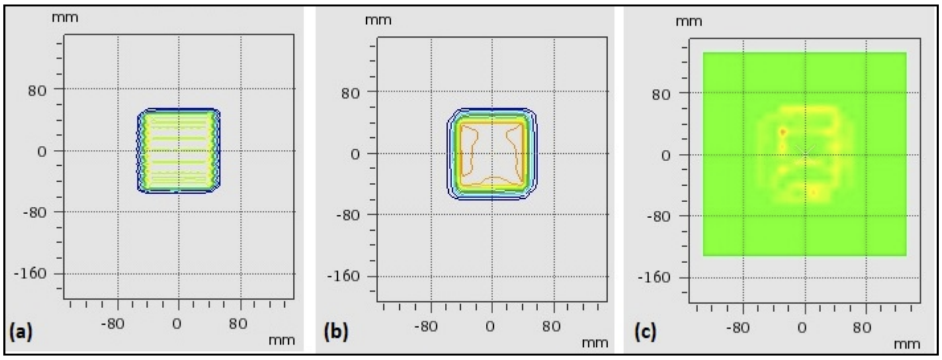

Figure 7. (a) Dose distribution calculated by RayStation; (b) Dose distribution measured by PTW OCTAVIUS; (c) Gamma Index results.

IMRT plans were made with the 9-field Step and Shoot technique for 5 different patients. The plans made were set to have 150 segments. Then, with the help of the QA mode in the RayStation system, the dose distribution created by these patients was obtained and 2-dimensional quality controls were made. The dose distribution obtained for an exemplary patient is shown in Figure 8.

All 2-dimensional dosimetric controls performed have a gamma rate of over 95%.

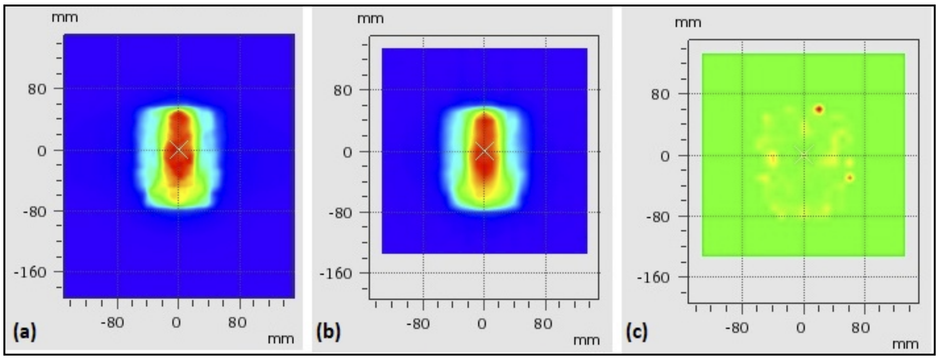

Figure 8. (a) Dose distribution calculated by RayStation; (b) Dose distribution measured by PTW OCTAVIUS; (c) Gamma Index results.

CONCLUSION

One of the most important quality control tests is TPS acceptance tests, which must be performed before clinical use. The necessary data of the Linac device should be measured completely and accurately and transferred to the Treatment planning system. The dosimetric accuracy of the RayStation treatment planning system was investigated for 6 MV and 15 MV beams obtained from the Siemens Artiste Linac. In the study, acceptable differences were observed between the treatment planning system and the measurement results. As a result of the examinations made in homogeneous and heterogeneous environments, it was observed that there was a high level of agreement between the treatment planning system and the measurement data. The difference between the absolute dose data measured and calculated according to the AAPM Task Group 53 should not be more than 3%. In the results we found, the difference was less than 3%. In this study, in which we checked the basic dose measurement and patient planning, it was seen that the RayStation TPS can be used in patient treatment for clinical use. The doses calculated by the RayStation TPS were found to be reliable and within the expected accuracy range. These results are sufficient for the application of 3-dimensional conformal radiotherapy (3D-CRT) and IMRT technique.

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КЛІНІЧНИЙ ПУСК ТА ДОЗИМЕТРИЧНА ПЕРЕВІРКА СИСТЕМИ ПЛАНУВАННЯ ЛІКУВАННЯ ПРОМЕНЕВОЮ СТАНЦІЄЮ

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Програмне забезпечення, яке використовується системами планування лікування (TPS), відіграє важливу роль для лікування з використанням радіації. Точність розрахункової дози при радіаційних обробках залежить від припущень, зроблених TPS. У цьому дослідженні ми підсумовуємо наші методи та результати щодо клінічного введення в дію основних функцій, необхідних для фотонної терапії. Матеріали та метод. Вимірювання проведено для енергій фотонів 6 і 15 МВ, отриманих з лінійного прискорювача Siemens Artiste. Важливі дані, такі як відсоток глибинної дози, профіль та вимірювання виходу, були зроблені у водному фантомі та передані в систему планування обробки RayStation. Результати: Коли абсолютні значення дози, розраховані RayStation TPS, порівнюються з даними водних фантомів, отримані відмінності становлять менше 3%. Коли двовимірний контроль якості асиметричних ділянок та пацієнтів із планом IMRT контролювали методом гамма-аналізу, рівень гамма-потужності становив більше 95%. Висновок: одним з найважливіших тестів контролю якості є приймальні тести TPS, які необхідно виконати перед клінічним використанням. У цьому дослідженні, в якому ми перевірили основне вимірювання дози та планування пацієнта, було виявлено, що RayStation TPS можна використовувати для лікування пацієнтів для клінічного використання. Дози, розраховані за допомогою RayStation TPS, виявилися надійними та в межах очікуваного діапазону точності. Цих результатів достатньо для застосування 3-вимірної конформної променевої терапії (3D-CRT) та техніки IMRT.

Ключові слова: променева станція, введення в експлуатацію, дозиметрична повірка