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DOSIMETRIC COMPARISON OF THE LINEAR ACCELERATORS AT THE UNIVERSITY CLINIC OF RADIOTHERAPY AND ONCOLOGY IN SKOPJE, MACEDONIA

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***Abstract* – In radiotherapy practice, for various practical reasons it is important to know whether two or more linear accelerators (linacs) are dosimetrically matched and whether the patient's treatment can be shifted from one linac to another without reducing the treatment quality. This work presents the data from the dosimetric comparison of the two Varian Clinacs 23EX and one Varian Clinac iX at the University Clinic of Radiotherapy and Oncology in Skopje. Both Percentage Depth Dose (PDD) and Beam Profile (BP) curves were compared for the photon energies (6MV, 15MV) in use at the clinic. The comparison was performed using the IBA OmniPro Accept 7.4™ software. The results from the comparison of the PDD curves showed that in the clinically significant region the dose differences were smaller than 1%. The results from the comparison of the inline and crossline BP curves showed that in the flattened area the dose differences were smaller than 2.5%, while in the penumbra region they were usually between 2% and 8%, but sometimes up to 21%. This suggests that for treatments where the influence of the penumbra region is small, the three linacs may be considered to be dosimetrically matched. For treatments where the influence of the penumbra region is greater, the patient can be switched to another machine only after recalculation of the treatment plan.**

***Keywords* – Linac matching**

1. INTRODUCTION

At the University Clinic of Radiotherapy and Oncology in Skopje three linear accelerators (linacs) are in clinical use: two Varian 23EX Clinacs, in use since 2004 (S/N 356 and S/N 357), and one Varian iX Clinac, in use from 2013 (S/N 5052). Occasionally, one of the linacs is out of use (in case of regular or interventional service) and the patient's treatments cannot be performed on the dedicated linac. Therefore it is useful to know how big the dosimetrical differences between the linacs are. If the differences are small, we can consider them as dosimetrically matched and we can incidentally switch the patients from one linac to another without reducing the quality of their treatment.

2. MATERIALS AND METHODS

During the commissioning of the linacs for clinical use, the Percentage Depth Dose (PDD) curves and the Beam Profile (BP) curves were measured [1, 2] with ionization chamber in water. In this work we compared these curves for all three linacs, for both photon energies used (6MV and 15MV). The comparison was performed with the IBA OmniPro Accept 7.4™ software [3]. The comparison was performed in pairs - linac 356 vs. linac 357, linac 356 vs. linac 5052 and linac 357 vs. linac 5052.

2.1. Comparison of the PDD curves

The measurements of the PDD curves were performed by using an ionization chamber in water phantom, starting from chamber depth of 300 mm all the way to the water surface. The PDD curves were measured for square fields with size varying between 30x30 mm^2 and 400x400 mm^2. The curves were normalized at the depth of the dose maximum. The comparison of the curves was performed by subtracting the two curves (subtracting the relative dose reading of the two curves for each depth), thus obtaining a new curve called "evaluation" curve – dose difference vs. depth (Fig.1).

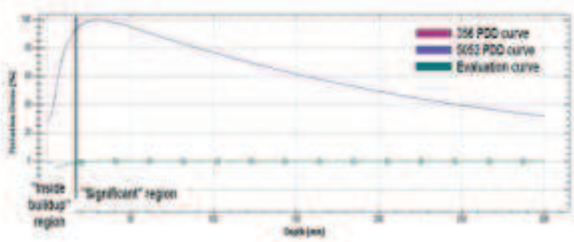

Fig. 1 - Comparison of two PDD curves with representation of the reporting regions

In most cases, the evaluation curve had two regions. In the first region, starting from the water surface to a certain depth (which is always inside the buildup region of the PDD curves) the dose difference was greater, while after this depth the dose difference was smaller and more stable. In this work the first region is called the "inside buildup" (IB) region, while the second region, which has much greater clinical significance, is called the "significant" region (Fig.1). When reporting the results, the maximum dose difference in the corresponding region for every measured field size was reported, as well as the depth of the "region meeting point" d_{rmp}(mm) – the depth where the IB region ends and the "significant" region begins.

2.2. Comparison of the BP curves

The BP curve gives the relative dose measured in a plane orthogonal to the central axis (CAX) of the beam and is a function relative dose vs. distance from the CAX. The BP curves were normalized to the dose at the central axis. In each plane two BP curves were measured - inline and crossline curve. The inline curve was measured in direction gantry-table, while the crossline curve was measured in direction orthogonal to the inline curve direction. The BP curves were measured for square fields with different field sizes (12 field sizes varying between 30x30 mm^2 and 400x400 mm^2 at five different depths in water (d_{max}, 50 mm, 100 mm, 200 mm and 300 mm)

The comparison of the BP curves was done by subtracting the two corresponding curves from the two linacs that were compared (subtracting the relative dose reading of the corresponding inline/crossline curves for each CAX distance), thus obtaining a new curve called "evaluation" curve – dose difference vs. CAX distance (Fig.2). This curve was evaluated in two regions - the flattened area and the 20%-region.

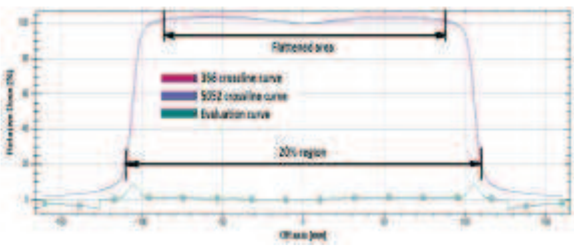

Fig. 2- Comparison of two BP curves with representation of the reporting regions

The flattened area is defined by using the field width (FW) parameter (Fig.3). The field width is determined as the distance between the two points on the profile curve where the dose is 50% of the dose at the CAX (Fig.3). The flattened area is determined as FW minus 2 cm for fields smaller than 10 cm and 0,8*FW for fields ≥ 10 cm.

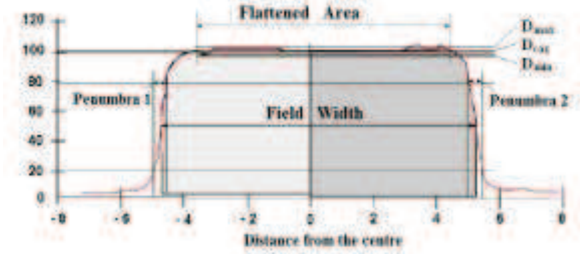

Fig. 3 – Definition of flattened area of a beam profile

The 20%-region is defined as the part of the profile curve where the dose is ≥ 20% of the CAX dose. By reporting both the differences in the flattened area and in the 20%-region we are actually reporting the dose inside the flattened area and outside of it, i.e. inside the penumbra region.

3. RESULTS

3.1. Comparison of the PDD curves

The results from the comparison of the PDD curves are given in Tables 1, 2 and 3 for the pairs 356 vs. 357, 356 vs. 5052 and 357 vs. 5052 respectively.

Table 1. Comparison of the PDD curves for different field sizes, 356 vs. 357 for 6 MV and 15 MV photons

	Maximum dose differences 356 vs. 357, for 6MV			Maximum dose differences 356 vs. 357, for 15MV		
Square field size (mm)	IB region (%)	Significant region (%)	d_{rmp} (mm)	IB region (%)	Significant region (%)	d_{rmp} (mm)
30	1.9	0.4	11	4	0.8	17
40	3	0.5	11	3.5	0.7	20
60	2.7	0.5	11	3.4	0.6	20
80	2.3	0.4	13	3	0.5	25
100	0.5	0.3	5	0.5	0.5	0
120	0.9	0.3	6	0.4	0.4	0
150	0.8	0.4	7	0.8	0.4	15
200	0.6	0.6	0	2	0.4	20
250	2.1	0.5	9	2	0.5	12
300	1.2	0.4	8	2	0.6	13
350	1.4	0.5	8	1.6	0.7	11
400	1.1	0.4	7	2.2	0.6	11

Table 2. Comparison of the PDD curves for different field sizes, 356 vs. 5052 for 6 MV and 15 MV photons

	Maximum dose differences 356 vs. 5052, for 6MV			Maximum dose differences 356 vs. 5052, for 15MV		
Square field size (mm)	IB region (%)	Significant region (%)	d_{rmp} (mm)	IB region (%)	Significant region (%)	d_{rmp} (mm)
30	1.8	0.6	9	4.3	0.8	18
40	1.2	0.5	9	3.4	1	18
60	0.6	0.3	6	2.5	0.8	18
80	1.3	0.5	9	4.5	0.9	18
100	2.1	0.4	9	1.2	0.4	4
120	1.9	0.5	9	0.8	0.5	7
150	2.2	0.5	10	0.8	0.5	15
200	1.4	0.4	8	1.6	0.3	16
250	0.9	0.5	7	1.2	0.4	13
300	0.9	0.5	3	1	0.5	12
350	0.6	0.6	0	3.3	0.6	15
400	0.8	0.8	0	4	0.5	18

Table 3. Comparison of the PDD curves for different field sizes, 357 vs. 5052 for 6 MV and 15 MV photons

	Maximum dose differences 357 vs. 5052, for 6MV			Maximum dose differences 357 vs. 5052, for 15MV		
Square field size (mm)	IB region (%)	Significant region (%)	d_{rmp} (mm)	IB region (%)	Significant region (%)	d_{rmp} (mm)
30	1.4	0.6	4	0.7	0.6	3
40	2.7	0.4	10	1	0.6	4
60	2.9	0.4	10	1.5	0.6	9
80	2.1	0.6	8	1.6	0.5	11
100	2.6	0.4	8	1.2	0.6	4
120	2.7	0.4	10	0.8	0.5	3
150	2.8	0.4	10	1	0.3	3
200	2	0.5	7	1.1	0.5	4
250	2	0.5	8	1.4	0.4	9
300	2	0.5	8	1.3	0.5	10
350	1.8	0.6	8	1.8	0.6	11
400	1.5	0.7	6	1.9	0.6	13

From the results presented in Tables 1, 2 and 3, it can be seen that, as expected, the maximum dose differences between the PDD curves in the IB region were found to be bigger than the ones in the "significant" region. In the IB region for 6 MV, for all three pairs of linacs, the maximum dose differences were found to be smaller than 3% and for 15 MV smaller than 4,5%. It can be seen that for 15 MV, in the IB region, the maximum dose differences between 357 and 5052 are much better than in the other two cases and are smaller than 2%.

The clinically more important part of the comparison, the comparison in the "significant" region, showed that, for all cases, the maximum dose differences in this region are smaller than 1%, which justifies considering all three linacs dosimetrically matched, at least when considering the PDD curves, i.e. the nominal energies of the linacs.

3.2. Comparison of the BP curves

The results from the comparison of the BP curves are given in Table 4. When comparing the linac pairs, each comparison was made for 12 field sizes at 5 different measurement depths, for both inline and crossline profiles (all the measured profiles during the commissioning of the linacs). That amounts to 240 evaluation curves per linac pair. Because of the large amount of data, the results are reported as range intervals in which the maximum dose differences for different field sizes and measurement depths lie.

Table 4. Comparison of the BP curves, range intervals for all field sizes and measurement depths

	Range of maximum dose difference (%) for different field sizes and measurement depths	
	flattened area	20%-region
356 vs. 357, 6 MV, inline	0.2 - 1.6	0.9 - 6.5
356 vs. 357, 6 MV, crossline	0.3 - 2.3	0.8 - 20.7
356 vs. 357, 15 MV, inline	0.4 - 1.4	0.8 - 5.2
356 vs. 357, 15 MV, crossline	0.3 - 1.8	0.2 - 20.7
356 vs. 5052, 6 MV, inline	0.2 - 1.3	1.8 - 11.3
356 vs. 5052, 6 MV, crossline	0.4 - 1.4	0.8 - 15.6
356 vs. 5052, 15 MV, inline	0.3 - 2.4	1.5 - 10.1
356 vs. 5052, 15 MV, crossline	0.2 - 2.1	1.0 - 15.2
357 vs. 5052, 6 MV, inline	0.2 - 1.3	1.0 - 7.2
357 vs. 5052, 6 MV, crossline	0.2 - 1.8	1.6 - 13.8
357 vs. 5052, 15 MV, inline	0.2 - 1.8	1.3 - 7.7
357 vs. 5052, 15 MV, crossline	0.2 - 1.6	2.1 - 9.8

From the results presented in Table 4, it can be seen that the maximum dose differences, when comparing the BP curves for the different linacs, in the flattened area were found to be smaller than 2.5%, while for the 20%-region, the maximum differences were much bigger, usually between 2% and 8%, but sometimes up to 21%.

It must be stressed that in the flattened area the values for the maximum dose difference were almost always smaller than 1.5% for 6 MV photons and 2% for 15 MV photons. Only for small number of BP curve pairs, the values were between 2% and 2.5%. These curve pairs were mostly inline BP curve pairs from the comparison of linac 356 vs. 5052, for 15 MV.

These results suggest that the three linacs can be considered dosimetrically matched, when irradiating patients with techniques where the influence of the penumbra region is of small importance. This would imply that patients treated with a 3D CRT may incidentally be switched from one to another linac, without recalculation of the treatment plan. However, for patients treated with more advanced techniques (like IMRT), the treatment plans need to be recalculated before transferring the patients to another linac.

4. CONCLUSION

The results presented above show that when comparing the PDD curves of the three linacs, in the clinically significant region, the maximum dose differences were found to be smaller than 1%. For the buildup region, the maximum dose differences go up to 3% for 6 MV and 4.5 % for 15 MV photons, but the clinical significance of these results is much smaller.

When comparing the BP curves, in the flattened area which is clinically most significant, the maximum dose differences were always found to be smaller than 2.5%, and in most cases even smaller than 1.5% for 6 MV beams and 2% for 15 MV beams. Outside the flattened area, i.e. in the penumbra region, the maximum dose differences were found to be bigger – in most cases are between 2% and 8%, but sometimes go up to 21%.

From these results, it can be concluded that for the treatment of patients with techniques where the influence of the penumbra region is of small importance, the three linacs can be considered dosimetrically matched. Therefore, for patients treated with a 3D CRT, in incidental situations, the treatment can safely be transferred to another linac without recalculation. For more advanced treatments like IMRT treatments, where the influence of the penumbra region is more important, the patient should be treated on the dedicated linac, or when switching to another linac is necessary, the treatment plan should be recalculated.

5. REFERENCES

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