Original article
UDC: 618.146-006:616.351-006:615.849.1:577.2

Rectal dosimetry in intracavitary applications of cervix carcinoma: Comparison of two methods

Milutin BAUCAL
Jovan BABIĆ
Zoran KUZMANOVIĆ

BACKGROUND: *Brachytherapy of cervix carcinoma often results in high doses to surrounding structures, such as rectum and bladder. Therefore, these organs should be closely monitored. Purpose of this work was to evaluate rectal marker made in our institution for rectal dose measurements by comparing it with the method recommended in ICRU (International Commission on Radiation Units and Measurements) Report 38.*

METHODS: *In this work rectal dosimetry was performed by two different methods. In one, rectal marker made in Institute of Oncology Sremska Kamenica was used, while in the other method recommended in ICRU Report 38 dose on ICRU rectal point was measured. A total of 34 applications using Microselectron HDR and its standard applicator set were performed in a prospective way. The prescribed dose was 7.6 Gy to point A for each application. Rectal doses were calculated by Nucletron Plato Treatment Planning System.*

RESULTS: *Differences found between the means of ICRU point R and rectal marker points R_{ref} and R_{max} were significant ($P<0.002$ and $P<0.00002$). The same result was obtained for R_{ref} and R_{max} pair ($P<0.003$).*

CONCLUSION: *Maximal doses obtained using rectal marker were in most cases higher than those obtained by ICRU method. It conforms well to several CT-based dosimetry studies where rectum dose was found to be higher from that obtained by ICRU method.*

KEY WORDS: *Cervix neoplasms; Brachytherapy; Radiotherapy Planning, Computer-assisted; Rectum*

INSTITUTE OF ONCOLOGY SREMSKA KAMENICA, YUGOSLAVIA

Archive of Oncology 2002,10(4):253-259©2002,Institute of Oncology Sremska Kamenica, Yugoslavia

INTRODUCTION

Brachytherapy of cervix carcinoma often results in high doses to surrounding structures, such as rectum and bladder. Therefore, these organs should be closely monitored. The late complications manifesting on these organs as a result of radiotherapy can lower the therapeutic ratio and significantly decrease patient quality of life. The most important treatment related factors that could lead to creation of late complications on rectum include total dose to the rectum, volume of irradiated rectum and dose rate of brachytherapy modality used (1-4). Of those, particularly important is the brachytherapy dose delivered to the rectum. All said adds to significance of proper definition of the reference points and the dosimetric methods used in intracavitary brachytherapy (IBT) in predicting the probability of late effects and in making comparative analyses. The International Commission on Radiation Units and Measurements (ICRU), in Report No. 38 (5), came out with certain recommendations for reporting the intracavitary treatment of carcinoma of the cervix. Apart from introducing the concept of reference volume and use of air kerma for source specification, the report also recommended standard definitions for reference points for critical organs like bladder and rectum. In ICRU method the posterior vaginal wall is visualized by means of an intravaginal mould or radio-opaque gauze. The rectal reference point is determined on a lateral radiograph, on antero-posterior (AP) line drawn through either the lower end of the intrauterine source or through the middle of the intravaginal

Address correspondence to:
Milutin Baucal (Radiation physicist), Institute of Oncology Sremska Kamenica, Novi Sad Institutski put 4, 21204 Sremska Kamenica E-mail: baucal@eunet.yu

The manuscript was received: 10. 09. 2002.

Provisionally accepted: 20. 09. 2002.

Accepted for publication: 11. 10. 2002.

© 2002, Institute of Oncology Sremska Kamenica,Yugoslavia

sources, 5 mm behind the posterior vaginal wall. It means that according to these recommendations, rectal reference point is determined by indirect marking (i.e. not using marking of the rectum itself). Different radiotherapy centers use various methods in order to determine absorbed dose on the anterior rectal wall, which is the most exposed part of the rectum. The most frequent techniques used for that purpose are:

* Recommended ICRU method
* *In vivo* dosimetry (i.e. measurement of absorbed dose in rectum during IBT treatment)
* Injection of contrast and air combination directly into rectum
* CT based dosimetry
* Use of rectal marker

Purpose of this work was to evaluate rectal marker made in our institution for rectal dose measurements by comparing it with the method recommended in ICRU Report 38.

MATERIALS AND METHODS

The study was carried out in a prospective way and total of 34 applications using Microselectron HDR and its standard applicator set were performed. The prescribed dose was 7.6 Gy to point A for each application. Stages Ib2-IVa were treated with radical irradiation (external beam irradiation and HDR brachytherapy) and without hysterectomy. Patients received external beam irradiation using 10 MV or 15 MV photons to a dose of 50 Gy in 30 fractions over a 6 weeks period. Of these, the first 20 Gy in 10 fractions were given with open fields and the remaining 30 Gy in 20 fractions were given with a midline block. Size of the field was determined individually according to the stage and patient anatomy. Brachytherapy part of the treatment was consisted of 5 HDR weekly fractions of 7.6 Gy to point A. IBT treatment was carried out on Microselectron HDR which uses ^{192}Ir as radioactive source. Activity of the source was in the range of 4-10 Ci in all 34 applications administered. Standard applicator set consists of a tandem (15°, 30° and 45°) and two ovoids (15, 20 or 25 mm in diameter). Rectal mucosa was marked using rectal marker made in Radiotherapy Department of the Institute of Oncology, Sremska Kamenica, while posterior vaginal wall was marked by means of intravaginal radio-opaque gauze. IBT treatment planning was performed on Nucletron - PLATO TPS for each insertion, based on AP and lateral orthogonal radiographs. Rectal doses were calculated using 13.7 version of Nucletron's - PLATO HDR Microselectron treatment planning software.

Rectal marker (Figure 1) used in this study consists of flexible plastic tube (b) (25 cm length, 7 mm diameter) on which one end, rubber balloon is attached (a) (8-10 cm length) while on the other, small faucet is mounted (c). Interior wall of the balloon is

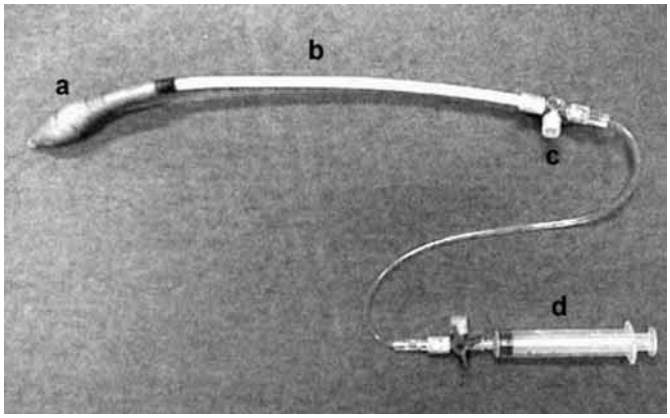

Figure 1. Rectal marker made in Institute of Oncology - Sremska Kamenica. a) Rubber balloon (8-10 cm length). b) Flexible plastic tube (25 cm length, 7 mm diameter). c) Small faucet. d) Syringe

impregnated by barium salt emulsion for the purpose of visualization of rectum. After insertion of the marker into the rectum the balloon is filled with 10 to 20 cm^3 of air using syringe (d), and faucet is closed. Posterior vaginal wall was also visualized by packing vagina with radio-opaque gauze in order to be able to use ICRU method of rectum wall dose determination. During treatment planning, 5 to 10 representative points at the anterior rectal wall were selected (at a distance of 3.5 mm one from another) on lateral radiography. The points are selected symmetrically in relation to the anteroposterior line passing through the middle of the intravaginal sources (on lateral radiography), at the same time touching the surface of the rectal marker balloon (Figure 2).

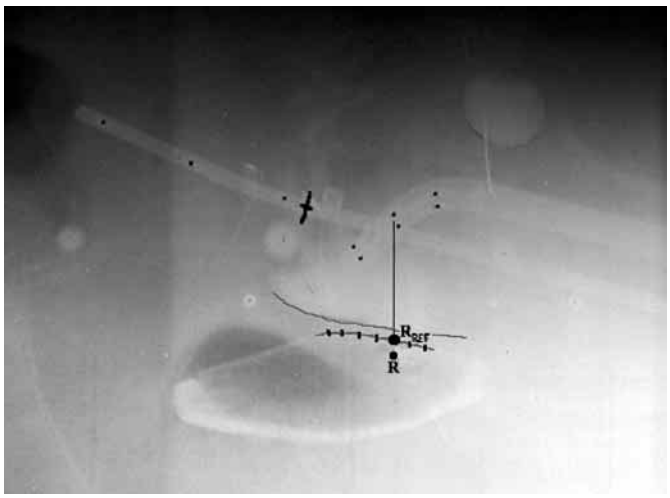

Figure 2. Lateral radiograph where rectal marker reference point (R_{ref}) and ICRU rectal reference point (R) could be seen

On AP radiography, rectal marker reference points are set along the mid caudo-cephalad line on the rectal marker balloon (Figure 3). Rectal marker points were placed densely in order to better estimate change of dose on them and to improve representation of rectal volume occupied by potentially unacceptable dose. ICRU rectal point (R) is set on AP radiography in the middle position,

© 2002, Institute of Oncology Sremska Kamenica,Yugoslavia

between two ovoids. Marker reference point (R_{ref}) always lied at the anteroposterior line drawn from the middle of intravaginal sources and crossing the marker. On the same line also lied ICRU rectal reference point R (Figures 2,3).

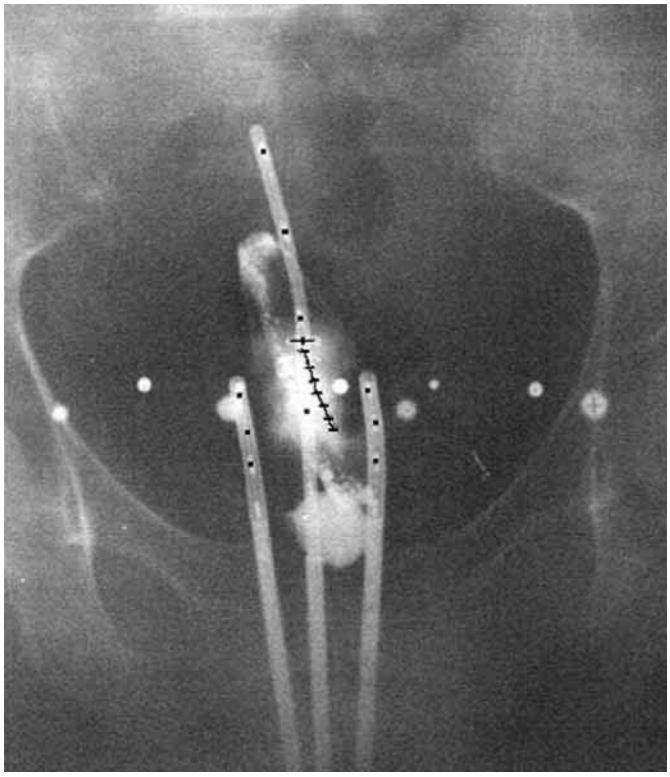

Figure 3. AP view where Standard Applicator set (tandem and two ovoids), rectal marker, radio-opaque gauze and Foley balloon are visualized

Dose on marker point (R_{ref}) was compared with ICRU rectal reference point (R). Point on marker that received maximal dose (R_{max}) was also compared with R (Figures 4,5). Some other conclusions were also drawn up on the basis of gathered data.

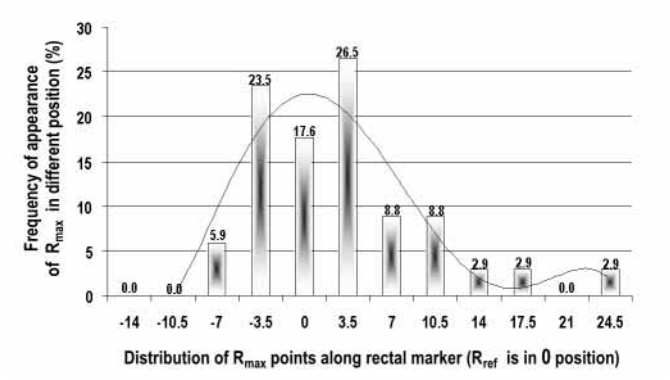

Figure 4. Distribution of maximal doses (R_{max}) along the rectal marker measured positions expressed in %. Trend line is also included

Reconstruction method of PLATO software package allows very accurate determination of the rectal reference points on lateral radiography (order of magnitude 1 mm), using and comparing their common coordinates on the AP radiography. Anterior rectal wall reference points which have been specified and reconstructed this way, made possible assessment and calculation of rectal mucosa dose exposure.

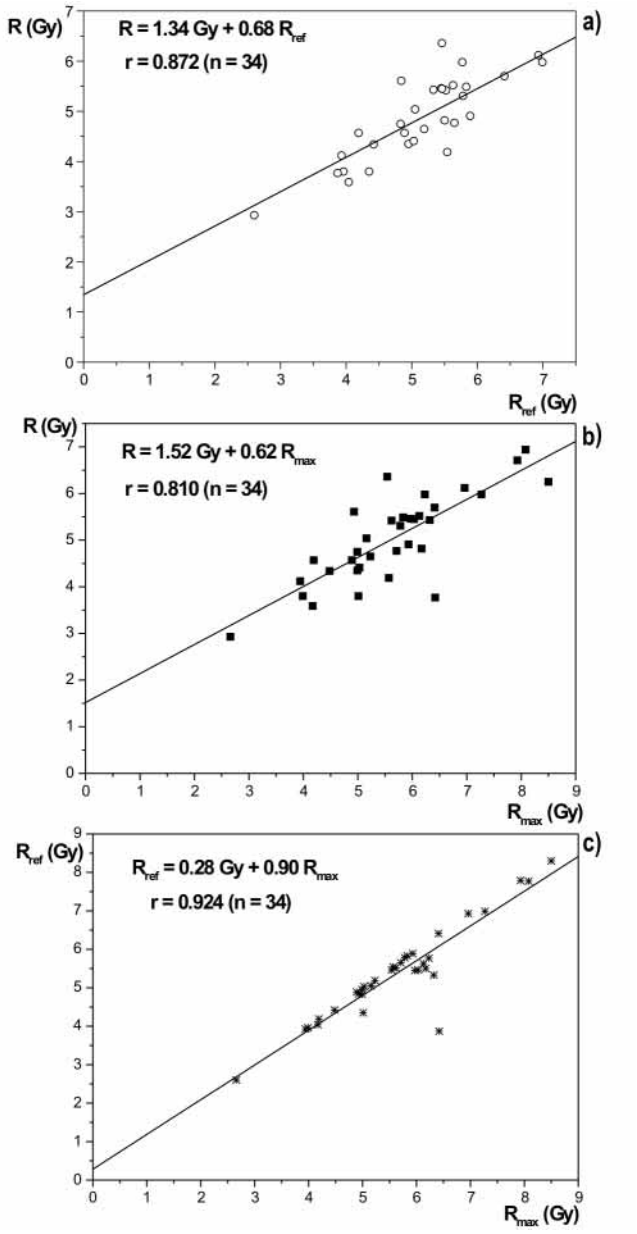

Figure 5. a) Correlation (r) between dose on ICRU point R and dose on rectal marker reference point R_{ref} with regression line included. b) Correlation (r) between dose on ICRU point R and dose on R_{max} with regression line included. c) Correlation (r) between dose on rectal marker reference point R_{ref} and dose on R_{max} with their regression line

Taking into account that doses were determined on selected points on rectal marker (R_{ref} and R_{max}) as well as on ICRU rectal point R, it was not of particular importance to specify some certain source positions in tandem and ovoids. It was just important for chosen source arrangement in applicator to be the same in every application, which would enable comparison of doses on specified rectal points from application to application. Within the tandem, dwell positions were activated from the tip to the level of

© 2002, Institute of Oncology Sremska Kamenica,Yugoslavia

tandem flange in the following manner: 1, 3, 5, 7, 10, 13, 16 etc. (depending on the length of tandem used). Four dwells were activated within each ovoid and these active positions were 4, 5, 6, and 7. Out of 34 executed applications, in just one, length of the tandem was 30 mm. In 23 cases tandem length was 40 mm, 8 times it was 50 mm and in 2 cases tandem length was 60 mm. Diameter of vaginal ovoids was 20 mm in 28 applications, while in 6 cases it was 15 mm.

As already was mentioned, on lateral radiography 5 to10 representative points at the anterior rectal wall were selected. These points were placed so that they lay in the region of rectum, which was the nearest to the radioactive sources. Amongst these 5 to 10 points, rectal marker reference point (R_{ref}) as well as point on marker that received maximal dose (R_{max}) should have found its place. This is the only reason that sometimes it was enough to select only 5 points, while in some other situations more points should have been marked in order to satisfy mentioned criterion. Point R_{ref} was fixed point and its position depended exclusively of the middle position of intravaginal sources. On the other hand, R_{max} was moving point, because its position was the site on the rectal marker that received maximal dose. Therefore, in some cases position of R_{max} was identical to the one R_{ref} had, while in others it could occupy position, which was up to 25 mm far from R_{ref}.

Statistical comparisons between rectal doses on rectal marker (R_{max} and R_{ref}) and the doses on ICRU rectal reference point (R) were made using paired t-test. Statistical significance was considered at the level of $p<0.05$.

RESULTS

In Table 1 values of doses on chosen rectal marker reference points (percents on prescribed dose to point A, i.e. percents normalized to 7.6 Gy) are given. Bolded values represent doses on R_{ref}, while the biggest values in every row present R_{max} for given application (rectangle marked numbers).

Values shown in Table 1 were obtained by Treatment Planning System calculations using its calculation algorithm. It could be seen that in 6 applications (17.6 %) R_{ref} was at the same time R_{max}, while in remaining 28 applications (82.4 %) distance between the two was from 3.5 to 24.5 mm (taking into account the fact that the distance between adjacent positions was 3.5 mm). Since rectal marker points (from R1 onwards) were placed in caudo-cephalad direction, it could be concluded from Table 1 that in majority of cases, the part of the rectal marker that accepted the highest doses (represented by R_{max}) was placed cephalic from point R_{ref} (i.e. towards the tip of the tandem), while minority of cases had R_{max} in caudal direction from R_{ref} (i.e. towards the end point of the tandem). Hence, out of 28 applications with $R_{max} \neq R_{ref}$ in 18 cases (64.3 %) R_{max} was above Rref and in 10 cases (35.7 %) it was below R_{ref} (looking in caudo-cephalad direction on AP radiography - Figure 2). In Figure 4, abscissa represented distribution of R_{max} rectal points along the rectal marker. Actually, part of the rectal marker (in mm) on which rectal doses were measured was put on abscissa. On ordinate, frequency of appearance of R_{max} in different positions is given. Part of the rectal marker, which was below reference rectal marker point (R_{ref}), had negative values on abscissa (towards end point of the tandem), while positive values represented part of the marker that was above point R_{ref}. Reference rectal marker point itself was placed in zero position. It can be easily noticed that significant majority (67.6 %) of applications had R_{max} in close proximity of R_{ref} (-3.5 to 3.5 mm), and that is the region which lies exactly below middle positions of the intravaginal sources. It means that using this rectal marker as rectal dosimetry instrument, the same region accepted the highest doses as in case of ICRU recommendations. Trend line in Figure 4 emphasizes that fact. Just in one application R_{max} was placed below tandem flange (24.5 mm far from R_{ref}). Doses on ICRU rectal point R were also calculated using TPS. The way of determining position of R point was already described in introduction and shown on Figure 2.

Table 1. Doses on rectal marker points calculated by Treatment Planning System (expressed in percents normalized to prescribed dose to point A)

APPL. NO.	TPS RESULTS OF DOSE TO RECTAL MARKER POINTS NORMALIZED TO PRESCRIBED DOSE (%)								
	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8	R_9
1	52.9	54.6	**55.2**	54.9	52.4				
2	89.1	91.5	**91.1**	89.7	84.3				
3	61.9	63.9	**64.3**	63.2	61.7				
4	72.1	75.1	**77.4**	78.0	76.9				
5	57.0	64.6	**71.7**	76.5	78.5				
6	61.4	64.6	65.7	**65.2**	62.0	57.6			
7	63.0	67.7	70.6	**72.9**	73.4	68.6	64.0	58.0	
8	68.0	72.8	**76.7**	76.5	74.6				
9	51.9	54.1	54.8	**53.1**	51.5	47.9			
10	87.2	96.4	**102.3**	106.3	105.7				
11	58.7	61.0	**63.7**	64.9	64.6				
12	49.0	50.9	**52.1**	52.5	52.4				
13	78.8	81.5	82.0	79.8	**75.9**	71.6			
14	67.5	67.8	67.3	**66.3**	63.6	59.5			
15	95.7	94.9	93.7	**92.0**	87.7	80.8			
16	49.6	50.7	**51.7**	51.9	51.5				
17	82.3	83.2	81.5	78.9	75.0	**70.1**	66.3		
18	62.6	68.3	70.8	**71.8**	72.9	70.0			
19	72.3	73.8	74.0	**72.6**	69.2				
20	81.2	81.1	80.4	77.9	75.1	**72.3**	67.9		
21	97.5	101.1	**102.5**	104.3	102.6	97.4			
22	71.2	74.5	75.1	**74.3**	69.4	63.8			
23	60.2	64.8	**71.8**	75.8	79.4	79.3			
24	65.9	67.7	68.9	**68.3**	65.7	63.2			
25	95.6	107.1	111.9	**109.2**	100.6				
26	60.3	66.6	71.8	**76.0**	75.2	71.1			
27	62.1	64.9	65.6	**63.6**	59.0				
28	65.9	63.7	60.7	**57.3**	53.0				
29	57.1	58.4	59.0	**58.1**	56.0	53.6			
30	80.7	79.4	76.7	**74.0**	68.5	63.8			
31	59.1	61.9	64.8	66.0	**66.2**	63.4			
32	79.2	84.5	81.6	72.4	66.1	60.9	57.0	53.4	**50.9**
33	76.3	80.4	83.0	**84.3**	81.8	78.5			
34	34.7	34.8	34.9	34.7	**34.2**	32.9			

© 2002, Institute of Oncology Sremska Kamenica,Yugoslavia

In Table 2 values of absorbed dose on ICRU point R were given in Gy as well as in percents normalized to prescribed dose to point A. Absorbed doses on R_{ref} and R_{max} (also in Gy and %) are given in the same table, this time independently, in order to make comparisons between these three more simple. In the last two columns absolute percentage dose differences between R_{ref} and R as well as between R_{max} and R are given.

Table 2. TPS results of rectal dose measurements by rectal marker (Rref and Rmax rectum anterior wall points) and ICRU method (R point)

Appl. No.	TPS rectum marker anterior wall results (Gy & % normalized to 7.6Gy) R_{ref}	R_{max}	ICRU rectal point R results (Gy & % of 7.6Gy)	$\|(R-R_{ref})\|/R$ (%)	$\|(R-R_{max})\|/R$ (%)
1	4.19 (55.2)	4.19 (55.2)	4.57 (60.1)	8.32	8.32
2	6.93 (91.1)	6.96 (91.5)	6.12 (80.6)	13.24	13.73
3	4.89 (64.3)	4.89 (64.3)	4.57 (60.1)	7.00	7.00
4	5.89 (77.4)	5.93 (78.0)	4.91 (64.6)	19.96	20.77
5	5.45 (71.7)	5.97 (78.5)	5.46 (71.8)	0.18	9.34
6	4.95 (65.2)	4.99 (65.7)	4.35 (57.2)	13.79	14.71
7	5.54 (72.9)	5.57 (73.4)	4.19 (55.1)	32.22	32.94
8	5.83 (76.7)	5.83 (76.7)	5.49 (72.3)	6.19	6.19
9	4.04 (53.1)	4.17 (54.8)	3.59 (47.2)	12.53	16.16
10	7.77 (102.3)	8.08 (106.3)	6.94 (91.3)	11.96	16.43
11	4.84 (63.7)	4.93 (64.9)	5.61 (73.9)	13.73	12.12
12	3.96 (52.1)	3.99 (52.5)	3.80 (50.1)	4.21	5.00
13	5.77 (75.9)	6.23 (82.0)	5.98 (78.7)	3.51	4.18
14	5.05 (66.4)	5.16 (67.8)	5.04 (66.3)	0.20	2.38
15	6.99 (92.0)	7.27 (95.7)	5.98 (78.7)	16.89	21.57
16	3.93 (51.7)	3.94 (51.9)	4.12 (54.1)	4.61	4.37
17	5.33 (70.1)	6.32 (83.2)	5.43 (71.4)	1.84	16.39
18	5.46 (71.8)	5.54 (72.9)	6.36 (83.6)	14.15	12.89
19	5.52 (72.6)	5.62 (74.0)	5.42 (71.3)	1.85	3.69
20	5.50 (72.3)	6.17 (81.2)	4.82 (63.4)	14.11	28.01
21	7.79 (102.5)	7.93 (104.3)	6.71 (88.3)	16.10	18.18
22	5.65 (74.3)	5.71 (75.1)	4.77 (62.8)	18.45	19.71
23	5.46 (71.8)	6.03 (79.4)	5.45 (71.7)	0.18	10.64
24	5.19 (68.3)	5.23 (68.9)	4.65 (61.2)	11.61	12.47
25	8.30 (109.2)	8.50 (111.9)	6.25 (82.3)	32.80	36.00
26	5.78 (76.0)	5.78 (76.0)	5.31 (69.9)	8.85	8.85
27	4.83 (63.6)	4.99 (65.6)	4.75 (62.5)	1.68	5.05
28	4.35 (57.3)	5.01 (65.9)	3.80 (50.0)	14.47	31.84
29	4.42 (58.1)	4.48 (59.0)	4.34 (57.1)	1.84	3.23
30	5.63 (74.0)	6.13 (80.7)	5.52 (72.7)	1.99	11.05
31	5.03 (66.2)	5.03 (66.2)	4.41 (58.1)	14.06	14.06
32	3.87 (50.9)	6.42 (84.5)	3.77 (49.6)	2.65	70.29
33	6.41 (84.3)	6.41 (84.3)	5.70 (75.0)	12.46	12.46
34	2.60 (34.2)	2.66 (34.9)	2.93 (38.6)	11.26	9.22
Mean ±SD	5.39Gy±1.2Gy (70.9±15.8)%	5.65Gy±1.2Gy (74.3±16.2)%	5.03Gy±0.9Gy (66.2±12.4)%	(10.26±8.2)%	(15.27±13.0)%

Results presented in Table 2 show that dose given to ICRU point R was in majority of cases smaller than that given to both rectal markers points (R_{ref} and R_{max}). In just 5 applications (14.7 %) R received higher dose than R_{max}, in 8 cases (23.5 %) R was bigger than R_{ref} with which it can be compared directly, taking into account they have the same y coordinate. Mean dose values for R, R_{ref} and R_{max} were 5.03, 5.39 and 5.65 Gy, respectively. When absorbed dose was given in percentages and normalized to reference dose (7.6 Gy), mean dose values for R, R_{ref} and R_{max} were 66.2 %, 70.9 % and 74.3 %, respectively. Mean absolute percentage dose difference between R_{ref} and R was 10.3 %, while for R_{max} and R it was 15.3 %. Differences between the means of ICRU point R and rectal marker points R_{ref} and R_{max} were significant ($P<0.002$ and $P<0.00002$ respectively) and so was the difference between the means of R_{ref} and R_{max} ($P<0.003$).

As it can be seen from Table 2, statistically significant differences exist between R, R_{ref} and R_{max}. However, there is a very good correlation between doses on these investigated rectal points, which can be seen from Figure 5 (a, b, and c). Linear dependence formula of the studied pairs is also given. The strongest correlation exists between R_{ref} and R_{max} ($r = 0.924$), weaker is between R and R_{ref} ($r = 0.872$), and the weakest (but still very strong) is between R and R_{max} ($r = 0.810$). Very good correlation between R_{ref} and R_{max} could be explained by already mentioned fact that majority of applications (67.6 %) had R_{max} in close proximity of the point R_{ref} (-3.5 to 3.5 mm). Majority of the points that diverge from regression line in the pair R-R_{ref}, does this because of significant differences amongst z coordinates of the R and R_{ref} points, while significantly smaller number of deviations from regression line is caused by differences that R and R_{ref} have in their x coordinates. Correlation of the pair R-R_{max} is worse than R-R_{ref} correlation because in this case, the third coordinate (y) of the points R and R_{max} is also different.

DISCUSSION

Specification of the region of rectal mucosa that absorbs the highest doses, based on empirical recommendations (such as ICRU report 38) is valid just as a mean of comparison amongst radiotherapy centers and under condition that all centers completely obey the rules that are dictated by these recommendations. In order to utilize all the benefits treatment individualization brings, it is desirable to use the method of direct rectal visualization employing rectal marker for that purpose. Accuracy of this method depends mainly on the rectal marker design.

Rectal marker made in our institution completely meets following constructional demands:

* It is inserted easily in rectal cavity and is adaptable to individual anatomical conditions of the rectum.
* It adheres to anterior rectal wall in the region where the rectal mucosa is closest to the radiation sources.
* It visualizes well on reconstruction radiographs and doesn't interfere (because of its negative contrast) with other marked reference points.
* Because of the small pressure it brings to rectal walls, marker could not bring anterior rectal wall closer to sources and thus present unrealistic picture.

There are not many studies that compare amount of dose received by ICRU rectal point and the point that is placed on the rectum and receives maximal dose and which could be estimated either by measurement (TLD or ionization chamber) or by TPS

© 2002, Institute of Oncology Sremska Kamenica,Yugoslavia

calculation. Serkies et al. (6) used in their comparative measurements rectal marker made of lead wire and ICRU method. In some centers, flexible wire rectal marker is usual way of marking the rectum during intracavitary brachytherapy treatment (7,8). Difference in calculated doses obtained by using these two methods was significant and the dose obtained by using ICRU method was higher, on average by 15 % than the one obtained by using lead wire rectal marker.

Deshpande et al. (9) reported that in about 70 % of applications maximal rectal doses obtained using rectal marker and calculated from orthogonal radiographs were in a range from 40-70 % of the dose prescribed to point A. However, measurements performed by Stuecklschweiger (10) showed that the mean dose on rectum measured by using flexible rectal plug (12 cm long and 2 cm wide) was about 85 % of the dose prescribed to point A. These differences may originate from the fact that wire rectal marker is inserted randomly in the rectal lumen (taking into account the fact they can not fill whole rectal lumen because their diameter is smaller), while flexible but firm marker can be set more precise under the recto-vaginal septum. Therefore, specific rectal points determined this way could not represent rectal wall. Lahtinen (11) also obtained lower values of the doses on rectal points that were visualized by injecting the contrast medium directly into rectum (doses were calculated by TPS), than these obtained by the same author on ICRU rectal point. Dose on ICRU point was higher on average by 19.9 % from the maximal rectal dose that was obtained using contrast medium and calculated by TPS.

It could be seen from the Table 2 that this study, that was carried out in Institute of Oncology Sremska Kamenica, produced somehow different results from the above mentioned studies. Our rectal marker was designed in different manner than mentioned markers, since it was made that way to fill completely part of the rectal lumen that is located in the area closest to radioactive sources and its balloon is flexible enough to follow precisely anterior rectal wall. Knowing that, it is to be expected for doses on rectal marker surface (R_{ref} and R_{max}) to remain higher than in case of rectal markers used elsewhere. Doses on rectal marker points were even higher from that, received by ICRU point (R), on average for 15.3 %. Accordingly, it has been demonstrated that doses on ICRU point and point on rectal marker that received maximal dose, differed significantly. That is in good agreement wit the results of several studies, where comparison was performed between the doses on ICRU point obtained using orthogonal radiographs and doses on maximally exposed rectum point which dose has been calculated using CT imaging (i.e. CT planning). Kapp (12) in his comparative study has got the maximal dose on rectum using CT based treatment planning, that is 1.4 times (40 %) higher than that received by ICRU point. Fellner (13) in similar study got 1.5 times higher dose using CT method, while Ling (14) for the same ratio obtained number 1.9. Schoeppel (15) has found out by examining dose-volume histograms obtained using CT-planning, that maximal dose on rectum is 1.6 times higher than that predicted by ICRU method.

As the majority of mentioned studies show it is insufficient to calculate dose in just one point of the rectum (as is recommended by ICRU). It is necessary to mark several points along the most exposed region of the rectum, in order to obtain real information where the maximally exposed region is, and also to enable calculation of the rectum volume that receives unacceptably high doses. That task can be accurately done just by using CT based treatment planning, while by using rectal marker for that purpose just approximate values could be obtained. On the other hand, by using just one rectal reference point, that information is impossible to obtain.Çetingöz (16) reports that the most exposed region of the rectum is located along the points of rectal marker that covers the length of 1.5-3 cm. Conclusions of some CT based studies (12,14) were that dose distributions of intracavitary implants put maximal rectal doses in points that were different from these recommended by ICRU report 38. From the Table 1 and Figure 4 it could be seen that similar conclusion might be drown in the case of this study as well. For instance, of 34 applications, just in 6 cases R_{max} was in same position as R_{ref}, while in 28 applications R_{max} was placed cephalically or caudally from R_{ref} (18-cephalically, 10-caudally). However, it should be said that significant majority of applications in this study (67.6 %) had R_{max} in very close proximity of R_{ref} (-3.5 to 3.5 mm) i.e. in the region that lies under mid positions of the vaginal sources.

From the CT based dosimetry studies it is well known that precise localization of the rectum is possible to obtain just by means of analyzing individual CT slices (15). Since brachytherapy applications based on imaging techniques are time consuming, expensive, hardly reproducible and can not be performed in all centers, hence, it is not easy to introduce them in daily clinical practice (for every patient and every application). Therefore, there is a need for invention of some simple method that could still be accurate enough, so it could be used in daily clinical practice. As far as ICRU rectal reference point is concerned, it is obvious that the point of this kind can not represent well rectal volume and thus, can not serve as a control tool when radiation consequences of the normal tissues are in question (15,17). Whether the dose on ICRU rectal point can serve as a reliable signal for development of late complications is still unclear. Some authors found that kind of correlation (1,18,19), while some others did not succeed in finding any significant correlation between dose received by ICRU rectal point and development of rectal complications (3,20-22).

Rectal marker of a good quality is satisfactory device for rectal

© 2002, Institute of Oncology Sremska Kamenica,Yugoslavia

dosimetry to be used in transitional period from ICRU recommendations to CT-MRI based concept of brachytherapy planning. This one, made in Radiotherapy Department of the Institute of Oncology in Sremska Kamenica, according to the results of this study, certainly falls into the category of rectal markers of a good quality and as that, it can satisfy criteria of accurate determination of absorbed dose on this critical organ. In the future, when application of imaging techniques becomes accessible to all centers, it will certainly replace methods of brachytherapy treatment planning used to date. When that happens, it will become possible to further increase the dose to target volume, while at the same time decreasing the dose to surrounding normal tissues.

CONCLUSION

As far as comparison of rectal marker points with ICRU rectal reference point is concerned the following conclusions could be drawn:

- Maximal doses obtained using rectal marker were in most cases higher than those obtained by ICRU method.
- Nevertheless, position of R_{max} point corresponds well with R_{ref}, which lies on the same line as ICRU rectal point. That means this region usually receives the highest dose. However, single point reference dose is not enough and multiple points must be determined over the length of the applicator. This is especially valid when rectum lies sideways from the applicator, which can significantly affect the estimated dose on it.
- Difference between ICRU dose point and doses on rectal marker points conforms well to several CT-based dosimetry studies where rectum dose was found to be higher from that obtained by ICRU method.

REFERENCES

1. Clark BG, Souhami L, Roman TN, Evans MDC, Pla C. Rectal complications in patients with carcinoma of the cervix treated with concomitant cisplatin and external beam irradiation with high dose rate brachytherapy: a dosimetric analysis. Int J Radiat Oncol Biol Phys 1994;28:1243-1250.
2. Haie-Meder C, Kramar A, Lambin P, et al. Analysis of complications in a prospective randomized trial comparing two brachytherapy low dose rate sin cervical carcinoma. Int J Radiat Oncol Biol Phys 1994;29:953-960.
3. van Lancker M, Storme G. Prediction of severe late complications in fractionated, high dose rate brachytherapy in gynecological applications. Int J Radiat Oncol Biol Phys 1991;20:1125-1129.
4. Montana GS, Fowler WC. Carcinoma of the cervix: analysis of blader and rectal radiation dose and complications. Int J Radiat Oncol Biol Phys 1989;16:95-100.
5. ICRU. Dose and volume specification for reporting intracavitary therapy in gynecology. Report no. 38. International Commission on Radiation Units and Measurements. Bethesda, MD, 1985.
6. Serkies K, Badzio A, Jereczek-Fossa B, Tarnavska Z, Nowak R, Szewczyk P, et al. Rectal doses in intracavitary brachytherapy of gynecological malignances: comparison of two dosimetric methods. Radiother Oncol 2001;58:37-41.
7. Roeske JC, Mundt AJ, Halpern H, et al. Late rectal sequaele following definitive radiation therapy for carcinoma of the uterine cervix: a dosimetric analysis. Int J Radiat Oncol Biol Phys 1997;37:351-358.
8. Wang Ch-J, Leung SW, Chen H-Ch, et al. The correlation of acute toxicity and late rectal injury in radiotherapy for cervical carcinoma: evidence suggestive on consequential late effect (CQLE). Int J Radiat Oncol Biol Phys 1998;40:85-91.
9. Deshpande DD, Shrivastav SK, Pradhan AS, et al. Dosimetry of intracavitary applications in carcinoma of the cervix: rectal dose analysis. Radiother Oncol 1997;42:163-166.
10. Stuecklschweiger GF, Arian-Schad KS, Poier E, et al. Bladder and rectal dose of gynecologic high-dose rate implants: Comparison of orthogonal radiografic measurements with in vivo and CT-assisted measurements. Radiology 1991;181:889-894.
11. Lahtinen T, Tenhunen M, Väyrynen M. ICRU reference points and maximum doses of rectum and bladder in intracavitary radiotherapy. Radiother Oncol 1993;28:174-176.
12. Kapp K, Stuecklschwieger G, Kapp D, Hacki A. Dosimetry of intracavitary placements for uterine and cervical carcinoma: results of orthogonal film, TLD, and CT assisted techniques. Radiother Oncol 1992;24:137-146.
13. Fellner C, Potter R, Knocke TH, Wambersie A. Comparison of radiography and computed tomography-based treatment planning in cervix cancer in brachytherapy with specific attention to some quality assurance aspects. Radiother Oncol 2001;58:53-62.
14. Ling CC, Schell MC, Working KR, Jentzsch K. CT-assisted assessment of bladder and rectum dose in gynecological implants. Int J Radiat Oncol Biol Phys 1987;13:1577-1582.
15. Schoeppel SL, LaVigne ML, Martel MK, et al. Three-dimensional treatment planning of intracavitary gynecologic implants: analysis of ten cases and implications for dose specification. Int J Radiat Oncol Biol Phys 1993;28:277-283.
16. Çetingöz R, Ataman ÖU, Tunçel N, et al. Rectum dose analysis of intracavitary applications in gynecologic cancers. Journal of BUON 1998;4:307-313.
17. Clark BG, Souhami L, Roman TN, et al. The prediction of late rectal complications in patients treated with high dose rate brachytherapy for carcinoma of the cervix. Int J Radiat Oncol Biol Phys 1997;38:989-993.
18. Crook JM, Esche BA, Chaplain G, et al. Dose-volume analysis and the prevention of radiation sequelae in cervical cancer. Radiother Oncol 1987;8:321-332.
19. Esche BA, Crook JM, Horiot J. Dosimetric methods in the optimization of radiotherapy for carcinoma of the uterine cervix. Int J Radiat Oncol Biol Phys 1987;13:1183-1192.
20. Pourquier H, Dubois J, Delard R. Cancer of the uterine cervix: dosimetric guidelines for prevention of the late rectal and rectosigmoid complications as a result of radiotherapeutic treatment. Int J Radiat Oncol Biol Phys 1982;8:1887-1895.
21. Kessaris N, Nori D. Rectal thermoluminescent dosimeter measurements using the microselectron high dose rate afterloader in postoperative intravaginal radiation cases. Int J Radiat Oncol Biol Phys 1995;26:341-345.
22. Perry W, Grigsby MD. Rectal complications in patients with carcinoma of the cervix. The concept of rectal reference dose. Int J Radiat Oncol Biol Phys 1994;28:1271-1272.

© 2002, Institute of Oncology Sremska Kamenica,Yugoslavia