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Analysis of daily changes in volume and predicted doses for critical organs and the prostate during radiotherapy

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Abstract

Introduction: The analysis of the differences in the daily volumes and the predicted dose to the actual dose in the bladder, rectum, and targets in prostate radiotherapy is presented.

Material and methods: The analysis was performed for 30 patients treated with prostate cancer. Precision treatment planning system was used to calculate the dose distribution. Patients were set up on the treatment table in the treatment position every day. kVCT images were acquired. kVCT images were imported into the PreciseART module. Organs at Risk and the prostate (PTV) volumes were copied onto these daily actual CT images and then automatically deformed to their current shapes. They were used to recalculate the updated therapeutic treatment plan. 726 CT examinations were analyzed. The volumes and dose values from clinical treatment plan have been used as reference values for the PTV, bladder, and rectum. Changes in volumes and doses for reference values and daily CT images were analyzed.

Results: The average daily changes in PTV, bladder and rectum volumes ranged from -0.3% to 14.4%, -21.7% to 32.5% and -10.5% to 32.5%, respectively. Corresponding standard deviations ranged from 1.0% to 5.5%, 4.9% to 35.5% and 5.8% to 25.2%, respectively. Corresponding median values ranged from -0.2% to 14.1%, -22.0% to 37.8% and -10.9 to 32.8, respectively. The average daily changes in PTV, bladder and rectum projected doses ranged from -1.4% to 2.9%, -9.0% to 24.8% and -25.4% to 15.9%, respectively. Corresponding standard deviations ranged from -1.4% to 2.6%, 0.0% to 14.8% and 0,0% to 17,2%, respectively. Corresponding median values ranged from -1.5% to 2.7%, -8.8% to 28.7% and -25.9% to 17.2%, respectively.

Conclusions: Qualitative data analysis showed that the greatest differences in volumes and doses occurred for these structures. For the prostate, these changes were lower than for other organs.

Keywords: prostate cancer; volume and dose changes; offline Adaptive Radiotherapy

Introduction

Prostate cancer is the one of the most common tumor that occurs in the male population[1]. External radiotherapy (intensity-modulated radiation therapy (IMRT) and volumetric modulated arc therapy (VMAT)) and brachytherapy are often utilized to treat prostate cancer. The accurate delivery of sufficient dose to the target and limiting dose to adjacent radiosensitive structures, such as the bladder and rectum, is a highly important element of this process[2]. The bladder and rectum are mobile organs. Clinical studies have shown the negative results of clinical outcome without properly accounting for patient and organ variations during the whole course of radiotherapy[3-4]. A main source of patient's treatment position uncertainty is the variation in the daily patient setup. The conventional method to reduce this effect involves adding a some margin around the target (PTV). This causes increasing the treatment volume and consequently increasing normal organ toxicity.

A common practice to verify patient setup were portal images developed in previous studies[5-10]. Now, Image Guided Radiation Therapy (IGRT) methods such MV Cone Beam Computed Tomography (MV CBCT) and kV Cone Beam Computed Tomography (kV CBCT) are used for this purpose. The offline and online correction procedures are applied to reduce the magnitude of setup errors[11]. Some other correction decision protocols as shrinking action level (SAL), no action level (NAL) or extended action level (eNAL) are used for offline procedures[12-15]. These kinds of verification do not account for daily changes in patient's anatomy.

Authors' contribution: A – Research concept and design, B – Collection and/or assembly of data, C – Data analysis and interpretation, D – Writing the article, E – Critical revision of the article, F – Final approval of the article.

Internal organ variations in position, shape, and size both inter- and intra-treatment are another source of treatment uncertainty. The bladder and rectum are important organs in the case of the prostate position. Improper and inconsistent bladder filling as well as rectal emptying can heavily impact on the prostate position during daily treatment. When this criteria are not sufficiently reproduced according to treatment planning CT scans, the dose delivered to the organs at risk and target may vary from fraction to fraction throughout the entire treatment process[16].

The process of treatment planning involves acquiring images of patient's anatomy to design the customized and personalized treatment plan. Currently, computed thomography (CT) is the primary method used for treatment preparation. Magnetic resonance imaging (MRI) and positron emission tomography (PET) are also used as additional supporting images. In the last decades, the treatment planning and irradiation process were highly improved, making them more precise and accurate[17-18]. CT scans for treatment planning purposes are acquired before the start of treatment. And treatment plan based on these images is carried out throughout the entire course of treatment process. The assumption that patient anatomy remains constant during the course of irradiation and the existing discrepancies can be neutralize by adding additional margins to the treatment volumes during treatment planning is failed. In reality, daily changes in organ filling in pelvic or abdominal regions can cause significant anatomical changes. They may lead to relative positional change and deformation of organs, fluctuations in patient weight (and consequently in external contour) and changes in tumor shape and volume[19-22]. Even very sophisticated treatment plan cannot take into accounts daily changes in patients anatomy[23]. Some previous studies have linked prostate movement to subcutaneous fat, body mass index (BMI), and organ shape[24,25].

Changes between the planned prostate and organs at risk position and actual position during treatment may lead to alterations in dose distribution. Positional and volumetric changes in the prostate during the treatment period has been widely investigated[26-28]. The recent improvements in image guided treatment methodologies offer opportunities to adapt treatments to on a daily basis. Various strategies, such as adaptive radiation therapy, magnetic resonance (MR) guided radiotherapy have been proposed in order to reduce this effect[29,30]. In recent years, the use of a MR-linear accelerator to treat prostate patients has been reported in literature[31-33].

Adaptive radiotherapy (ART) is a solution to take into account daily patient anatomy changes. It allows to reduce unwanted dose to the target and organs at risk by adjustment of the treatment plan to the current patient anatomy[34].

One ART possibility is to perform a new CT images upon identifying unacceptable changes in patient anatomy and then update treatment plan. In online ART, daily CT imaging can be sent to the appropriate system, which will compare it with the reference plan. This system analyzes the occurrence of possible displacements of structures and changes in tissues volume. Based on this, the system automatically reconstructs contours of the tissues to their current shape. The dose distribution is recalculated and a new treatment plan is created. The updated treatment plan is then carried out on the therapeutic machine. Offline ART facilitates systematic assessment of anatomical changes and comprehensive adaptation through periodic updates of treatment plans.

The aim of the work is to analyze daily dosimetric and volumetric changes in PTV (prostate) and organ at risks bladder and rectum.

Material and methods

The analysis was carried out for 726 kVCT daily examinations for 30 patients treated with prostate cancer. Patients were treated with helical technique on a Radixact (Accuray Inc., USA) accelerator, with 6 MeV energy. Patients were irradiated up to a prescribed dose of 46-78 Gy with the fraction dose of 2–3 Gy (20–39 fractions). Each patient was asked to drink half a liter of water half a hour before CT examination. A CT images was acquired. Next, the PTV and internal organs volumes were delineated on those images. The treatment plan was carried out in the Precision treatment planning system (TPS). This plan was used to irradiate patients throughout the entire course of treatment. Also each patient was asked to drink a half a liter of water half a hour before every start of the treatment. Every day before starting treatment, patients were also asked to drink a half a liter of water half a hour before to ensure that the bladder was filled in each therapeutic fraction to a level similar to that during the CT examination used for treatment planning. Next, patients were positioned on the treatment couch by aligning the lasers to the three tattoos on pelvic area. Daily setup control started. Helical fan beam kVCT imaging was performed using the ClearRTTM Helical kVCT system. Next, these images were imported into the PreciseART module. Contours of PTV, bladder, rectum and other internal organs have been copied onto these daily kVCT images. This module automatically reconstructs contours of the PTV and internal organs to their current shape in the event of changes in their position and volume, The new, update dose distributions were recalculated and a new treatment plans were created for 726 kVCT examinations. The new plan was not used clinically. New values of volumes for PTV, bladder and rectum were read from these treatment plans. Next, daily fraction report was generated, which includes, among others things, projected doses values for PTV, bladder and rectum (**Figure 1**).

Dose ID	Line Style	Dose Details
D1	—	Total Planned Dose
D2	- - -	Projected Dose

Contour	Color	Max Dose		Min Dose		Mean Dose	
		D1	D2	D1	D2	D1	D2
BLADDER		56.26	57.64	1.86	1.91	20.89	22.11
CTV		56.36	58.14	54.41	52.17	55.19	56.57
PTV		57.08	58.49	47.46	43.13	55.02	56.20
RECTUM		55.34	55.62	2.44	2.06	23.35	20.97

Figure 1. Daily fraction report including projected doses values for PTV, bladder and rectum.

The analysis was performed for projected Mean Dose [Gy] values. This is the projected dose to a given structure, which will be delivered in the remaining fractions, under the assumption that the anatomical structures retained the same contours (volumes) throughout the remaining treatment fractions. Volumes and dose values for the PTV, bladder, and rectum from the CT study performed before the start were adopted as a baseline, reference values. The percentage differences *Vol* between the current organ volume *Vact* and the corresponding reference volume *Vref* were calculated according to formula[1]. As well as the percentage differences *Dose* between the projected current dose *Dact* for a given organ and the corresponding reference dose *Dref* were calculated according to formula[2].

$$\mathrm{Vol} = \frac{Vact - Vref}{Vref} \quad (1)$$

where:
Vact – current volume value of the given organ [ml],
Vref – reference volume value of the given organ [ml].

$$\mathrm{Dose} = \frac{Dact - Dref}{Dref} \quad (2)$$

where:
Dact – projected current dose value for a given organ [Gy],
Dref – reference dose value for a given organ [Gy].

The mean values (Mean), standard deviations (SD), and median (Med.) were calculated for each patient according to the standard formulas.

Statistical analysis was conducted to evaluate the differences between the daily volume and recalculated projected dose values and the baseline for the PTV, bladder, and rectum, for each patient. The analysis was performed using a test T for the mean by comparing the mean value of sample to the reference value using an equation[3].

$$\mathrm{T} = \frac{m - mo}{\sigma / \sqrt{n}} \quad (3)$$

where:
T – calculated test value,
m – the average value of daily volumes and doses for a single patient,
mo – the reference value,
σ - standard deviation,
n – number of daily CTs for each patient.
The significance level was set at $p < 0.05$.

Results

Tables 1-3 presents the results of the average percentage differences for volumes and projected doses, their corresponding standard deviations and medians, for the bladder, rectum, and PTV, respectively. **Figure 2** shows percentage differences between volume Volact and Volref [%] for PTV, bladder, rectum for all CT scans. **Figure 3** shows percentage differences between projected dose Volact and Volref [%] for PTV, bladder, rectum for all CT scans.

Table 1. Mean values of percentage differences for volumes and projected doses, corresponding standard deviations and medians, for the bladder.

Patient nr	Bladder					
	Mean		SD		Med.	
	Vol	Dose	Vol	Dose	Vol	Dose
1	-7.3%	-6.0%	21.1%	7.8%	-15.4%	7.0%
2	3.1%	-1.4%	19.5%	2.9%	-1.6%	-0.7%
3	-12.3%	5.0%	15.1%	3.8%	-13.4%	5.7%
4	-14.1%	8.5%	23.0%	5.9%	-17.0%	8.4%
5	-12.5%	-3.2%	4.9%	0.6%	-12.8%	-3.3%
6	-19.2%	-7.3%	10.3%	2.5%	-22.2%	-7.3%
7	-21.7%	-5.5%	15.2%	2.4%	-22.0%	-5.9%
8	6.8%	5.4%	26.0%	2.5%	10.3%	5.3%
9	-0.2%	-2.9%	6.0%	2.6%	0.0%	-2.2%
10	15.8%	-9.0%	23.6%	1.8%	14.4%	-8.8%
11	-7.3%	4.7%	21.1%	14.8%	-15.4%	3.7%
12	-19.4%	-1.1%	6.2%	0.8%	-19.4%	-1.1%
13	0.0%	6.1%	20.7%	5.7%	-11.0%	7.4%
14	29.3%	2.7%	27.8%	5.1%	27.4%	4.2%
15	-7.7%	-3.5%	17.3%	1.7%	-15.9%	-3.4%
16	-5.2%	6.4%	22.2%	10.5%	-6.3%	9.3%
17	-3.3%	-2.0%	18.4%	1.1%	-4.3%	-1.6%
18	18.5%	11.8%	18.9%	3.0%	17.6%	11.7%
19	-20.3%	1.4%	17.7%	9.6%	-20.6%	3.2%
20	6.9%	-1.0%	9.9%	2.4%	7.9%	-0.4%
21	-2.5%	0.5%	10.8%	1.5%	-4.6%	0.3%
22	40.7%	2.1%	35.5%	10.0%	37.8%	-0.5%
23	-7.7%	0.0%	7.4%	0.0%	-7.6%	0.0%
24	0.3%	24.8%	23.2%	10.8%	-5.2%	28.7%
25	-6.8%	0.7%	7.5%	0.9%	-76.0%	0.4%
26	-10.8%	0.0%	26.8%	2.8%	-19.9%	-0.2%
27	17.3%	3.7%	23.6%	3.8%	23.1%	4.0%
28	-14.9%	0.8%	7.9%	1.5%	-15.7%	1.4%
29	-20.4%	-4.7%	10.7%	3.9%	-21.0%	-3.7%
30	-7.4%	0.1%	16.0%	0.1%	-10.4%	0.1%

Table 2. Mean values of percentage differences for volumes and projected doses, corresponding standard deviations and medians, for the rectum.

Patient nr	Rectum					
	Mean		SD		Med.	
	Vol	Dose	Vol	Dose	Vol	Dose
1	16.0%	-0.2%	12.9%	-0.2%	13.7%	1.0%
2	10.1%	8.8%	12.0%	8.8%	11.9%	8.7%
3	5.9%	-11.4%	13.1%	-11.4%	4.9%	-12.3%
4	19.7%	7.0%	10.4%	7.0%	15.3%	6.4%
5	-4.9%	-2.1%	8.7%	-2.1%	-7.4%	-2.5%
6	27.1%	15.9%	9.5%	15.9%	28.1%	17.2%
7	9.4%	1.1%	6.4%	1.1%	11.6%	1.2%
8	11.1%	3.4%	6.2%	3.4%	12.5%	3.3%
9	2.1%	0.4%	8.9%	0.4%	0.0%	-0.8%
10	1.0%	4.5%	6.3%	4.5%	-0.6%	3.6%
11	16.0%	4.3%	12.9%	4.3%	13.7%	1.4%
12	17.3%	4.2%	5.8%	4.2%	16.5%	4.5%
13	21.7%	-13.8%	10.8%	-13.8%	19.9%	-13.9%
14	16.6%	-8.2%	25.2%	-8.2%	11.2%	-8.9%
15	10.1%	9.1%	6.2%	9.1%	11.0%	9.9%
16	14.8%	0.7%	12.0%	0.7%	9.3%	-0.2%
17	14.7%	-2.5%	9.3%	-2.5%	15.3%	-1.9%
18	-10.5%	-15.6%	9.3%	-15.6%	-10.9%	-15.1%
19	28.9%	3.6%	12.5%	3.6%	26.5%	4.0%
20	1.0%	15.3%	6.2%	15.3%	3.1%	15.9%
21	3.4%	0.4%	8.3%	0.4%	1.5%	0.1%
22	10.3%	-6.4%	19.9%	-6.4%	0.7%	-5.5%
23	32.5%	0.0%	6.8%	0.0%	32.8%	0.0%
24	14.2%	-25.4%	14.4%	-25.4%	10.2%	-25.9%
25	22.1%	10.4%	9.1%	10.4%	19.4%	10.7%
26	15.6%	8.6%	12.5%	8.6%	13.0%	9.0%
27	28.4%	-1.0%	11.4%	-1.0%	29.2%	-1.2%
28	3.8%	-0.5%	12.9%	-0.5%	0.9%	-1.0%
29	20.6%	14.6%	7.9%	14.6%	19.0%	14.6%
30	16.5%	-0.1%	11.2%	-0.1%	15.6%	-0.1%

Table 3. Average percentage differences for volumes and projected doses, corresponding standard deviations and medians, for PTV.

Patient nr	PTV					
	Mean		SD		Med.	
	Vol	Dose	Vol	Dose	Vol	Dose
1	3.8%	0.9%	2.0%	0.8%	4.1%	0.7%
2	4.1%	-0.1%	1.7%	0.5%	4.0%	-0.2%
3	5.9%	0.6%	1.5%	0.3%	5.9%	0.6%
4	3.0%	2.6%	2.6%	0.3%	3.2%	2.6%
5	5.7%	-1.3%	2.6%	0.3%	6.2%	-1.3%
6	4.2%	-1.4%	1.0%	1.1%	4.3%	-1.5%
7	9.4%	0.5%	1.3%	1.0%	9.3%	1.3%
8	4.4%	1.3%	1.1%	0.2%	4.4%	1.3%
9	6.6%	-0.7%	1.4%	0.4%	6.8%	-0.7%
10	4.7%	0.8%	2.1%	0.5%	4.4%	0.7%
11	3.8%	1.4%	2.0%	1.0%	4.1%	1.4%
12	0.5%	2.0%	1.5%	0.2%	0.3%	2.1%
13	14.4%	1.0%	4.2%	0.4%	14.1%	1.0%
14	2.7%	1.3%	2.5%	0.6%	2.1%	1.3%
15	5.5%	1.1%	2.2%	0.3%	5.4%	1.2%
16	4.6%	0.6%	2.0%	0.5%	4.5%	0.6%
17	5.5%	0.1%	1.8%	0.6%	5.4%	0.2%
18	6.5%	-0.4%	1.7%	0.3%	6.8%	-0.3%
19	7.7%	-0.6%	2.4%	0.5%	7.7%	-0.5%
20	2.5%	0.0%	1.8%	0.6%	2.6%	0.0%
21	5.0%	1.9%	1.2%	0.2%	5.1%	1.9%
22	5.4%	-1.3%	4.8%	3.3%	4.2%	-1.4%
23	6.5%	0.0%	3.6%	0.0%	7.4%	0.0%
24	7.5%	0.3%	2.1%	0.7%	6.9%	-0.2%
25	0.0%	1.2%	2.4%	0.5%	-0.2%	1.0%
26	4.7%	2.5%	4.5%	0.0%	3.7%	2.7%
27	5.1%	1.6%	1.6%	0.2%	4.8%	1.6%
28	6.3%	1.4%	2.8%	0.5%	7.0%	1.4%
29	-0.3%	1.7%	1.8%	0.4%	-0.2%	1.8%
30	4.0%	2.9%	5.5%	0.0%	3.7%	3.0%

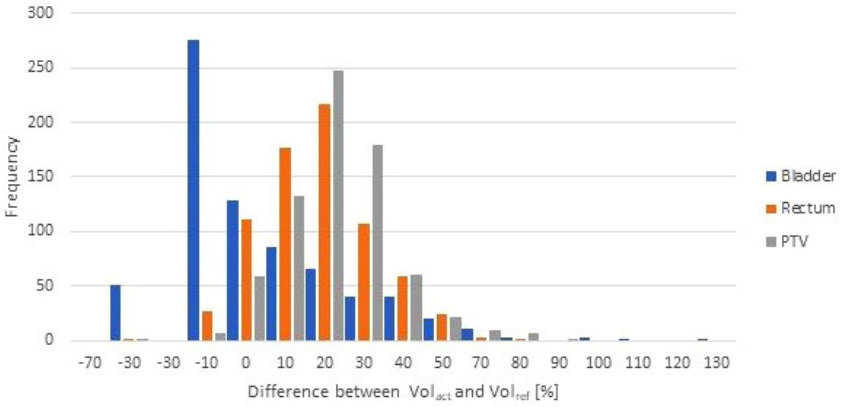

Figure 2. Percentage differences between volume Volact and Volref [%] for PTV, bladder, rectum for all CT scans.

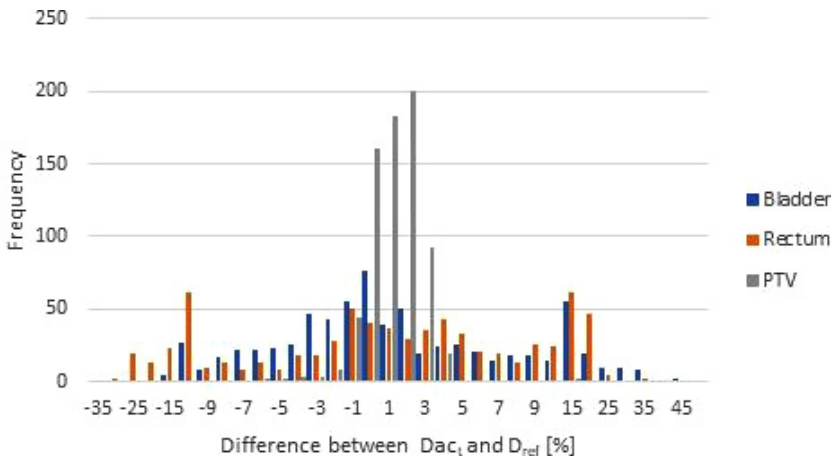

Figure 3. Percentage differences between projected dose Volact and Volref [%] for PTV, bladder, rectum for all CT scans.

Discussion

Daily imaging allow to obtain the current information on the patient's anatomy. Appropriate tools allow for copying the treatment plan onto these daily images and updating it by recalculating the dose distribution and deforming the contours of internal structures to match their current dimensions. This updated plan can be implemented on the treatment unit; however, the process is still time-consuming. Offline analysis can offer insights into the changes in internal organ volumes (contours) throughout the entire course of treatment. n this work, the results of the offline analysis of volume and dose changes for the structures were not applied clinically.

Among the analyzed structures, the bladder volume exhibited the highest degree of variability. The percentage analysis shows that mean values (Mean Vol), standard deviations (SD Vol) and median values (Med. Vol) ranged from -21.7% to 32.5%, 4.9% to 35.5% and -22.0% to 37.8%, respectively. Bladder volume changed consistently from baseline between fractions. This variability was observed even though the patient consistently drank a fixed volume of water before each radiotherapy session. Average bladder volumetric differences exceeding ±10% were observed in 15 patients, and those exceeding ±20% in 5 patients. The ±10% and ±20% thresholds were selected arbitrarily for the purpose of qualitative analysis of the results. For one patient, a high variability in volume measurements was observed (Mean Vol 40.7%, SD Vol 35.5%), which also translated into dose variability (Mean Dose 35.3%, SD Dose 10%). For another patient, mean volumetric differences value Mean Vol of 0.0% was observed. However, on the other hand, the standard deviation SD Vol was equal to 20.7%. This indicates a large spread of the results. Mean Vol values were in the range of -25.6% to 39.8%, respectively. But there is no time trend in bladder filling fluctuations for this patients.

The volume of the rectum also showed significant variations depending on the volume of rectal gas and stool content. Percentage-based analysis reveals that, mean values Mean Vol, standard deviations SD Vol and median Med. Vol values ranged from -10.5% to 32.5%, 5.8% to 25.2% and -10.9 to 32.8, respectively. Average rectum volumetric differences exceeding ±10% were observed in 21 patients, and those exceeding ±20% in 7 patients. A mean difference Mean Vol as low as 1% was recorded in two patients. For first patient, only two values exceeded 10% value (10.9% and 14.0%), while a single value reached 10.7% for second patient The standard deviation SD Vol of the differences is comparable (6.3% and 6.2%, respectively) for these two patients. The maximum value of mean volumetric differences Mean Vol reached 32.5% for another patients and was associated with a relatively narrow range of values 16.5%–45.4% (SD Vol 6.8%). The differences in rectal volume were positive, meaning that the rectum volume exceeded the reference value on every treatment day for this patient.

The volume of the PTV exhibited minor variation for each patient throughout the untired treatment period. Based on the results, percentage-based analysis reveals that, mean values Mean Vol, standard deviations SD Vol and median Med. Vol values change throughout the course of treatment ranged from -21.7% to 32.5%, 4.9% to 35.5% and -22.0% to 37.8%, respectively. The difference exceeded Mean Vol 10% for only one patient (14,4%) with the smallest and largest differences being 7.7% and 23.8%, respectively. The minimum difference Mean Vol was -0.3%, and the range of values spanned from -4,9% to 3,2%.

Changes in bladder volume strongly affected on recalculated projected dose in this organ. The percentage analysis of projected doses changes shows that mean values Mean Dose, standard deviations SD Dose and median values Med. Vol ranged from -9,0% to 24,8%, 0,0% to 14,8%,-8,8% to 28,7%, respectively. In this group of patients, no difference exceeded a Mean Dose value of 10%. For one patient, the projected Mean Dose changes values exhibited minimal variability, the minimum and maximum values were -8.7% and 8.4% (SD 5,1%), respectively. Although the volume changes showed considerable dispersion (Mean Vol 29,3%, SD Vol 27,8%). The greatest average dose difference Mean Dose was 24% (SD Dose 10.8). Analysis of the data for this patient indicates that from the 7th fraction onward, the projected dose consistently exceeded the baseline by 17% to 42%. Starting from the 7th fraction, no association can be observed between greater changes in bladder volume and increased doses.

Comparable variations are also observed for the rectum. Percentage-based analysis projected dose variations reveals that, mean values Mean Dose, standard deviations SD Dose and median Med. Dose values ranged from -25,4% to 15,9%, 0,0% to 17,2%, 0,0% to 17,2%, respectively. Average rectum dosimetric differences Mean Dose exceeding ±10% were observed in 8 patients. A Mean Dose greater than 20% was observed in only one patient (–25.4% value). The delivered dose was consistently lower than the baseline across all fractions (ranged from -32.4% to 13.6%; SD 4.0%.

Among these analyzed structures, the PTV exhibited the smallest projected dose changes. An analysis indicates that mean values Mean Dose, standard deviations SD Dose and median Med. Dose values ranged from -1,4% to 2.9%, -1.4% to 2.6% and -1.5% do 0.3%, respectively. None of the mean differences Mean Dose exceed 3%.

Statistically significant differences in daily volumes versus baseline were observed in 19, 25 and 28 patients for bladder, rectum, PTV, respectively. Similarly, statistically significant differences in daily projected doses were observed in 23, 20 and 25 patients for bladder, rectum, PTV, respectively.

Patients were asked to drink a half a liter of water, both before the CT imaging performed for treatment planning and before each subsequent therapy sessions. This hydration protocol was designed to achieve a bladder filling level comparable to the reference volume. The analysis of daily bladder volume variations shows that the bladder was filled to varying degrees compared to the baseline. In two patients, the Mean Vol exceeded 100% (and for two patients, it exceeded 90%), indicating that the bladder volume was approximately twice that observed in the planning CT Imaging. However, this volume change affected the PTV Mean Dose value (-12%) in only one patient. On the other hand, there is no information regarding the amount and frequency of fluid intake by the patient between fractions. This may have influenced the varying bladder filling levels prior to drinking water before the start of treatment. For the rectum, the planning CT imaging was performed under conditions of minimal gas content and maximal emptying of the organ, which was achieved by administering appropriate medical agents to the patient and repeating the CT examination if necessary. Nevertheless, considerable changes in rectal volume were observed. Changes in the position of the PTV during each treatment fraction and their impact on the dose were not taken into account in this study.

Conclusion

The bladder and rectum are internal organs that change their volume depending on their filling. Qualitative data analysis showed that the greatest differences in volumes and doses occurred for these structures. For the prostate, these changes were much smaller. The collected data were used to assess changes in the volume and projected dose of bladder, rectum and PTV. New updated structure contours were generated automatically. The data were not reviewed by physicians to verify the accuracy of their adaptation to the current shapes. For further research, physicians should be involved to determine whether the target and organs contours are appropriately deformed on daily CTs.

References

1. Polish National Cancer Registry. https://onkologia.org.pl/
2. Huang TC, Chou KT, Yang SN, Chang CK, Liang JA, Zhang G. Fractionated changes in prostate cancer radiotherapy using cone-beam computed tomography. Medical Dosimetry. 2015;40(3):222-225. doi:10.1016/j.meddos.2014.12.003
3. de Crevoisier R, Tucker SL, Dong L, et al. Increased risk of biochemical and local failure in patients with distended rectum on the planning CT for prostate cancer radiotherapy. International Journal of Radiation Oncology*Biology*Physics. 2005;62(4):965-973. doi:10.1016/j.ijrobp.2004.11.032
4. Heemsbergen WD, Hoogeman MS, Witte MG, Peeters STH, Incrocci L, Lebesque JV. Increased Risk of Biochemical and Clinical Failure for Prostate Patients with a Large Rectum at Radiotherapy Planning: Results from the Dutch Trial of 68 GY Versus 78 Gy. International Journal of Radiation Oncology*Biology*Physics. 2007;67(5):1418-1424. doi:10.1016/j.ijrobp.2006.11.014
5. Valicenti RK, Michalski JM, Bosch WR, et al. Is weekly port filming adequate for verifying patient position in modern radiation therapy? International Journal of Radiation Oncology*Biology*Physics. 1994;30(2):431-438. doi:10.1016/0360-3016(94)90025-6
6. de Boer HCJ, Heijmen BJM. A protocol for the reduction of systematic patient setup errors with minimal portal imaging workload. International Journal of Radiation Oncology*Biology*Physics. 2001;50(5):1350-1365. doi:10.1016/s0360-3016(01)01624-8
7. Dąbrowski A, Kukołowicz PF, Sadowska E. Quantitative evaluation of setup deviations during the course of pelvic irradiation with 4 field box technique. Nowotwory. 2001;51(2):123-128
8. Hurkmans CW, Remeijer P, Lebesque JV, Mijnheer BJ. Set-up verification using portal imaging; review of current clinical practice. Radiotherapy and Oncology. 2001;58(2):105-120. doi:10.1016/s0167-8140(00)00260-7
9. Bel A, van Herk M, Bartelink H, Lebesque JV. A verification procedure to improve patient set-up accuracy using portal images. Radiotherapy and Oncology. 1993;29(2):253-260. doi:10.1016/0167-8140(93)90255-7
10. Bijhold J, Lebesque JV, Hart AAM, Vijlbrief RE. Maximizing setup accuracy using portal images as applied to a conformal boost technique for prostatic cancer. Radiotherapy and Oncology. 1992;24(4):261-271. doi:10.1016/0167-8140(92)90233-k
11. Stroom JC, Olofsen-van Acht MJJ, Quint S, et al. On-line set-up corrections during radiotherapy of patients with gynecologic tumors. International Journal of Radiation Oncology*Biology*Physics. 2000;46(2):499-506. doi:10.1016/s0360-3016(99)00386-7
12. de Boer HCJ, Heijmen BJM. eNAL: An Extension of the NAL Setup Correction Protocol for Effective Use of Weekly Follow-up Measurements. International Journal of Radiation Oncology*Biology*Physics. 2007;67(5):1586-1595. doi:10.1016/j.ijrobp.2006.11.050
13. Dąbrowski A, Zielińska-Dąbrowska S, Kuszewski T, Lis K. Daily patient geometry correction: application of NAL and eNAL protocols. Polish Journal of Medical Physics and Engineering. 2020;26(4):181-184. doi:10.2478/pjmpe-2020-0021

14. Kukolowicz P, Mietelska M, Kiprian D. Effectiveness of the No action level protocol for head & neck patients – Time considerations. Reports of Practical Oncology & Radiotherapy. 2020;25(5):828-831. doi:10.1016/j.rpor.2020.04.005
15. Martens D, Luesink M, Huizenga H, Pasma KL. eNAL++: a new and effective off-line correction protocol for rotational setup errors when using a robotic couch. J Applied Clin Med Phys. 2015;16(6):177-185. doi:10.1120/jacmp.v16i6.5583
16. Huang TC, Chou KT, Yang SN, Chang CK, Liang JA, Zhang G. Fractionated changes in prostate cancer radiotherapy using cone-beam computed tomography. Medical Dosimetry. 2015;40(3):222-225. doi:10.1016/j.meddos.2014.12.003
17. Ahmad SS, Duke S, Jena R, Williams MV, Burnet NG. Advances in radiotherapy. BMJ. 2012;345(dec04 1):e7765-e7765. doi:10.1136/bmj.e7765
18. Connell PP, Hellman S. Advances in Radiotherapy and Implications for the Next Century: A Historical Perspective. Cancer Research. 2009;69(2):383-392. doi:10.1158/0008-5472.can-07-6871
19. Antolak JA, Rosen II, Childress CH, Zagars GK, Pollack A. Prostate target volume variations during a course of radiotherapy. International Journal of Radiation Oncology*Biology*Physics. 1998;42(3):661-672. doi:10.1016/s0360-3016(98)00248-x
20. de Crevoisier R, Melancon AD, Kuban DA, et al. Changes in the Pelvic Anatomy After an IMRT Treatment Fraction of Prostate Cancer. International Journal of Radiation Oncology*Biology*Physics. 2007;68(5):1529-1536. doi:10.1016/j.ijrobp.2007.01.069
21. McDermott LN, Wendling M, Sonke JJ, van Herk M, Mijnheer BJ. Anatomy changes in radiotherapy detected using portal imaging. Radiotherapy and Oncology. 2006;79(2):211-217. doi:10.1016/j.radonc.2006.04.003
22. Noble DJ, Yeap PL, Seah SYK, et al. Anatomical change during radiotherapy for head and neck cancer, and its effect on delivered dose to the spinal cord. Radiotherapy and Oncology. 2019;130:32-38. doi:10.1016/j.radonc.2018.07.009
23. Lim-Reinders S, Keller BM, Al-Ward S, Sahgal A, Kim A. Online Adaptive Radiation Therapy. International Journal of Radiation Oncology*Biology*Physics. 2017;99(4):994-1003. doi:10.1016/j.ijrobp.2017.04.023
24. Maruoka S, Yoshioka Y, Isohashi F, et al. Correlation between patients' anatomical characteristics and interfractional internal prostate motion during intensity modulated radiation therapy for prostate cancer. SpringerPlus. 2015;4(1). doi:10.1186/s40064-015-1382-z
25. Wong JR, Gao Z, Merrick S, et al. Potential for Higher Treatment Failure in Obese Patients: Correlation of Elevated Body Mass Index and Increased Daily Prostate Deviations From the Radiation Beam Isocenters in an Analysis of 1,465 Computed Tomographic Images. International Journal of Radiation Oncology*Biology*Physics. 2009;75(1):49-55. doi:10.1016/j.ijrobp.2008.07.049
26. Roeske JC, Forman JD, Mesina CF, et al. Evaluation of changes in the size and location of the prostate, seminal vesicles, bladder, and rectum during a course of external beam radiation therapy. International Journal of Radiation Oncology*Biology*Physics. 1995;33(5):1321-1329. doi:10.1016/0360-3016(95)00225-1
27. Ma TM, Neylon J, Casado M, et al. Dosimetric impact of interfraction prostate and seminal vesicle volume changes and rotation: A post-hoc analysis of a phase III randomized trial of MRI-guided versus CT-guided stereotactic body radiotherapy. Radiotherapy and Oncology. 2022;167:203-210. doi:10.1016/j.radonc.2021.12.037
28. Zelefsky MJ, Crean D, Mageras GS, et al. Quantification and predictors of prostate position variability in 50 patients evaluated with multiple CT scans during conformal radiotherapy. Radiotherapy and Oncology. 1999;50(2):225-234. doi:10.1016/s0167-8140(99)00011-0
29. de Muinck Keizer DM, Kerkmeijer LGW, Willigenburg T, et al. Prostate intrafraction motion during the preparation and delivery of MR-guided radiotherapy sessions on a 1.5T MR-Linac. Radiotherapy and Oncology. 2020;151:88-94. doi:10.1016/j.radonc.2020.06.044
30. Tanabe Y, Ishida T, Eto H, Sera T, Emoto Y, Shimokawa M. Patient-specific radiotherapy quality assurance for estimating actual treatment dose. Medical Dosimetry. 2021;46(1):e5-e10. doi:10.1016/j.meddos.2020.08.003
31. Tetar SU, Bruynzeel AME, Oei SS, et al. Magnetic Resonance-guided Stereotactic Radiotherapy for Localized Prostate Cancer: Final Results on Patient-reported Outcomes of a Prospective Phase 2 Study. European Urology Oncology. 2021;4(4):628-634. doi:10.1016/j.euo.2020.05.007
32. Alongi F, Rigo M, Figlia V, et al. 1.5 T MR-guided and daily adapted SBRT for prostate cancer: feasibility, preliminary clinical tolerability, quality of life and patient-reported outcomes during treatment. Radiat Oncol. 2020;15(1). doi:10.1186/s13014-020-01510-w
33. Cuccia F, Corradini S, Mazzola R, et al. MR-Guided Hypofractionated Radiotherapy: Current Emerging Data and Promising Perspectives for Localized Prostate Cancer. Cancers. 2021;13(8):1791. doi:10.3390/cancers13081791
34. Yan D, Vicini F, Wong J, Martinez A. Adaptive radiation therapy. Phys Med Biol. 1997;42(1):123-132. doi:10.1088/0031-9155/42/1/008