

The Effect of Treatment Position on Rectal and Bladder Dose-Volume Histograms for Prostate Radiotherapy Planned with 3-Dimensional Conformal Radiotherapy, Intensity-Modulated Radiotherapy and Volumetric Modulated Arc Therapy

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Abstract

Purpose: To compare target coverage and organ at risk (OAR) sparing in the supine and prone positions with 3-dimensional conformal radiotherapy (3DCRT), intensity-modulated radiotherapy (IMRT) and volumetric modulated arc therapy (VMAT) in low- and high-risk prostate radiotherapy cases. **Materials and Methods:** Using magnetic resonance images of five healthy volunteers, six treatment plans (supine 3DCRT, prone 3DCRT, supine IMRT, prone IMRT, supine VMAT and prone VMAT) were generated. Planning target volume 1 (PTV1) was defined as the prostate gland plus the seminal vesicles with adequate margins in a high-risk setting, while PTV2 was defined as prostate only with margins in a low-risk setting. The mean dose for both PTV1 and PTV2 was set at 78 Gy. Plans generated by each of the 3 techniques were compared between the supine and prone positions using dose-volume histograms (DVHs). **Results:** For PTV1, prone 3DCRT provided a significantly higher D98% than did supine 3DCRT, and its homogeneity index (HI) was significantly better. IMRT and VMAT values did not differ significantly between the prone and supine positions. For PTV2, no values differed significantly between the supine and prone positions under any treatment plan. With respect to OAR, the rectal Dmean, D2%, V50, and V60 values of PTV1 were

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statistically higher in supine 3DCRT than in prone 3DCRT, while there were no significant differences in rectal values between the supine and prone positions with IMRT or VMAT. The rectal Dmean, V50, V60, V70, and V75 values of prone 3DCRT were significantly higher than those of supine IMRT or supine VMAT. There were no significant differences in any values for the rectum and bladder for PTV2. **Conclusion:** Although prone 3DCRT was found to be superior to supine 3DCRT in terms of rectal sparing in high-risk prostate cancer, IMRT and VMAT techniques could possibly cover this disadvantage.

Keywords

Prostate Radiotherapy, Dosimetric Comparison, 3DCRT, IMRT, VMAT

1. Introduction

External beam radiation therapy (RT) for prostate cancer has been widely used as an important option for radical treatment, and higher dose delivery to the prostate has been known to improve outcome. Although advanced radiation treatment techniques are available, such as 3-dimensional conformal RT (3DCRT), intensity-modulated RT (IMRT), and volumetric modulated arc therapy (VMAT), rectal toxicity is amplified with increased radiation doses.

The selection of treatment position is a critical choice in RT. The choice of position can alter the external contour of the treated area and has the potential to alter the spatial relationship between internal organs. Several authors have demonstrated that the rectal dose is reduced in the prone position [1]-[3]. However, in most previous reports, rectal doses were evaluated in patients treated with 3DCRT, and the effect of patient position on normal tissue doses in IMRT or VMAT is not well known.

The aim of the present study was to compare target coverage and organ at risk (OAR) sparing in the supine and prone positions with 3DCRT, IMRT and VMAT in low- and high-risk cases in order to determine whether differences in the spatial relationship between the critical organs and the target would have an impact on dosimetric improvement in treatment planning.

2. Materials and Methods

2.1. Patient Population

Five healthy male volunteers were included in the present study. All volunteers gave their informed consent before the investigation began, after being provided with a detailed explanation of the scope and methods to be used. Each volunteer was asked not to empty his bladder for 1 hour before the imaging sessions. No rectal protocol was specified before the imaging sessions.

For treatment planning, 3-tesla magnetic resonance (MR) images were used because we anticipated an increase in the accuracy of delineation of the target or organs. In addition, there was no radiation exposure for normal volunteers.

MRI scans were made of each volunteer in the prone and supine positions on a flat board. No immobilization devices were used. The scans were performed with a 3T Achieva Quasar Dual (Philips Medical Systems, Best, The Netherlands) using T2-weighted fast spin-echo (repetition time/echo time, 4930 - 5620 msec/90 msec; 90° flip angle; length, 21 ET; 2.6 SENSE factor; no fat suppression; thickness, 2 mm; gap, 0 mm). An image data acquisition matrix of 490 × 490 or 448 × 436 was used with a rectangular field of view of 400 × 400 mm or 360 × 360 mm. Acquisition time was from 5 minutes 35 seconds to 7 minutes 7 seconds. MR images were transferred to the treatment planning system (ECLIPSE® version 10.0; Varian Medical Systems, Inc., Palo Alto, CA, USA), and all structures were postulated as water-equivalent material. The supine scan was performed initially with the prone scan following immediately.

2.2. Target and OAR Delineation

The prostate, seminal vesicles, rectum and bladder were delineated by one of the investigators to minimi-zepo-

tential interobserver variations. Clinical target volume 1 (CTV1) consisted of the prostate gland plus the seminal vesicles in a high-risk setting, while CTV2 was defined as prostate only in a low-risk setting. Planning target volumes PTV1 and PTV2 included CTV1 and CTV2, respectively, plus an 8-mm safety margin, except at the prostate gland-rectum interface, where a 5-mm margin was used. The bladder and rectum were considered to be solid organs, and the outer circumference was drawn. The bladder was contoured from its base to the dome, and the rectum from 1.0 cm above the upper end of PTV1 to 1.0 cm below the lower end of PTV1.

2.3. Treatment Planning

Six treatment plans (supine 3DCRT, prone 3DCRT, supine IMRT, prone IMRT, supine VMAT and prone VMAT) were generated for each volunteer. With a conventional fractionation scheme (39 daily fractions of 2 Gy), a dose of 78 Gy was prescribed as the mean dose for PTV1 and PTV2 with 10 m ega volt X-rays in all plans. The anisotropic analytical algorithm (AAA) version 10.0.28 with a grid size of 2.5 mm was adopted as the computational algorithm. For 3DCRT plans, a six-field isocentric coplanar technique was planned, as described by Zelefsky *et al.* [3]. This technique consists of lateral opposed fields and four oblique fields at 35° from the coronal plane; the plan was to deliver 50% of the dose laterally and 50% from the four equally-weighted oblique fields.

For the IMRT plans, a seven-field coplanar with segmental multileaf collimation delivery technique was adopted. Plans were optimized using an inverse planning module. For VMAT via RapidArc (Varian Medical Systems, Palo Alto, CA), one single rotation from 179° - 181° in clockwise direction (Varian IEC scale) was used. The collimator was 30° for all cases. Our plan acceptance criterium for prostate cancer IMRT and VMAT was that more than 95% of the prescribed dose should be delivered to more than 95% of the PTV volume (D95%). The following rectal constraints are used: V75 < 15%, V70 < 20%, V65 < 25%, and V60 < 35% [4]. The 50% isodose line needed to fall within the rectal contour as much as possible on any individual image slice. For the bladder [5] the constraints were as follows: V75 < 25%, V70 < 35%, and V65 < 50%.

2.4. Dosimetric Analysis and Plan Comparison

Plans generated by each of the 3 techniques were compared using dose-volume histograms (DVHs). In compliance with the International Commission on Radiation Units and Measurements (ICRU) 83 report ICRU [6], D98%, D50%, and D2% values were evaluated for PTV1 and PTV2. In accordance with ICRU guidelines [6], the homogeneity index (HI) was calculated as follows:

$$HI = (D2\% - D98\%)/D50\% \quad (1)$$

To characterize the degree of dose conformity, the Dice similarity coefficient (DSC) was used [7]:

$$DSC = 2 \times (TV \cap PTV)/(TV + PTV) \quad (2)$$

In Equation (2), TV was the treated volume. The optimal value for DSC is 1. D98% was used to delineate the TV according to the ICRU guidelines.

For the OAR, several dosimetric indexes were considered: V20, V50, V60, V70, and V75 were the OAR volumes (expressed as a percentage) that received doses of at least 20, 50, 60, 70, and 75 Gy, respectively. The mean dose and the near-maximum absorbed dose (D2%) were also recorded. The patient-averaged DVHs for PTV1, PTV2, and rectal and bladder values were compared in the supine and prone positions.

For statistical analysis, results were compared using a two-sided paired t-test. The threshold for statistical significance was set at $P < 0.05$. All statistical analyses were carried out using JMP Version 5 (SAS Institute, Cary, NC, USA).

3. Results

Table 1 shows the dose characteristics for CTV1, CTV2, PTV1, PTV2, rectum and bladder. No significant differences in volumes were noticed except for the bladder.

For PTV1 (**Table 2(a)**), prone 3DCRT provided a significantly higher D98% than did supine 3DCRT, and HI was significantly better in prone 3DCRT. D2%, D50%, and DSC values planned by 3DCRT did not differ significantly. Additionally, no values planned by IMRT and VMAT differed significantly between the prone and supine positions. For PTV2 (**Table 2(b)**), no values differed significantly between supine and prone positions in

Table 1. Structure volume information for the supine and prone positions.

	Supine	Prone	<i>p</i> -value
CTV1 volume (cm ³)	39 ± 12.0 (21.7 - 50.6)	40.0 ± 12.8 (21.7 - 53.4)	n.s
PTV1 volume (cm ³)	128.3 ± 23.9 (94.2 - 148.9)	134.2 ± 31.1 (87.9 - 164)	n.s
CTV2 volume (cm ³)	27.1 ± 11.1 (13.0 - 40.2)	25.6 ± 10.3 (15.4 - 41.7)	n.s
PTV2 volume (cm ³)	82.74 ± 23.6 (51.9 - 106.3)	79.5 ± 21.0 (56.8 - 109.9)	n.s
Rectal volume (cm ³)	38.7 ± 20.3 (21.4 - 71.6)	43.5 ± 19.5 (21.3 - 68.6)	n.s
Bladder volume (cm ³)	236.0 ± 107.7 (138.2 - 398.6)	257.9 ± 111.3 (152.5 - 425.9)	0.003

Abbreviations: CTV = clinical target volume; PTV = planning target volume; n.s. = not significant.

any of the three treatment plans.

With respect to OAR, the rectal D2%, V50, and V60 values of PTV1 were statistically higher with supine 3DCRT than with prone 3DCRT. When supine and prone positions with IMRT or VMAT were compared, there tended to be higher rectal values in supine position, however there was no significant difference in any rectal value (**Table 3(a)**). For the bladder, only D2% in prone 3DCRT was higher than supine 3DCRT. No significant differences in other values were observed between the supine and prone positions (**Table 4(a)**). For PTV2 (**Table 3(b)**, **Table 4(b)**), there was no significant difference in any value for the rectum and bladder, although there tended to be a higher irradiated volume of the rectum in the supine position, especially in 3DCRT.

Because differences in rectal dose were noted between prone 3DCRT and supine 3DCRT for PTV1, we compared rectal values for prone 3DCRT, supine IMRT and supine VMAT. The rectal Dmean, V50, V60, V70, and V75 values for prone 3DCRT were found to be significantly higher (**Table 5**). Although the rectal V20 value for 3DCRT was lower than that for IMRT or VMAT, the differences were not significant, and supine IMRT and VMAT were found to be superior to prone 3DCRT in terms of rectal sparing. Compared to supine IMRT, supine VMAT provided significantly better rectum wall sparing for V50 and V60, but not for D2% and V75, which were not significant.

4. Discussion

There has been a debate over the supine versus prone position for some years, and the published literature demonstrates variations in results between the use of these positions for prostate cancer radiotherapy. Several authors have demonstrated that, with 3DCRT, the rectal dose is reduced in the prone position [1] [2] [8]. Therefore, from the viewpoint of dose reduction to the rectum, the prone position may be recommended in patients treated with 3DCRT. We also found that prone 3DCRT was associated with better rectal dose reduction than supine 3DCRT, especially in cases of including seminal vesicles in the CTV. It is considered that seminal vesicle position variability based on position may possibly affect this result. The position of the seminal vesicles in the supine position, which affects the PTV1 area, may be associated with the lower D98% and higher HI of PTV1 compared to values in the prone position. In contrast, this is not the case with IMRT. Kato *et al.* [9] compared rectal dose between supine 3DCRT, prone 3DCRT, and supine IMRT, concluding that, although prone 3DCRT resulted in significant improvements in some patients compared with supine 3DCRT, supine IMRT was significantly superior to prone 3DCRT. In the present study, we also found that supine IMRT and VMAT were superior to prone 3DCRT for rectum sparing. Between supine IMRT and supine VMAT, rectal V50 and V60 with supine VMAT were superior to that with supine IMRT which is consistent with the results of previous reports [10]-[12].

There was a significant difference in bladder volume between the supine and prone positions. Because the supine scan was performed initially with the prone scan following in the present study, this result may have been due to increased bladder filling during examination. In the present study, the results for bladder sparing did not show significant differences between the prone and supine positions except in the D2% value of 3DCRT in PTV1, which might have been affected by bladder volume.

McLaughlin *et al.* [8] found smaller differences in percent rectal volume at >80% and >90% of the isocenter dose for prone versus supine positioning for prostate-only treatments compared to prostate and seminal vesicle

Table 2. (a) Summary of the dosimetric results for PTV1; (b) Summary of the dosimetric results for PTV2.

		Supine		Prone		
		Ave.	Range (min - max)	Ave.	Range (min - max)	<i>p</i> -value
3DCRT	D98%	74.35	74.11 - 74.71	74.78	74.44 - 75.08	0.049
	D2%	79.71	79.32 - 80.47	79.45	79.02 - 79.90	n.s.
	D50%	78.30	78.14 - 78.39	78.26	78.16 - 78.36	n.s.
	HI	0.068	0.061 - 0.070	0.060	0.053 - 0.070	0.007
	DSC	0.728	0.701 - 0.760	0.753	0.706 - 0.808	n.s.
IMRT	D98%	74.46	73.86 - 74.76	74.65	74.22 - 75.19	n.s.
	D2%	80.14	80.02 - 80.21	80.29	79.86 - 81.29	n.s.
	D50%	78.16	78.09 - 78.22	78.09	77.93 - 78.18	n.s.
	HI	0.073	0.068 - 0.081	0.072	0.063 - 0.091	n.s.
	DSC	0.897	0.886 - 0.911	0.898	0.865 - 0.921	n.s.
VMAT	D98%	75.66	74.54 - 78.15	75.27	70.34 - 77.95	n.s.
	D2%	79.73	79.49 - 80.22	80.99	79.68 - 81.79	n.s.
	D50%	78.12	78.01 - 78.17	78.85	78.07 - 79.98	n.s.
	HI	0.058	0.046 - 0.068	0.073	0.045 - 0.146	n.s.
	DSC	0.907	0.896 - 0.925	0.886	0.840 - 0.911	n.s.

		Supine		Prone		
		Ave.	Range (min - max)	Ave.	Range (min - max)	<i>p</i> -value
3DCRT	D98%	74.36	74.07 - 74.55	74.63	74.46 - 74.84	n.s.
	D2%	79.36	79.26 - 79.46	79.44	79.28 - 79.55	n.s.
	D50%	78.34	78.32 - 78.37	78.34	78.24 - 78.38	n.s.
	HI	0.064	0.060 - 0.069	0.062	0.059 - 0.063	n.s.
	DSC	0.728	0.615 - 0.761	0.857	0.756 - 1.219	n.s.
IMRT	D98%	74.45	74.32 - 74.66	74.56	74.27 - 74.82	n.s.
	D2%	79.50	79.43 - 79.57	79.55	79.20 - 79.85	n.s.
	D50%	78.32	78.25 - 78.39	78.30	78.24 - 78.38	n.s.
	HI	0.065	0.061 - 0.067	0.064	0.056 - 0.068	n.s.
	DSC	0.846	0.720 - 0.917	0.945	0.903 - 1.071	n.s.
VMAT	D98%	76.23	76.01 - 76.64	75.90	75.31 - 76.18	n.s.
	D2%	79.48	79.21 - 79.91	79.54	79.2 - 79.89	n.s.
	D50%	78.15	78.01 - 78.67	78.03	78.01 - 78.05	n.s.
	HI	0.046	0.039 - 0.045	0.0466	0.041 - 0.054	n.s.
	DSC	0.894	0.793 - 0.922	0.909	0.885 - 0.936	n.s.

Abbreviations: Ave. = average; HI = homogeneity index; DSC = Dice similarity coefficient; n.s. = not significant; 3DCRT = 3-dimensional conformal radiotherapy; IMRT = intensity-modulated radiotherapy; VMAT = volumetric modulated arc therapy.

Table 3. (a) Summary of the dosimetric results for rectum planned for PTV1; (b) Summary of the dosimetric results for rectum planned for PTV2.

(a)						
		Supine		Prone		<i>p</i> -value
		Ave.	Range (min - max)	Ave.	Range (min - max)	
3DCRT	D2%	79.40	79.01 - 80.11	78.36	78.14 - 78.81	0.002
	Dmean	59.39	55.07 - 64.27	51.95	40.01 - 56.63	n.s.
	V20Gy	90.31	86.92 - 91.93	84.73	76.14 - 91.04	n.s.
	V50Gy	68.94	62.24 - 79.00	55.44	34.3 - 64.62	0.035
	V60Gy	61.33	51.27 - 74.74	48.64	28.19 - 57.14	0.043
	V70Gy	56.81	40.2 - 73.32	40.16	21.22 - 48.03	n.s.
	V75Gy	39.90	31.05 - 59.96	29.54	14.16 - 36.55	n.s.
IMRT	D2%	77.95	77.25 - 78.42	77.42	75.42 - 78.70	n.s.
	Dmean	44.16	44.26 - 46.88	40.75	35.57 - 43.13	n.s.
	V20Gy	89.88	88.77 - 91.09	86.57	82.38 - 92.33	n.s.
	V50Gy	37.58	31.41 - 44.15	30.19	17.79 - 34.65	n.s.
	V60Gy	27.21	21.18 - 32.39	22.61	12.33 - 27.59	n.s.
	V70Gy	22.43	11.28 - 46.32	14.90	7.06 - 19.28	n.s.
	V75Gy	9.29	5.54 - 12.71	9.55	3.55 - 12.11	n.s.
VMAT	D2%	78.53	77.62 - 79.45	79.06	77.27 - 80.70	n.s.
	Dmean	42.45	37.91 - 46.41	40.92	32.14 - 45.63	n.s.
	V20Gy	88.06	84.48 - 91.78	86.21	81.14 - 91.52	n.s.
	V50Gy	34.06	25.96 - 40.97	31.24	14.14 - 46.11	n.s.
	V60Gy	25.19	18.42 - 30.46	22.94	10.35 - 28.67	n.s.
	V70Gy	16.18	11.16 - 21.56	14.35	6.58 - 20.2	n.s.
	V75Gy	10.23	6.59 - 15.36	9.95	4.12 - 14.94	n.s.
(b)						
		Supine		Prone		<i>p</i> -value
		Ave.	Range (min - max)	Ave.	Range (min - max)	
3DCRT	D2%	77.80	77.16 - 78.33	77.32	76.43 - 77.77	n.s.
	Dmean	31.90	24.49 - 42.74	26.02	17.24 - 28.63	n.s.
	V20Gy	54.87	44.97 - 71.92	43.49	31.05 - 50.86	n.s.
	V50Gy	29.75	18.33 - 42.54	24.27	12.73 - 30.63	n.s.
	V60Gy	24.30	14.25 - 35.31	20.27	9.94 - 26.83	n.s.
	V70Gy	17.71	9.55 - 27.25	15.15	6.7 - 21.22	n.s.
	V75Gy	11.24	5.41 - 19.36	9.30	3.52 - 14.0	n.s.

Continued

	D2%	77.05	75.37 - 78.42	77.54	75.96 - 78.54	n.s.
	Dmean	31.96	25.97 - 39.78	29.24	23.01 - 34.22	n.s.
	V20Gy	64.80	52.37 - 78.79	59.61	48.46 - 73.05	n.s.
IMRT	V50Gy	23.11	15.91 - 31.33	19.76	12.79 - 22.75	n.s.
	V60Gy	15.67	10.06 - 22.06	13.89	8.34 - 18.96	n.s.
	V70Gy	9.10	5.18 - 14.07	8.68	4.58 - 12.88	n.s.
	V75Gy	5.19	2.32 - 9.29	5.42	2.46 - 8.82	n.s.
	D2%	77.77	76.17 - 79.14	78.33	76.35 - 79.27	n.s.
	Dmean	30.22	24.49 - 38.30	27.32	22.23 - 32.14	n.s.
	V20Gy	63.34	53.04 - 78.10	56.44	44.82 - 72.30	n.s.
VMAT	V50Gy	19.71	13.19 - 28.70	17.34	10.94 - 22.93	n.s.
	V60Gy	13.61	8.65 - 20.05	12.59	7.43 - 17.31	n.s.
	V70Gy	8.50	4.87 - 13.65	8.26	4.39 - 12.18	n.s.
	V75Gy	5.48	2.73 - 9.87	5.82	2.60 - 9.00	n.s.

Abbreviations: Ave. = average; 3DCRT = 3-dimensional conformal radiotherapy; IMRT = intensity-modulated radiotherapy; VMAT = volumetric modulated arc therapy; n.s. = not significant.

treatment. In the present study, although the prone position was found to be superior to the supine position with respect to rectal PTV1 values, there was no significant difference between the supine and prone positions in prostate-only treatment (PTV2), suggesting that the differences in rectal doses between the supine and prone positions were influenced primarily by movement of the seminal vesicles.

In the present study, we used AAA to calculate the dose. Because the same algorithm was used for all dose calculations, the limitation of AAA might not influence the dosimetric comparison. However, a more accurate dose calculation algorithm, such as Acuros XB (available in the Eclipse TPS), had been reported [13] [14], which could further improve the dose calculation accuracy of the dosimetric results.

Sze HC *et al.* [15] reported that double-arc could improve target volume coverage while maintaining equivalent normal tissuesparing when compared with IMRT, and single-arc achieved the greatest treatment efficiency but with the highest rectal dose. Rana S *et al.* [16] reported the partial-single arc technique in RapidArc is better in sparing the rectum and bladder without compromising plan conformity or target homogeneity when compared to the full-single arc technique. In this present study, we used seven-field IMRT plans and single-arc VMAT plans, and compared between the prone and supine positions. The selection of techniques such as the number of fields in IMRT, beam angles, and the rotation angle in VMAT might possibly influence the dosimetric results.

In addition to improvements in dose distribution, treatment results may be affected by other factors such as daily setup reproducibility, respiratory motion of the prostate, or rectal filling status. Weber *et al.* [1] demonstrated that daily setup reproducibility may be less accurate for the prone position, primarily due to systematic setup variations. We previously reported that internal organ motion is less frequent in the supine position than in the prone position using cine-MRI [17]. Treatment results may depend on institution-specific protocols for patient immobilization. Image-guided techniques, which have become widely available in recent years, may reduce interfraction motion.

5. Conclusion

The present study demonstrated that, although prone 3DCRT is superior to supine 3DCRT in terms of rectal sparing for high-risk prostate cancer, IMRT and VMAT techniques could possibly cover this disadvantage. With IMRT or VMAT, there was no significant difference between the supine and prone positions.

Table 4. (a) Summary of the dosimetric results for bladder planned for PTV1; (b) Summary of the dosimetric results for bladder planned for PTV2.

		Supine		Prone		
		Average	Range (min - max)	Average	Range (min - max)	<i>p</i> -value
3DCRT	D2%	77.85	77.54 - 78.12	78.12	77.66 - 78.42	0.003
	Dmean	28.3	17.71 - 36.27	27.24	15.44 - 33.15	n.s.
	V20Gy	48.75	30.08 - 59.19	46.06	24.42 - 63.30	n.s.
	V50Gy	24.06	14.33 - 36.68	25.23	12.89 - 31.71	n.s.
	V60Gy	21.90	11.5 - 31.61	21.63	10.49 - 27.74	n.s.
	V70Gy	16.51	8.17 - 24.57	16.96	7.58 - 22.36	n.s.
	V75Gy	10.53	5.27 - 15.76	12.16	5.01 - 16.54	n.s.
IMRT	D2%	78.42	77.38 - 78.98	78.36	77.58 - 78.89	n.s.
	Dmean	36.67	23.24 - 44.85	31.95	17.86 - 46.88	n.s.
	V20Gy	71.32	47.48 - 92.26	59.15	32.72 - 96.13	n.s.
	V50Gy	31.15	14.71 - 41.17	27.95	13.02 - 40.5	n.s.
	V60Gy	21.65	9.76 - 31.53	19.80	9.08 - 26.25	n.s.
	V70Gy	14.66	6.13 - 23.07	13.54	6.07 - 19.09	n.s.
	V75Gy	10.40	4.0 - 17.4	9.57	4.29 - 14.34	n.s.
VMAT	D2%	78.51	77.54 - 79.13	79.18	78.23 - 80.34	n.s.
	Dmean	36.68	24.1 - 44.46	32.80	17.94 - 46.64	n.s.
	V20Gy	70.91	49.48 - 93.24	58.49	32.86 - 93.79	n.s.
	V50Gy	29.09	13.58 - 39.66	28.11	11.59 - 38.73	n.s.
	V60Gy	21.34	8.94 - 32.83	20.98	7.93 - 27.45	n.s.
	V70Gy	15.07	5.3 - 25.62	14.96	5.14 - 20.94	n.s.
	V75Gy	11.14	3.61 - 19.73	11.41	3.58 - 16.77	n.s.

		Supine		Prone		
		Average	Range (min - max)	Average	Range (min - max)	<i>p</i> -value
3DCRT	D2%	76.53	72.92 - 77.72	76.98	74.73 - 77.97	n.s.
	Dmean	18.89	7.96 - 27.53	17.07	8.58 - 22.07	n.s.
	V20Gy	28.79	11.09 - 40.97	25.84	12.19 - 33.55	n.s.
	V50Gy	17.29	6.01 - 27.76	15.46	6.72 - 21.88	n.s.
	V60Gy	14.18	4.57 - 23.64	12.57	5.18 - 18.39	n.s.
	V70Gy	9.99	2.76 - 17.60	8.87	3.42 - 13.5	n.s.
	V75Gy	5.95	1.27 - 11.03	5.40	1.92 - 8.52	n.s.

Continued

	D2%	76.44	68.59 - 78.74	76.74	71.19 - 78.59	n.s.
	Dmean	18.39	7.33 - 25.35	15.23	7.64 - 21.14	n.s.
IMRT	V20Gy	31.52	11.54 - 40.63	25.45	12.18 - 39.04	n.s.
	V50Gy	14.03	4.45 - 22.42	11.30	4.77 - 15.36	n.s.
	V60Gy	10.27	3.04 - 17.61	8.30	3.38 - 12.06	n.s.
	V70Gy	6.79	1.83 - 12.39	5.44	2.16 - 8.31	n.s.
	V75Gy	4.61	1.09 - 8.76	3.69	1.43 - 5.79	n.s.
	D2%	77.14	71.59 - 78.88	77.70	75.79 - 78.38	n.s.
	Dmean	20.45	8.35 - 27.92	17.22	8.89 - 23.95	n.s.
VMAT	V20Gy	33.56	12.51 - 42.53	28.07	13.68 - 42.97	n.s.
	V50Gy	16.12	5.01 - 25.32	13.13	5.85 - 18.47	n.s.
	V60Gy	12.31	3.55 - 20.83	10.06	4.41 - 14.89	n.s.
	V70Gy	8.76	2.23 - 16.08	7.18	3.04 - 11.23	n.s.
	V75Gy	6.51	1.45 - 12.62	5.28	2.18 - 8.72	n.s.

Abbreviations: Ave. = average; 3DCRT = 3-dimensional conformal radiotherapy; IMRT = intensity-modulated radiotherapy; VMAT = volumetric modulated arc therapy; n.s. = not significant.

Table 5. Comparisons of rectal dosimetric values for PTV1 between prone 3DCRT, supine IMRT, and supine VMAT.

Rectum	Prone 3DCRT	Supine IMRT	Supine VMAT	Prone 3DCRT vs. Supine IMRT	Prone 3DCRT vs. Supine VMAT	Supine IMRT vs. Supine VMAT
	Ave.	Ave.	Ave.	<i>p</i> -value	<i>p</i> -value	<i>p</i> -value
D2%	78.36	77.95	78.53	n.s.	n.s.	n.s.
Dmean	51.95	44.16	42.45	0.031	0.013	n.s.
V20Gy	84.73	89.88	88.06	n.s.	n.s.	n.s.
V50Gy	55.44	37.58	34.06	0.009	0.003	0.006
V60Gy	48.64	27.21	25.19	0.004	0.003	0.001
V70Gy	40.16	22.43	16.31	0.030	0.003	n.s.
V75Gy	29.54	9.29	10.23	0.001	0.004	n.s.

Abbreviations: Ave. = average; 3DCRT = 3-dimensional conformal radiotherapy; IMRT = intensity-modulated radiotherapy; VMAT = volumetric modulated arc therapy; n.s. = not significant.

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