Pathology & Oncology Research (2019) 25:995–1002
https://doi.org/10.1007/s12253-018-0436-2

ORIGINAL ARTICLE

Prone Positioning on a Belly Board Decreases Rectal and Bowel Doses in Pelvic Intensity-Modulated Radiation Therapy (IMRT) for Prostate Cancer

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Received: 1 May 2018 / Accepted: 29 May 2018 / Published online: 7 June 2018

Abstract
The presence of normal tissues in the irradiated volume limits dose escalation during pelvic radiotherapy (RT) for prostate cancer. Supine and prone positions on a belly board were compared by analyzing the exposure of organs at risk (OARs) using intensity modulated RT (IMRT). The prospective trial included 55 high risk, localized or locally advanced prostate cancer patients, receiving definitive image-guided RT. Computed tomography scanning for irradiation planning was carried out in both positions. Gross tumor volume, clinical and planning target volumes (PTV) and OARs were delineated, defining subprostatic and periprostatic rectal subsegments. At the height of the largest antero-posterior (AP) diameter of the prostate, rectal diameters and distance from the posterior prostate wall were measured. IMRT plans were generated. Normal tissue exposure and structure volumes were compared between supine and prone plans using paired t-test. In the volumes of the prostate, PTV, colon and small bowel, no significant differences were found. In prone position, all rectal volumes, diameters, and rectum–prostate distance were significantly higher, the irradiated colon and small bowel volume was lower in dose ranges of 20–40 Gy, and the exposure to all rectal segments was more favorable in 40–75 Gy dose ranges. No significant difference was found in the exposure of other OARs. Prone positioning on a belly board is an appropriate positioning method aiming rectum and bowel protection during pelvic IMRT of prostate cancer. The relative reduction in rectal exposure might be a consequence of the slight departure between the prostate and rectal wall.

Keywords Prostate cancer · IMRT · Prone · Belly board · Small bowel · Rectum

Introduction

Prostate cancer is the second most common malignancy worldwide [1]. Its prognosis has improved as a result of adjuvant androgen deprivation therapy and the escalated dose, and the efficacy of radiotherapy (RT) [2]. Therefore, pelvic irradiation including the prostate, seminal vesicles, and lymphatic regions is an integral component of high-risk [3], organ-confined, and locally advanced prostate cancer management.

Although RT is getting more targeted, the tolerance of normal tissues limits dose escalation and tumor control probability, and makes the incidence of acute and chronic gastrointestinal (GI) morbidity higher, aggravating the co-existing urological, sexual, and psychological problems of the increasing number of cancer survivors [4]. The phenomena of GI injury secondary to RT are described as pelvic radiation disease (PRD) [5]. Acute PRD, occurring during or shortly after RT, presents in abdominal–anorectal pain, lack of appetite, nausea, vomiting, bloating, diarrhea, and rectal bleeding. Chronic complications developing between 1.5 and 6 years after the completion of pelvic RT may manifest as anorexia, lactose intolerance, malabsorption, fistula formation, bowel obstruction, perforation, and fecal incontinence [6]. The symptoms depend on the degree and extent of the tissue damage [7] and have a significant adverse effect on the patient's quality of life [8]. The most important factors related to the probability of the complications are the total dose of RT delivered to the pelvic organs, the applied regime, the size of the treatment fields, the presence

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of radiation implants, concurrent chemotherapy, and the volume of the bowel irradiated [7].

The irradiated bowel volume can be minimized by surgical and non-surgical methods [9]. Surgical means include pelvic reconstruction, reperitonealization of the pelvic floor, placement of an omental sling, and the inserting of a synthetic prosthesis under the small intestine. Radiotherapeutic techniques embrace among others the use of intensity modulated (IM) and image-guided (IG) RT, adaptive irradiation, a shrinking field, modified fractionation schemes, endorectal balloons, tissue spacers, bladder distension, and optimal patient position.

The purpose of our study was to assess whether a supine or prone position on a belly board, applying IMRT technique, results in the reduction of the radiation dose to organs at risk (OARs), primarily the rectum, colon, and small intestines during pelvic RT of prostate cancer patients.

Materials and Methods

Patient Population

The prospective analysis included patients with a histologically confirmed, high risk [10], localized or locally advanced (2009 TNM classification [11] stage T2–4 N0–1 M0) prostate cancer graded according to the Gleason score system [12], receiving a definitive pelvic RT at the Department of Oncotherapy, University of Szeged, Hungary. The tumor stage assessment was based on the findings of thoracic computed tomography (CT), abdominal and pelvic CT and magnetic resonance imaging (MRI), and whole-body bone scintigraphy. Clinical and pathological data were extracted from the patient files.

Patient Positioning and Computed Tomography Scanning

Patients were positioned on the supine and prone pelvis modules of the All in One (AIO) Solution (ORFIT, Wijnegem, Belgium) system. In supine pose, the patient was positioned with bent knees, and the genitalia were distracted with extruded polystyrene blocks. In prone position, a belly board was applied to allow the abdomen to extend into its aperture, and a polystyrene wedge was placed between the buttocks. For immobilization a six-point thermoplastic mask fixation (Pelvicast system, ORFIT, Wijnegem, Belgium) was employed. All patients underwent five-millimeter slice-increment topometric CT scanning in both positions from the diaphragm to the level of 10 cm below the femoral necks, using a Somatom Emotion 6 CT Simulator (Siemens, Erlangen, Germany). CT scanning was prepared with full bladder according to our internal protocol, and following an antiflatulent diet for at least 7 days prior and during RT delivery.

Target and Critical Structure Delineation

The gross tumor volume (GTV), clinical target volume (CTV), planning target volume (PTV), and OARs were delineated in the ARIA Oncology Information System (Varian Oncology Systems, Palo Alto, CA, USA) in both positions by radiation oncologists and reviewed by an experienced radiologist. The prostate was contoured as GTV_p, the proximal thirds, or in case of involvement, the full extension of the seminal vesicles were contoured as GTV_{vs}, and pathologic lymph nodes, if present, as GTV_N, considering MRI records. CTV_N included the parailiac, upper subaortic presacral and obturator lymph nodes, contoured according to the RTOG GU Radiation Oncology Specialists Reach Consensus [13]. PTV_p included GTV_p with a 10 mm margin along the supero-inferior, left–right axis, in anterior direction and 7 mm in posterior direction. PTV_{pvs} was defined as the combination of GTV_p and GTV_{vs} with a safety margin of 10 mm and 15 mm in posterior direction and any other directions, respectively. PTV was determined as PTV_{pvs}, a 7 mm margin around CTV_N and 10 mm around GTV_N, if present. The rectum, large and small intestines, urinary bladder, femoral heads, and bony structures were outlined as OARs. The rectum was defined from the ischial tuberosities to the sigmoid flexure, but at least 2 cm above PTV_{pvs}. Each rectal section, the whole rectum (R), the segment at the height of the prostate (R1), and R1 + 10 mm along the supero-inferior axis (R2) were individually delineated. Large and small bowel volumes contained all identifiable segments. The bladder was delineated from the apex to the dome [14].

Rectal Extension and Rectum–Prostate Distance Measurement

At the height of the largest antero-posterior (AP) diameter of the prostate, rectal diameters along the AP and left–right axis were defined, and perpendicular lines were created from the center and lateral edges of the back wall of the prostate to the outer anterior rectal wall in both supine and prone positions (Fig. 1). Two independent radiation oncologists performed rectum–prostate distance measurements, both of them twice.

Intensity-Modulated Radiotherapy Planning and Dosimetric Analysis

IMRT planning was performed using the Eclipse treatment planning system (Varian Oncology Systems, Palo Alto, CA, USA). The prescribed doses were 45 Gy to the center of the PTV (1.8 Gy/day, 5 days/week), 14 Gy of the PTV_{pvs} and 18 Gy of PTV_p, both delivered in daily 2 Gy fractions, 5 days per week. OAR dose constraints were determined as the following [13]: $V_{55Gy\ (bladder)} \leq 50\%$, $V_{70Gy\ (bladder)} \leq 30\%$; $V_{50Gy\ (rectum)} \leq 50\%$, $V_{70Gy\ (rectum)} \leq 20\%$; $V_{50Gy\ (colon)} \leq 50\%$, V_{70Gy}

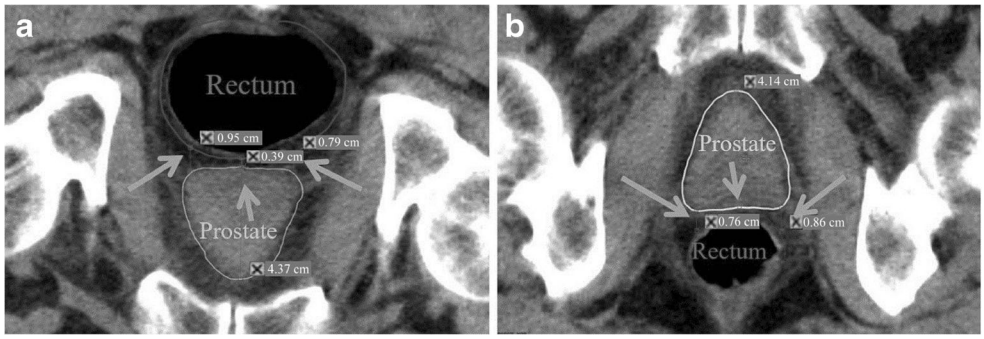

Fig. 1 Rectal extension and rectum–prostate distance measurement: At the height of the largest antero-posterior diameter of the prostate perpendiculars were created from the center and both lateral edges of the posterior prostate wall to the anterior rectal wall in both prone (**a**) and supine (**b**) positions. Larger rectal diameters in prone, smaller in supine position in case of the same patient at the same time

$_{(colon)} \leq 20\%$; $V_{52Gy\ (small\ intestine)} = 0\%$; $V_{50Gy\ (femoral\ heads)} <$ 5%. For the coverage of the PTV sliding window IMRT plans were designed in both positions with a seven-field beam arrangement using 6 MV photon beam quality, consisting coplanar beam directions as the following: in prone position 0°, 136.1°, 208.3°, 258.7°, 101.7°, 306.1° and 55.2°, in supine position 0°, 38.2°, 98°, 142°, 215.7°, 269.5° and 318.2°. For the PTV_{pvs} and PTV_p volumetric modulated arc therapy (VMAT) plans were generated in both positions using 6 MV photon beam quality, 181°–179° and 179°–181° gantry angles and 30° and 15° collimator angles, respectively. IMRT plans were created to obtain a 95% coverage of the PTV with the 95% isodose curve. The highest priority was PTV coverage, and the second one was the sparing of OARs. Planning assistant contours of the PTV, PTV_{pvs}, and PTV_p were designed with uniform margins of 15 mm, 30 mm, 40 mm, and 50 mm in both positions. Dose-volume histograms were calculated for all defined volumes. Data of mean volumes of the contoured structures, mean absolute volumes of the small bowel and colon receiving 20–50 Gy, mean relative volumes of the rectal segments receiving 30–75 Gy and of the bladder receiving 30–70 Gy doses and mean of doses regarding PTV D95, PTV_{pvs} D95, and PTV_p D95 were collected.

Radiation Treatment and Image-Guidance

Irradiation was carried out by using a Varian TrueBeamSTx (Varian Oncology Systems, Palo Alto, CA, USA) in prone position. Image-guidance was based on daily kV-cone beam CT (CBCT) scanning of the pelvis prior to treatment, using the standard mode settings: 125 kV, 80 mA, 13 ms, and half-fan bowtie filter. An automatic match algorithm was used to match the bony structures displayed on the planning CT and the CBCT.

Statistical Analysis

Data were reported as mean ± SD, mean ± SE or median values. The difference between the volumes and doses in supine and prone position was analyzed with the paired samples t-test. Intraobserver and interobserver variabilities were calculated from the mean of distances by using correlation analysis, given a correlation coefficient (r). SPSS 20.0 for Windows (SPSS Inc., Chicago, IL, USA) was used to perform the analysis. A p value <0.05 was considered significant.

Results

Patient Population

Between October 13, 2016 and October 11, 2017, 55 patients with high risk localized or locally advanced prostate cancer were administered definitive pelvic lymph node RT. Patients belonged to the elderly age group with a median [range] age of 65.60 [53.33–83.49] years, and they were mostly overweight showing a median [range] value of body mass index of 26.96 [19.37–41.62] kg/m^2. More than three-quarters of them had a cardiovascular co-morbidity, and one-third of them were smokers. All the patients had stage T2–4 N0 M0 tumor with a Gleason score ≥ 7 and a prostate specific antigen (PSA) level at the time of the diagnosis established >5 ng/ml. Most of the patients received a 6-month course of luteinizing hormone-releasing hormone analogue and antiandrogen (total androgen blockade, TAB) endocrine therapy, launched before the commencing of RT. The relevant patient and tumor characteristics are shown in Table 1.

Structure Volumes and Rectal Extension

No significant differences were found between prone and supine positions in the volumes of the GTV_p, PVS, PTV, colon, small bowel, and urinary bladder. All rectal volumes (R, R1 and R2) were significantly higher in prone position. The higher SD values of mean bladder volumes in the two positioning methods might be the consequence of pre-existing urinary symptoms, such as incontinence. At the height of the largest

Table 1 Patient and tumor characteristics

Tumor and patient characteristics	Number of patients (%)
Number of patients	55
Concurrent cardiovascular disease	44 (80.00)
History of smoking	18 (32.73)
Clinical stages	
T2	41 (74.55)
T3	12 (21.82)
T4	2 (3.64)
Gleason scores	
7	27 (48.21)
8	5 (9.09)
9	19 (33.93)
10	4 (7.14)
PSA levels on establishing the diagnosis (ng/ml)	
$10 > x > 5$	13 (23.21)
$20 > x \geq 10$	9 (16.36)
≥ 20	33 (58.93)
Endocrine treatment	49 (89.09)

AP level of the prostate, both the AP and the lateral rectal diameters were significantly higher in prone position (Table 2).

Table 2 Volumes of the delineated structures and rectal diameters in prone and supine positions

Structure	Position	Mean volume (cm^3)	Standard deviation (SD)	p value
GTV_p	Prone	130.11	49.13	0.217
	Supine	133.28	50.87	
PVS	Prone	188.77	58.19	0.748
	Supine	190.23	58.20	
PTV	Prone	1123.54	138.90	0.282
	Supine	1130.98	146.66	
Whole rectum (R)	Prone	155.13	105.26	<0.001
	Supine	95.61	45.89	
Rectal subsegment R1	Prone	50.32	31.84	<0.001
	Supine	34.76	23.64	
Rectal subsegment R2	Prone	74.37	41.51	<0.001
	Supine	50.78	27.64	
Colon	Prone	580.32	299.38	0.486
	Supine	604.37	337.12	
Small bowel	Prone	812.93	354.25	0.373
	Supine	772.71	353.21	
Urinary bladder	Prone	184.18	117.13	0.403
	Supine	192.40	112.56	
Rectal diameter	Position	Mean diameter (mm)	Standard error (SE)	p value
AP	Prone	50.60	2.20	<0.001
	Supine	36.70	1.50	
Lateral	Prone	43.80	2.60	0.003
	Supine	35.90	1.80	

Rectum–Prostate Distance

The rectum–prostate distance measured from the center of the rear prostate wall to the outer anterior rectal wall was significantly higher in prone position. No significant differences in the distance values measured from the left and right edges of the posterior prostate wall were found. Both intraobserver and interobserver variabilities showed close correlation (Table 3).

Normal Tissue Doses

A prone position with the additional use of a belly board led to a significant decrease in the absolute volumes receiving doses greater than 20 to 40 Gy in the small intestine and the colon; however, the difference between the volumes receiving 50 Gy was not significant (Table 4). In dose ranges of 40 to 75 Gy, the exposure of all rectal segments was more favorable in prone position. The relative volume receiving 30 Gy dose was lower in respect of R1 segment; nonetheless, the difference was not significant. The relative exposed volume of the urinary bladder, femoral heads, and bony structures was in accordance with the dose constraints. No significant difference was found between the positioning methods (Table 5).

Planning Target Volume Coverage

PTV coverage did not differ significantly between the two positions (PTV D95 - mean of dose 43.01 vs. 43.00 Gy, SD 0.26 vs. 0.26 in prone vs. supine position, respectively, $p = 0.782$; PTV_{pvs} D95 - mean of dose 13.36 vs. 13.35 Gy, SD 0.07 vs. 0.07 in prone vs. supine position, respectively, $p = 0.591$; PTV_p D95 - mean of dose 17.16 vs. 17.15 Gy, SD 0.09 vs. 0.07 in prone *vs.* supine position, respectively, $p = 0.435$).

Discussion

Clinically localized high-risk prostate cancer frequently shows micrometastatic spreading to the pelvic lymph nodes; therefore, RT and three years of androgen suppressing endocrine treatment are the standard of care. Dose escalation to the prostate even to 80–86.4 Gy reduces biochemical failure and the appearance of distant metastases [2]. However, survival data are controversial regarding field size [2]. There is no consensus recommendation for patient selection for pelvic RT in this population, considering the increased exposure of OARs and toxicity. 90% of patients treated with pelvic RT develop permanent alterations in bowel habits [8], 50% of them complain about adverse changes in life quality [15], and 20–40% of them assess this impact as moderate or severe [16]. The small intestine, the rectum, and to a lesser extent, the colon are dose-

Table 3 Rectum–prostate distance and intraobserver and interobserver variability correlation in prone and supine positions

Distance	Position	Mean (mm)	Standard error (SE)	p value	Intraobserver variability – Correlation coefficient (r)		Interobserver variability – Correlation coefficient (r)
					Examiner 1	Examiner 2	
Left lateral	Prone	6.50	0.40	0.062	0.92	0.90	0.89
	Supine	5.70	0.40				
Mediosagittal	Prone	2.80	0.30	0.026	0.86	0.89	0.95
	Supine	2.20	0.30				
Right lateral	Prone	5.90	0.40	0.173	0.80	0.74	0.78
	Supine	5.40	0.40				

limiting organs, tolerating a 50–60 Gy dose at conventional fractionation [17, 18]. Normal tissue complication probability (NTCP) studies suggest that the small intestine volume receiving 15 and 45 Gy (V_{15} and V_{45}) is a relevant parameter for GI morbidity [19, 20]. According to the review of Fiorino et al. [21], keeping V_{70} and V_{75} to <25 and 5%, respectively, results in a decrease in the development of late rectal bleeding. Moderate dose volumes, such as V_{40} and V_{50} are predictive for chronic late incontinence [22] and are also important in developing rectal bleeding [21]. The dosimetric analysis [23] of the anatomical subregions showed that rectal bleeding is associated with V70 of the anorectal region, fecal incontinence with V15 of external sphincter, and V55 of the iliococcygeal muscle, whereas stool frequency with V40 of the levator ani and V45 of the iliococcygeal muscle. In the prospective study of Dréan et al. [24], rectal subregions at risk have been delineated, and the authors have found that the exposure of the subprostatic anterior hemirectum and the upper part of the anal canal was 4 Gy higher in patients developing rectal bleeding.

Table 4 Small intestine and colon exposure in prone and supine position

Organ at risk	DVH parameter	Position	Mean volume (cm^3)	Standard deviation (SD)	p value
Small intestine	$V_{20\ Gy}$	Prone	79.85	89.83	<0.001
		Supine	170.34	103.62	
	$V_{30\ Gy}$	Prone	36.74	51.24	<0.001
		Supine	84.55	63.01	
	$V_{40\ Gy}$	Prone	16.99	26.08	<0.001
		Supine	32.91	31.35	
	V_{50Gy}	Prone	0.16	1.06	0.398
		Supine	0.33	1.54	
Colon	$V_{20\ Gy}$	Prone	122.43	74.52	<0.001
		Supine	181.22	109.48	
	$V_{30\ Gy}$	Prone	84.09	57.17	<0.001
		Supine	121.21	73.36	
	$V_{40\ Gy}$	Prone	53.23	44.20	0.043
		Supine	63.19	44.89	
	$V_{50\ Gy}$	Prone	2.06	4.02	0.627
		Supine	1.81	3.62	

Table 5 Exposure of rectal segments and urinary bladder in prone and supine positions

Organ at risk	DVH parameter	Position	Mean relative volume (%)	Standard deviation (SD)	p value
Whole rectum	V_{30Gy}	Prone	106.40	118.98	0.296
		Supine	89.60	7.46	
	V_{40Gy}	Prone	65.79	14.96	<0.001
		Supine	78.58	10.14	
	V_{50Gy}	Prone	35.51	13.83	<0.001
		Supine	48.38	12.29	
	V_{60Gy}	Prone	17.45	8.18	<0.001
		Supine	24.04	9.11	
	V_{70Gy}	Prone	7.57	4.10	<0.001
		Supine	10.43	4.97	
	V_{75Gy}	Prone	3.67	2.61	0.021
		Supine	4.58	3.19	
Rectal subsegment R1	$V_{30\ Gy}$	Prone	99.78	0.75	0.735
		Supine	99.80	0.61	
	V_{40Gy}	Prone	80.58	13.50	<0.001
		Supine	94.95	5.74	
	V_{50Gy}	Prone	52.25	14.18	<0.001
		Supine	68.55	10.90	
	V_{60Gy}	Prone	32.37	10.90	<0.001
		Supine	40.49	10.13	
	V_{70Gy}	Prone	16.51	5.83	<0.001
		Supine	20.74	7.14	
	V_{75Gy}	Prone	8.79	4.52	0.099
		Supine	9.97	5.67	
Rectal subsegment R2	V_{30Gy}	Prone	99.52	1.21	0.001
		Supine	98.61	1.96	
	V_{40Gy}	Prone	78.55	12.66	<0.001
		Supine	91.45	6.05	
	V_{50Gy}	Prone	49.40	13.14	<0.001
		Supine	64.83	9.89	
	V_{60Gy}	Prone	28.95	9.04	<0.001
		Supine	37.43	8.76	
	V_{70Gy}	Prone	13.52	4.75	<0.001
		Supine	17.86	5.79	
	V_{75Gy}	Prone	6.82	3.59	0.051
		Supine	7.86	4.43	
Bladder	V_{30Gy}	Prone	95.82	7.10	0.657
		Supine	95.45	5.13	
	V_{40Gy}	Prone	67.99	18.89	0.687
		Supine	68.78	16.13	
	V_{50Gy}	Prone	41.90	16.53	0.982
		Supine	41.86	14.84	
	V_{60Gy}	Prone	26.73	11.77	0.235
		Supine	25.36	10.62	
	V_{70Gy}	Prone	15.91	7.90	0.276
		Supine	14.94	7.31	

Technological advances allowing rectal sparing include endorectal balloons filled with air or water, reducing the exposure of the posterior rectal wall by moving away the prostate from it, depending on the volume of the balloons [25]. Bioabsorbable tissue spacers injected into the retroprostatic fascia also increase the distance between the prostate and the anterior rectal wall, resulting in significant reduction in both acute and late GI toxicities [26]. Regarding patient positioning, Zelefsky et al. [27] and McLaughlin et al. [28] have described significantly lower rectal doses in prone position, using 3DCRT technique. The results have also been confirmed in the phase II trial of O'Neil et al. [29] and by Bajon et al. using tomotherapy [30]. Nevertheless, Baylay et al. [31] have found supine position more favorable by using larger PTV margins in prone position, and Kato et al. [32] by applying IMRT in supine and 3DCRT in prone position. In prone position, the decreased rectal exposure is a result of the posterior retraction of the rectum and anterior displacement of the prostate; however, the accurate mechanism of it is unknown [27, 28, 32].

In the 3D-CRT of rectal malignancies, a prone treatment position without a belly board compared to a supine posture results in the reduction of the irradiated small intestine volume [33]. In case of pelvic malignancies, a larger decrease in the small intestine exposure can be obtained by the additional use of a belly board in comparison with both prone position alone [34, 35] or supine position [36, 37]. The use of IMRT technique decreases bowel doses by 40–50%, as compared to 3D-CRT [38, 39]. In case of gynecological and rectal tumors, a belly board assisted prone position using IMRT results in a further reduction in the irradiated volume of the small intestine, even in low dose areas [40, 41]. The advantage of the use of a belly board is also confirmed in postoperatively irradiated patients [42, 43], which might be the consequence of the significantly higher mobilization of the small intestine loops. The findings of Fu et al. [44] show that the gain of the use of a belly board is greater if the irradiated small intestine volume close to the target volume is larger. According to that study, a prone position on a belly board results in a remarkable decrease in the small bowel volume in case of gynecological malignancies but not in rectal cancer patients. A full bladder also functions as a natural spacer, transposing the small intestine loops from the pelvis to the abdomen, resulting in a reduction in the irradiated small intestine volume [42].

In rectal cancer patients treated with chemo-radiotherapy, Baglan et al. [19] have demonstrated an explicit relationship between the volume of the small bowel receiving at least 15 Gy and the degree of acute small intestinal toxicity. Robertson et al. [45] have proved that a reduction in the small bowel volume receiving low dose results in a significant decrease in the complication rate. Both authors have delineated the single small intestinal loops. In case of gynecological cancer patients treated with pelvic IMRT, Roeske et al. [20] have detected that drawing the abdominal space, the risk of acute GI toxicity is five times as little for small bowel volume of 100 cm^3 gaining the prescribed 45 Gy dose as of 200 cm^3. According to Gunnlaugsson et al. [46], the former technique is the recommended contouring method instead of delineating the abdominal space. Gunnlaugsson et al. have observed strong correlation between the occurrence of early side effects and small intestinal loop exposure, and no significant connection with the peritoneal cavity.

Our study was limited by the lack of delineating the penile bulb, and the relatively small number of patients involved, which however was double the number of patients previously reported. As most papers have described larger intrafraction prostate and respiratory motion in prone position [11] and literature data [47] show that a 3 mm PTV margin allows for CTV to be covered for 99% of cases when daily CBCT is used, accurate patient repositioning, daily reconstruction of the rectum, prostate safety margins, early toxicity and life quality during and after RT were also evaluated, and found to be similar to literature data of patients treated in supine position. These promising results have recently been submitted. Late toxicities need further examination due to the short follow-up period.

In conclusion, in the pelvic IMRT for prostate cancer, a prone position on a belly board decreases the irradiated small bowel volumes even in low dose ranges and contributes to rectal sparing. The relative dose reduction in the rectal exposure might be a consequence of the slight departure between the prostate wall and the rectal wall, as consistent with the literature, and the increasing volume and diameters of the rectum generated by the displacement of rectal gases. Considering the dosimetric advantages, prone position on a belly board could be recommended for the pelvic IMRT of prostate cancer.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The study was registered on September 19, 2016 by the Human Investigation Review Board, Regional Human Biomedical Research Ethics Committee, Albert Szent-Györgyi Health Centre, University of Szeged, Hungary, registration number: WHO 3856/2016.

Informed Consent Informed consent was obtained from all individual participants included in the study.

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