ESTIMATION OF RECTAL FLUCTUATIONS DURING RADIOTHERAPY OF RECTAL CANCER USING CBCT MEASURED ON THE BONE STRUCTURES AND THE POSTERIOR RECTAL WALL

by

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This study aims to determine the deviation of the rectum from the reference position in the various parts of the rectum. Fifty neoadjuvant patients were included in the retrospective study. All patients had long-course radiotherapy. At the time of treatment, we acquired six cone-beam computed tomography (CBCT) images. The anatomical structures of the rectum and sacrum were visualized on transverse CBCT images using Eclipse software. In the upper rectum, a statistically significant difference was found between the variable's posterior ± when aligned to bone structures ($p = 0.017$), while when aligned to the posterior rectal wall, the variables posterior ± represent a borderline statistical significance ($p = 0.051$). In the lower rectum, a statistically significant difference was found between the variables left ± ($p = 0.0001$) and between right ± ($p = 0.008$) when aligned to bone structures. When aligned to the posterior rectal wall, a statistically significant difference was found between left ± ($p = 0.006$) and right ± ($p = 0.005$). Daily CBCT imaging and adaptive radiotherapy should be considered, especially in patients with tumors in the highly mobile upper third of the rectum, to minimize these deviations and ensure optimal treatment accuracy.

Key words: rectal carcinoma, rectal movement, preoperative radiation, alignment method

INTRODUCTION

The rectum is a movable structure that continuously shifts position due to fluctuations in rectal and bladder filling, which should be considered organ motion. The rectal motion can also be affected by temporary motion such as peristalsis, and voluntary and in-voluntary tensing of pelvic muscles of the rectum and mesorectum [1]. To make optimal use of the most advanced radiation techniques, an adequate planning target volume (PTV) margin and visualization of the target volume before the application of each fraction are essential. Safety margins in the pelvic region are usually very extensive due to daily variations in target volumes [2]. In patients with rectal cancer and patients with other malignant tumors in the pelvis, the daily fluctuations in rectal and bladder filling often lead to considerable deformations of the target volumes, which cannot be corrected by adjusting the treatment couch. Bladder and bowel interventions, such as drinking protocols and dietary advice, have a limited effect on organ motion [3]. In patients with rectal cancer, it is known that reduced safety margins of PTV and consequently reduced radiation exposure to healthy tissue or the organ at risk (OAR) can reduce the negative effects of radiation treatment [4]. The study of mesorectal motion is important for optimizing the treatment of rectal cancer with radiation therapy in which the mesorectum receives a homogeneous dose according to short or long treatment regimens [5]. In rectal cancer, the target and OAR vary during the irradiation process due to anatomical changes in size and position, which is the main cause of daily variations in target volumes [6, 7]. These changes can be caused by movements within or between the fractions. Increasing the dose poses a challenge because the target (the rectal tumor) is not visible on CBCT images. Using the pelvic bone as a surrogate for tumor localization is unreliable because rectal tumors originate in the rectal wall, which is visible on a CBCT image. Consequently, aligning with the rectal wall is more reliable than aligning with the pelvic bone [7]. The rapid and efficient development of imaging technology has facilitated the emergence of adaptive radiation therapy (ART), which enables adjustments to the dosage to adapt to the changing position of target volumes during radiation therapy [8]. Nijkamp *et al*. [9] suggested at the time that ART could be rather useful in the treat-

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ment of rectal cancer due to the significant changes in the clinical target volume.

We were very interested in contributing new research to this field, as we are all involved with this issue in our daily clinical practice, as well as with prostate cancer irradiation [10]. Moreover, there is a limited number of published articles focusing on rectal cancer motion. This is the first study conducted in Slovenia from the RTT perspective on rectal cancer, with a specific emphasis on rectal cancer motion. It provides many ideas for further investigation of this issue. Moreover, the results offer important information on rectal motion that can support radiation oncologists in treatment planning and decision-making. This study aimed to determine the deviation of the rectum from the reference position in the upper, middle, and lower third of the rectum using different alignment methods.

MATERIALS AND METHODS

Patient selection

Fifty neoadjuvant (pre-operated) patients were included in this retrospective study. We included 30 males (60 %) and 20 females (40 %), which were selected randomly. All included patients had long-course radiotherapy (22 fractions with a total tumor dose of 48.40 Gy). During the treatment, we acquired 6 CBCT images (in the 1st, 2nd, 3rd, 8th, 13th, and 18th fractions), which were performed according to the protocol. We reviewed and analyzed 315 CBCT images, in total. Before the CT simulation and radiation, all patients received instructions on water intake and bladder preparation (0.5 L of water 45 minutes ahead of the procedure). The planning CT scan was performed on the CT simulator (Somatom Definition AS CT Simulator – Siemens, Erlangen, Germany). It started at the L2-L3 junction and ended 5 cm below the mark at the beginning of the anus. The scan thickness on the CT simulator and the CBCT images was 3 mm. All patients were irradiated on a TrueBeam linear accelerator (Varian Medical Systems, Palo Alto, USA).

Experimental procedures

The anatomical structures of the rectum and sacrum were visualized on transverse (cross-sectional) CBCT images using Eclipse software (Varian Medical Systems, Palo Alto, USA). The CBCT acquisition parameters were 125 kV and 1025 mAs. The entire rectum was also delineated on the reference CT image, extending from the end of the sigmoid colon to the beginning of the anus. A CBCT image (daily position) was fused with a planning CT image (reference position) concerning the sacrum and the posterior rectal wall. At the same time, the output of the collected data was obtained for each part of the rectum.

The alignment of the sacrum's bone structures was achieved using the automatic anatomical alignment tool. It was performed in all six directions, *i. e.*, in three translational and three rotational directions. For each fusion, the data obtained was output to predetermined points on the sacrum. The measurement points are shown in the fig. 1 and include: the beginning of the sacroiliac joint of the inferior border in the caudo-cranial direction for the upper rectum, the distal end of the coccyx for the lower rectum, and for the mid-rectum (the midpoint between the two predefined points) when the femoral head merges with the femoral neck.

In rare cases, the predefined measurement points could not be reached due to the low anatomical position of the rectum. In these cases, the selected points were simulated and included: the beginning of the rectum or the end of sigmoid flexure in the cranio-caudal direction for the upper rectum, the beginning of the femoral neck for the mid-rectum and the measured difference between the two points mentioned above for the lower rectum. These points are shown in fig. 2. In this case, a fixed point was established in the lower rectum. After fusion with the posterior rectal wall, the deviation was measured, representing the deviation of the bone structures (the sacrum).

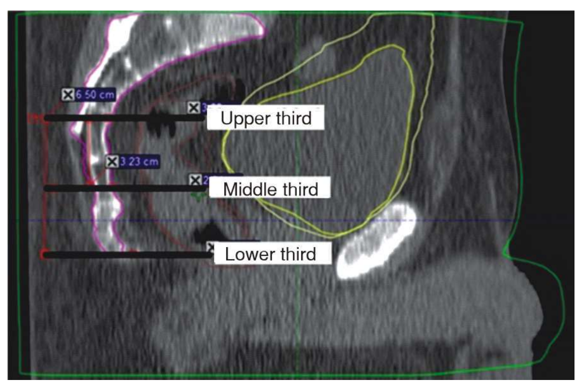

Figure 1. The measurement points for the upper, middle, and lower third of the rectum

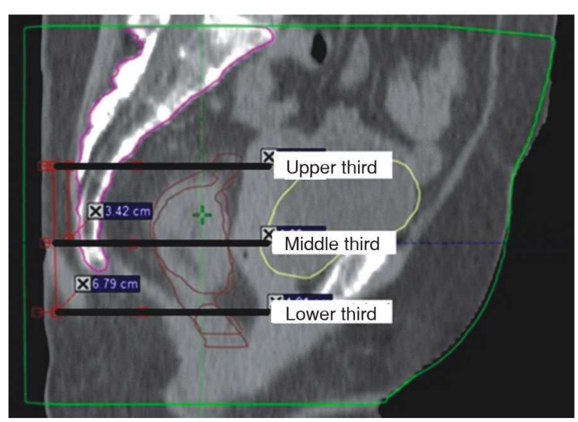

Figure 2. The simulated measurement points for the upper, middle and lower third of rectum

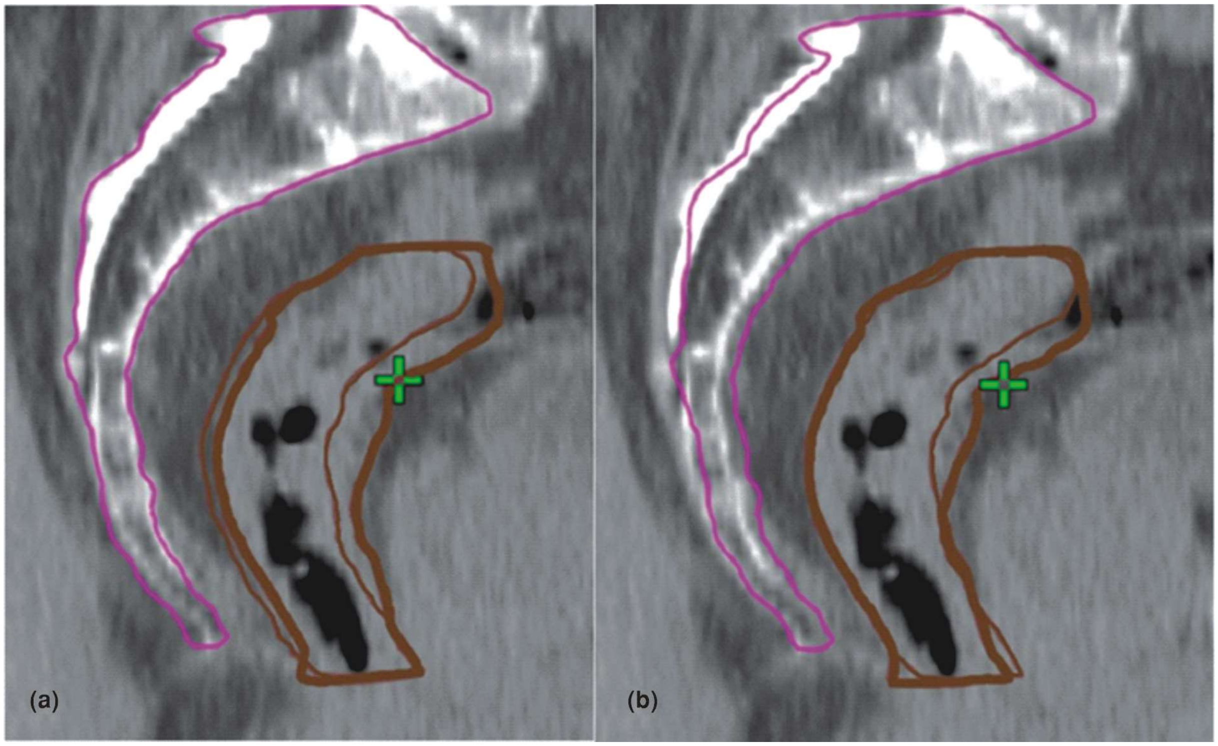

Figure 3. Example of the same case with different alignment methods; (a) image shows alignment to the bone structure – the sacrum (automatically by fusion) *vs*. (b) image showing alignment to the posterior rectal wall (performed manually in an anterior-posterior direction). The bold line represents the reference position while the thin line represents the daily position

After the alignment to the bone structure (sacrum), which was performed by automatic fusion, the radiation therapist did the alignment on the posterior rectal wall, which was performed manually in the anteroposterior direction on the sagittal scan, fig. 3.

In addition to the deviation in the rectal wall, the deviation in the bone structures (sacrum) was also measured at all three defined points. The posterior rectal wall was considered misaligned unless it had already been aligned with the sacrum or if the misalignment was due to the pitch of the rectal wall. The deviation of the bone structures was performed in the anteroposterior direction.

During the measurements, deviations of the rectal wall were measured in the anterior, posterior, left, and right directions. The measurements in the superior and inferior directions were not performed due to the predefined measurement points for the upper, middle, and lower third of the rectum. When measuring deviations, the values were measured in a positive value if the rectal wall deviated outside the reference position and in a negative value if the rectal wall was inside the reference position. The measurements were always performed on a reference CT image in the transverse scan. When performing the measurements, positive values were given priority. The measurement was also performed at the point of maximum deviation relative to the reference position fig. 4, (where the bold line represents the reference position while the thin line represents the daily position.

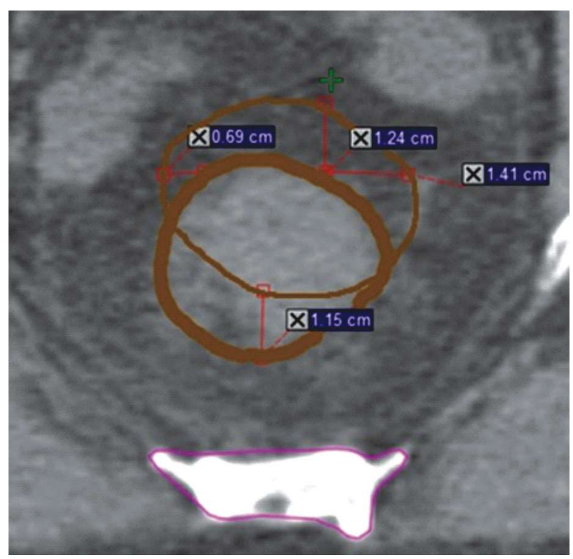

Figure 4. Example of how the measurements were taken in our study (the bold line represents the reference

Statistical analysis

Microsoft Excel 2010 and the Statistical Package for the Social Sciences, Version 26.0 (SPSS Inc., Chicago, IL, USA) were used to analyze and evaluate the collected data. The general data were presented using descriptive statistics. The Shapiro-Wilk test was used to determine the normality of the sample distribution. Subsequently, the parametric (ANOVA, T-test, Mann-Whitney test) or non-parametric tests (Wilcoxon test, Kruskal--Willis test) were applied based on the results. Spearman correlation was utilized to perform various analyses. A statistically significant difference was assessed at a p-value $p \leq 0.05$ (at a risk level of 5).

RESULTS

Fifty neoadjuvant (pre-operated) patients were included in this retrospective study. We included 30 males (60 %) and 20 females (40 %), which were selected randomly. The mean age was 60.5 years (37-81 years). At the time of treatment, we acquired 6 CBCT images (on the 1st, 2nd, 3rd, 8th, 13th, and 18th fractions). On average, we reviewed and analyzed 6.30 CBCT scans per patient (ranging from 5 to 9 CBCT scans per patient). We reviewed and analyzed 5 CBCT scans for 4 patients, 6 scans for 31 patients, 7 scans for 12 patients, 8 scans for 2 patients, and 9 scans for 1 patient. We obtained more than 6 CBCT images when the patient did not have a full bladder. However, we analyzed less than 6 CBCT images because we had to eliminate some due to the presence of excessive artifacts, such as those caused by a very gassy colon. We reviewed and analyzed 315 CBCT images in total. Most patients were diagnosed with stage T3, accounting for 76 % of patients. Stage T4 was identified in 22 % of patients, while stage T2 was found in 2 %. Stage N2 was observed in 58 % of patients, N1 in 24 %, and stage N0 in 18%. 96 % of patients had no distant metastases (M0), while 4 % were assessed as stage M1 indicating solitary liver metastasis. The largest number of patients had a tumor in the lower/middle third (26 %), followed by patients with a tumor in the lower third (24 %). An equal proportion of patients had tumors in the middle and middle/upper thirds (22 %), with the fewest patients having tumors in the upper third (6 %).

The main part of the analysis was divided into two parts: the alignment to bone structures and the alignment to the posterior rectal wall. In both parts, the following dependent variables were analyzed: anterior ±, posterior ±, left ±, right ±, and bone ±. The analysis was divided based on the section of the rectum: the upper, middle, and lower third. A positive value (+) means that the position of the rectal wall was larger and outside the reference position. A negative value (–) means that the position of the rectal wall was smaller and inside the reference position.

The highest deviations were observed in the anterior direction for the upper rectum. When aligned to the bone structures, the maximum deviation was in the anterior + direction (24.67 mm) and the anterior – direction (25.18 mm). When aligned to the posterior rectal wall, the maximum deviation was found in the anterior + direction (23.75 mm) and the anterior – direction (25.18 mm). In the middle rectum, the left ± direction showed the greatest deviation for both methods, with slightly higher values for alignment with the bone structures. For alignment with the bone structures, the maximum deviation for the left + direction was 20.70 mm, while for the left – direction it was 18.50 mm. When aligned to the posterior rectal wall, the maximum deviation for the left + direction was 20.20 mm, while for the left – direction it was 18.50 mm. The highest deviations for the lower rectum were observed in the anterior and posterior directions for both methods. When aligning to the bone structures, the maximum deviation for the anterior – direction was 16.28 mm, while for the posterior + direction it was 15.12 mm. When aligned to the posterior rectal wall, the maximum deviation for the anterior – direction was 15.77 mm, while for the posterior + direction it was 14.65 mm. The results of our study are shown in tab. 1.

In the upper rectum, a statistically significant difference was found between the variable's posterior ± when aligned to bone structures ($p = 0.017$). In 30 patients, the value of posterior – was greater than that of posterior +, while in 20 patients, it was smaller. When aligned to the posterior rectal wall, the variables posterior ± represent a borderline statistical significance ($p = 0.051$). In the middle rectum, no statistically significant differences were found, either when aligned to bone structures or the posterior rectal wall. In the lower rectum, a statistically significant difference was found between the variables left ± ($p = 0.0001$) and between right ± ($p = 0.008$) when aligned to bone structures. The value of left – was smaller than that of left + in 37 patients, while it was larger in 13 patients. The value of right – was lower than that of right + in 33 patients, whereas it was higher than 17 patients. When aligned to the posterior rectal wall, a statistically significant difference was found between left ± ($p = 0.006$) and between right ± ($p = 0.005$). The value of left – was smaller than that of left + in 37 patients, while it was larger in 13 patients. The value of right – was smaller than right + in 34 patients, while it was larger in 16 patients.

Tumor localization

We divided the analysis of differences based on tumor localization into the upper, middle, and lower third of the rectum, separately for both alignment methods (bone structures – sacrum and the posterior rectal wall). For all thirds of the rectum, we first performed the Shapiro-Wilk test to assess the normality of the sample distribution. Based on the Shapiro-Wilk test values for the distribution of the dependent variable (anterior ±, posterior ±, left ±, right ±, bone ±) we applied the non-parametric Kruskal-Wallis's test in cases of non-normal distribution of variables. For normally distributed variables, we used the parametric ANOVA test.

Table 1. Represents mean, standard deviation (SD), minimum and maximum value, and *p*-value for upper, middle, and lower rectum for different alignment methods (bone structures – sacrum *vs*. posterior rectal wall) obtained by Wilcoxon Signed-Rank test. All measurements are in millimeters

	Upper rectum									
	Align to bone structures – sacrum					Align to posterior rectal wall				
	Mean	SD	Min	Max	*p*-value	Mean	SD	Min	Max	*p*-value
Anterior +	6.31	5.28	0.00	24.67	0.490	6.28	5.24	0.00	23.75	0.347
Anterior –	5.68	5.89	0.00	25.18		5.43	5.67	0.00	25.18	
Posterior +	2.80	2.25	0.00	8.04	0.017	2.75	2.04	0.00	6.85	0.051
Posterior –	4.23	2.94	0.00	11.14		3.98	2.73	0.00	11.14	
Left +	5.42	3.47	0.00	15.87	0.612	5.51	3.83	0.00	17.30	0.553
Left –	5.12	4.78	0.00	18.50		5.10	4.61	0.00	17.96	
Right +	6.11	3.25	0.00	15.98	0.133	6.25	3.81	0.00	16.27	0.146
Right –	4.75	3.95	0.00	15.40		4.69	3.89	0.00	15.40	
Bone +	0.00	0.00	0.00	0.00	/	1.17	1.59	0.00	5.14	0.465
Bone –	0.00	0.00	0.00	0.00		1.39	1.60	0.00	5.27	
	Middle rectum									
	Align to bone structures – sacrum					Align to posterior rectal wall				
	Mean	SD	Min	Max	*p*-value	Mean	SD	Min	Max	*p*-value
Anterior +	5.23	3.69	0.00	16.34	0.671	5.23	3.69	0.00	15.62	0.569
Anterior –	5.06	4.68	0.00	18.86		4.94	4.37	0.00	16.30	
Posterior +	2.34	1.80	0.00	7.61	0.062	2.16	1.69	0.00	7.61	0.132
Posterior –	3.08	2.06	0.00	9.50		2.77	2.09	0.00	9.50	
Left +	5.64	4.43	0.00	20.70	0.224	5.07	4.42	0.00	20.20	0.732
Left –	4.77	4.61	0.00	18.50		4.84	4.66	0.00	18.50	
Right +	4.96	3.07	0.00	12.70	0.935	4.97	3.10	0.00	12.70	0.992
Right –	5.17	3.79	0.00	14.48		5.29	3.83	0.00	15.43	
Bone +	0.00	0.00	0.00	0.00	/	1.14	1.55	0.00	5.10	0.664
Bone –	0.00	0.00	0.00	0.00		1.29	1.57	0.00	5.08	
	Lower rectum									
	Align to bone structures – sacrum					Align to posterior rectal wall				
	Mean	SD	Min	Max	*p*-value	Mean	SD	Min	Max	*p*-value
Anterior +	3.58	2.80	0.00	10.13	0.647	3.59	2.62	0.00	10.13	0.758
Anterior –	4.01	3.99	0.00	16.28		4.05	3.86	0.00	15.77	
Posterior +	3.69	3.02	0.00	15.12	0.372	3.70	2.80	0.00	14.65	0.130
Posterior –	3.07	2.32	0.00	11.35		2.80	2.34	0.00	10.70	
Left +	4.96	2.90	0.00	12.94	0.0001	4.52	2.87	0.00	12.94	0.006
Left –	2.89	2.97	0.00	10.75		3.02	3.33	0.00	13.00	
Right +	4.36	2.38	0.00	11.63	0.008	4.37	2.35	0.00	11.63	0.005
Right –	2.91	3.28	0.00	13.78		2.84	3.15	0.00	13.74	
Bone +	0.00	0.00	0.00	0.00	/	0.96	1.31	0.00	4.50	0.387
Bone –	0.00	0.00	0.00	0.00		1.26	1.44	0.00	4.33	

In the upper rectum, when aligned to bone structures – sacrum, the variables posterior – and left + were normally distributed, while the other variables were not. A statistically significant difference was found in left + ($p = 0.043$), with results presented in tab. 2.

When aligned with the posterior rectal wall, the posterior ± measurements followed a normal distribution, while the other variables did not. No statistically significant difference was found ($p > 0.05$). In the middle rectum, when aligned with bone structures - the sacrum, the anterior + and right + variables exhibited a normal distribution, whereas the other variables did not. No statistically significant differences were found in the dependent variables ($p > 0.05$). When aligned to the posterior rectal wall, the posterior – and right + measurements were normally distributed, while the other variables were not. No statistically significant difference was found ($p > 0.05$). The homogeneity of variance test showed significance in the dependent variable posterior – ($p = 0.007$ from the Robust Test of Equality of Means). No statistically significant difference was found ($p > 0.05$). In the lower rectum, when aligned to bone structures – sacrum, the anterior + and left + variables were normally distributed, while the other variables were not. No statistically significant differences were found in the dependent variables ($p > 0.05$). When aligned to the posterior rectal wall, the anterior + and left + measurements were normally distributed, while the other variables were not. No statistically significant difference was found ($p > 0.05$).

Table 2. Normal distribution of variable left + in the upper rectum (aligned to bone structures – sacrum) with number of patients, mean, SD, standard error, 95 % confidence interval for mean, minimum and maximum value

Left +	N	Mean	SD	SE	95 % CI	Min	Max
Lower third	12	5.20	4.28	1.24	[2.48, 7.92]	0.00	15.87
Middle third	11	5.37	2.59	0.78	[3.63, 7.11]	0.00	8.77
Upper third	3	8.67	4.79	2.76	[–3.22, 20.57]	3.20	12.09
Middle third/upper third	11	7.12	2.66	0.80	[5.33, 8.91]	3.18	11.80
Lower third/middle third	13	3.47	2.73	0.76	[1.82, 5.12]	0.00	8.68

DISCUSSION

The study aimed to determine the deviation of the rectum from its reference position in the upper, middle, and lower thirds, and whether these deviations are influenced by the different alignments of the anatomical structures. The results are based on an analysis of 315 images obtained from fifty patients. They provide valuable insight into the alignment of the rectal wall relative to the bone structures and the posterior rectal wall, in which the rectum was divided into the upper, middle, and lower thirds. We have not found any similar studies in our review of the literature. Many researchers have described the impact of rectal filling fluctuations on prostate cancer treatment, but very little is known about the effects of these fluctuations on the treatment of rectal cancer [11,12].

Analysis of the upper third of the rectum revealed statistically significant differences in alignment with the bone structures, particularly in the posterior direction. This indicates a remarkable variance in rectal movement in this region. When alignment to the posterior rectal wall was analyzed, no statistically significant differences were found, although the posterior direction was a significant cut-off point. In the middle third of the rectum, statistically significant differences were found in alignment with either bone structures or the posterior rectal wall. This may indicate a more uniform pattern of movement of the rectum in this third. In the lower third of the rectum, a statistically significant difference was found in the alignment of the bone structures, particularly in the left and right directions. This indicates a different alignment pattern in the lower third of the rectum compared to the other two thirds. Similarly, a statistically significant difference was found in the alignment to the posterior rectal wall, indicating a notable difference in the position of the rectal wall when the alignment to the posterior rectal wall is used. The results regarding alignment with bone structures relative to the posterior rectal wall also provide valuable insights. When comparing the different alignment methods, statistically significant differences were observed for several variables, suggesting that these alignments may not always coincide.

When comparing the results of the descriptive statistics for the upper, middle, and lower thirds of the rectum in the case of alignment with bone structures and the posterior rectal wall, the largest deviations of the rectum from the reference position were observed in the upper rectum. However, the smallest deviations were observed in the lower rectum. Nugent *et al*. also found a larger movement of the rectal wall in the upper third of the rectum [12], while Ingle *et al*. emphasized that rectal movement is greater in the middle rectum [13]. It was also observed that the deviations of the rectum from the reference position were smaller when aligned to the posterior rectal wall compared to alignment with bone structures, *i. e*., the sacrum, which was expected based on the alignment method.

When observing a positive (+) value, it is important to consider that the target volume was outside the intended radiation target volume and was not sufficiently irradiated with the therapeutic dose or that the safety margins were insufficient. When a negative (–) value was observed, the target volume was too large, resulting in an unintended inclusion of a greater part of the OAR within the irradiation field. Despite smaller average deviations in the descriptive statistics, the largest individual variable deviations show values not within the acceptable range in modern radiotherapy. Focusing on the maximum measurement values in the upper rectum, which is the most movable third of the rectum it can be observed that most variables exhibit the largest deviations with an average of 10 mm, and sometimes up to 20 mm and more. This is very concerning because the PTV margin we use is 8 mm. Because of that, we would suggest at least daily use of CBCT and if possible, implementation of ART, especially for the patients with rectal cancer in the upper third. It is important to recognize that our analysis relies on average values of the deviations, meaning that in certain cases, exceeded values may be higher. To achieve more precise results, a larger pattern should be applied. Van Beek et al. reported that, within the treatment plan library, the most frequently selected plan had smaller safety margins than the original. In rare cases, treatment plans with larger safety margins were selected instead [14]. Ingle *et al*. [13] studied the reduction of safety margins and found that it is both safe and acceptable when using ART. De Jong *et al*. [15] reported that ART was needed in 50 % of fractions which indicates significant intrafractional rectal movement highlighting the benefits of using ART. Our findings suggest that aligning to bone structures often leads to greater deviations in rectal positioning than alignment to the posterior rectal wall, potentially resulting in suboptimal radiation dose targeting. Therefore, daily CBCT imaging and ART should be considered, especially in patients with tumors in the highly mobile upper third of the rectum, to minimize these deviations and ensure optimal treatment accuracy. Future studies could obtain more precise results by incorporating a larger, gender-balanced patient sample.

CONCLUSION

In this retrospective study, we analyzed CBCT images of fifty patients who underwent neoadjuvant radiotherapy for rectal cancer. The anatomical structures of the rectum and sacrum were visualized on transverse (cross-sectional) CBCT images using Eclipse software (Varian Medical Systems, Palo Alto, USA) and measured to bone structures and the posterior rectal wall. The analysis revealed significant deviations, especially in the upper and lower third, which carry important clinical implications for radiotherapy. In conclusion, daily CBCT alignment to the posterior rectal wall in clinical practice may enhance treatment outcomes and improve the quality of life for patients with rectal cancer. This approach improves overall treatment precision by accounting for daily organ movement and ensuring accurate dose delivery to the target while minimizing OAR exposure and toxicity risks. Moreover, the possibility of monitoring daily anatomical changes provides opportunities for adaptive radiotherapy and further optimization of patient outcomes.

AUTHORS' CONTRIBUTIONS

K. Salmič and V. Žager Marciuš contributed to developing of the research plan, data collection, and preparation for data analysis. K. Salmič conducted the data analysis. All the authors have participated in the preparation of the article.

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ПРОЦЕНА РЕКТАЛНИХ ФЛУКТУАЦИЈА ТОКОМ РАДИОТЕРАПИЈЕ РЕКТАЛНОГ КАНЦЕРА КОРИШЋЕЊЕМ КОНУСНО-ЗРАЧНЕ КОМПЈУТЕРИЗОВАНЕ ТОМОГРАФИЈЕ, МЕРЕНО НА КОШТАНИМ СТРУКТУРАМА И ЗАДЊЕМ ЗИДУ РЕКТУМА

Рад има за циљ да утврди одступање ректума од референтне позиције у различитим деловима ректума. Педесет неоадјувантних пацијената укључено је у ретроспективну студију. Сви пацијенти примали су дуготрајну радиотерапију. У време лечења, снимљено је 6 снимака компјутеризоване томографије конусним снопом. Анатомске структуре ректума и сакрума визуализоване су на снимцима попречне компјутеризоване томографије конусним снопом коришћењем софтвера Eclipse. У горњем делу ректума, утврђена је статистички значајна разлика између постериор варијабле када је поравната са коштаним структурама (p = 0,017), док када је поравната са задњим зидом ректума, постериор варијабле представљају граничну статистичку вредност (p = 0,051). У доњем делу ректума, утврђена је статистички значајна разлика између варијабли лево (p = 0,0001) и између варијабли десно (p = 0,008), када су поравнате са коштаним структурама. Када су поравнате са задњим зидом ректума, утврђена је статистички значајна разлика између лево (p = 0,006) и десно (p = 0,005). Треба размотрити свакодневно снимање конусном компјутеризованом томографијом и адаптивну радиотерапију, посебно код пацијената са туморима у високо мобилној горњој трећини ректума, како би се минимизовала ова одступања и осигурала оптимална тачност лечења.

Кључне речи: карцином ректума, померање ректума, преоперативно зрачење, метода поравнања