Original article

The consistency of Fletcher-Suit applicator geometry and of the rectal probe's position in high dose rate brachytherapy treatment fraction of cervix carcinoma

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Abstract

Purpose: The dose values computed with the treatment planning system and the in vivo dose measurements with semiconductor detectors in rectum during the high dose rate brachytherapy treatment fraction of the cervix carcinoma are occasionally significantly different. We've investigated the consistency of the Fletcher-Suit applicator geometry and the in vivo rectal probe's position stability during the high dose rate brachytherapy treatment fraction.

Material and methods: The patient lied in a lithotomic position during a biplane reconstruction images, throughout the treatment planning and dose administration. We obtained post-treatment reconstruction images and prepared a post-treatment plan. The amount of 14 treatment fractions of 10 patients were considered in the study. Two methods were applied: evaluation of the difference of reconstructed pre-treatment and post-treatment applicator points and rectal probe's detectors being relevant to the co-ordinate system fixed to the applicator, and estimation of applicators and rectal probe's reallocation with respect to the pelvic bones with registration of pre- and post-treatment reconstruction images.

Results: We've experienced good consistency in the Fletcher-Suit applicator geometry in all treatment fractions. 70% of them presented small variation in the rectal probe's position, while the rest showed significant shift in the applicator or rectal probe's position with regard to the pelvic bones.

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Key words: Fletcher-Suit applicator, in vivo detector.

Purpose

For the estimation of the late complications of radiotherapy treatment in cervix cancer patients, the volume of a dose delivered to the organs at risk is significant. With regards to the computation of dose to points or volumes of organs at risk, in vivo dose measurements were performed with semiconductor detectors or with thermoluminescence dosimetry [1-3]. The accuracy of dose measurements with semiconductor detectors is influenced by several factors, such as: angular change in sensitivity of the diode, the temperature dependence [4], the change of sensitivity as a function of depth, the change in calibration factor, a dose/dose rate dependence [5], the energy dependence and variation of sensibility with accumulated dose. Additionally, the high gradient in dose distribution near brachytherapy applicator resulted in a large difference between computed and measured dose values which was probably due to a movement of a probe during the treatment fraction [6]. The aim of our investigation was to check the consistency of the Fletcher-Suit (FS) applicator geometry and the stability of position of the rectal probe's during the course of brachytherapy treatment fraction.

Material and methods

We considered 14 treatment fractions of 10 patients treated with the Fletcher-Suit applicator with 15 degrees tandem (Nucletron®, Netherlands). Oval ovoid's spacers of the same form and dimensions (round or D-profile) were applied for each treatment fraction. The in vivo dose measurements were performed with five-channel rectal probe (PTW, Germany). We inserted radio-opaque markers spaced 1 cm into the applicator and obtained post-anterior (PA) and posterior oblique (PO) reconstruction images.

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The possible applicator displacement was avoided due to transportation of the patient and *in situ* images in brachytherapy treatment room were acquired with the use of C-arm (Mobilgil AR7®, Giraldoni, Italy). The video signal from the C-arms monitor was recorded [7] and treatment plans with dicomized images using PLATO Brachytherapy Treatment Planning System (BPS) v13.7 (Nucletron®) were prepared. The dose distribution was normalized to the ICRU Report 38 reference points (A) and 7 Gy dose per fraction was administered. The patient lied in a lithotomic position during the treatment planning and dose administration. Pairs of post-treatment reconstruction images were obtained and a new treatment plan was prepared. The post-treatment images were acquired with the same reconstruction angles as the pre-treatment images, but with a slight difference in magnification and in the position of the central beam axis of the applicator. For comparison of corresponding images, we registered them with a landmark that initiated a mutual information registration method. Due to lack of applicator shift of the bony structures, the registered images showed both the FS applicator and the pelvis bones overlap, whereas in case of applicator movement, the bony structures appeared shifted. We estimated the extent of the shift with the radio-opaque markers spaced 1 cm in a horizontal position. For checking the relative position of the tandem and the ovoid's, we estimated the reconstructed three – dimensional pre- and post-treatment coordinates of the first, the 7th radio-opaque markers inserted into the tandem, the second markers from the ovoid's tip and the coordinates of the rectal probe's detectors.

Results

The time stamp of the pre- and post-treatment reconstruction images differed between 25 and 50 minutes, the average 34 minutes. In all treatment fractions a good match in reconstructed pre- and post-treatment coordinates of the first and the 7th tandem markers and in the ovoid markers were experienced. The average three-dimensional difference in marker coordinates was 1.6 ±1.2 mm, while for the rectal probe's detectors was 8 ±6 mm. Based on the evaluation of the registered pre- and post-treatment reconstruction images, we separated the treatment fractions into two groups (Table 1). In Group A, on the pre- and

Table 1. Three-dimensional (3D) difference in coordinates of the first and the seventh radio-opaque markers inserted into the tandem, and the second marker inserted into the left and right ovoid, and the rectal probe's detectors obtained with pre- and post-treatment plans. The difference of dose values to the rectal probe's detectors computed by BPS in percentage of the reference dose (7Gy) to the ICRU points 'A'. Based on the evaluation of registered pre- and post-treatment reconstruction images, the insertion administered within Group A showed no shift of the FS applicator with respect to the pelvic bones, while insertions from Group B, the post treatment reconstruction images showed a shift in the rectal probe's or in applicator position

Patient #. Treatment Fraction	3D difference (mm) Tandem 1st marker	Tandem 7th marker	Ovoid #1	Ovoid #2	Detector #1	#2	#3	#4	#5		Difference of computed post- and pre-treatment dose to detector To detector #1	#2	#3	#4	#5	(minutes)
1.1	1.2	1.4	0.6	0.4	9.9	8.3	8.3	7.4	7.2		−6.0	−11.0	−15.0	−14.0	−8.0	26
1.2	3.1	1.3	2.6	1.6	9.7	8.7	8.5	8.5	7.8		2.0	2.0	1.0	0.0	2.0	40
1.3	2.0	2.1	1.2	0.8		8.5	7.7	8.3	6.9		−2.0	0.0	0.0	1.0	2.0	27
2.1	0.1	0.9	0.6	1.0	9.5	6.7	5.0	10.8	3.3		−3.4	−5.0	−0.1	1.1	−14.4	33
2.2	0.6	0.9	1.0	2.0	3.8	2.6	1.7	1.9	3.4	A	−3.0	1.0	−2.0	−2.0	−4.0	32
3.1	3.1	1.7	2.1	3.4		7.5	3.7	6.0	4.6			5.0	5.0	3.0	−1.0	25
4.2	0.5	0.8	2.1	0.7	5.3	3.5	8.1	7.4			−4.0	−6.0	−5.0	−4.0		36
5.1	1.3	0.6	1.7	2.2	6.1	5.5	6.0				−2.9	2.5	2.8	3.6	6.0	41
							Average		6.5				Average		−2	
							St. dev.		2.4				St. dev.		5.3	
6.1	1.0	1.1	0.4	1.0	3.5	3.8	4.1				−6.8	−15.0	−13.6			28
4.1	2.6	0.3	0.8	2.2	8.0	15.0	10.7	9.0	4.4		−10.0	−9.0	−9.0	−8.0		32
7.1	2.2	1.0	3.0	2.7			18.1	11.0	9.2				8.3	15.1	35.4	53
8.1	4.0	1.4	2.0	2.1	26.2	31.7	19.5	10.7		B	−1	0.0	6.0	10.0	15.0	32
9.1	2.1	1.3	1.3	2.0	0.9	1.3	1.1	0.9				0.0	1.0	4.0	4.0	32
10.1	1.3	2.4	1.9	1.0	11.0	6.9	3.5				4	1.6	0.4			32
			Average	1.6			Average		10.0				Average		1.5	Average 34
			St. dev.	1.1			St. dev.		8.0				St. dev.		11.0	

post-treatment reconstruction images the bony structures showed good match, and the shift in rectal probe's position was smaller than 5 mm. The difference in reconstructed three-dimensional coordinates of pre- and post- treatment position of the rectal probe's detectors was in average 6.5 ±2.4 mm. The standard deviation of computed dose to points of the semiconductor detectors was 5% of the reference dose (7 Gy). These values for insertions with a shift larger than 5 mm (Group B) were 10 ±9 mm and 11%, respectively.

Discussion and Conclusion

The lateral and sagittal position of the ovoid's with regard to the tandem showed good consistency during brachytherapy treatment fraction. These parameters contain the main influence on the FS applicators dose distribution [8]. The three-dimensional difference of pre- and post-treatment applicator coordinates were within the error of reconstruction accuracy, comparing to those of larger extent in rectal probe's semiconductor detectors. Despite the same position of a patient during the whole treatment, some significant applicator or rectal probe displacement with respect to bony structures were experienced during 30% of treatment fractions. In case of a difference bigger than 5% between the dose values at points of the semiconductor detectors computed by the treatment planning system and the readout from in vivo detectors, the applicator and rectal probe position with post-treatment reconstruction images was verified.

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