The Effects of Treatment Position on Normal Tissue Dose in Prostate Cancer Patient Treated with Intensity-Modulated Radiotherapy

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Abstract

Purpose: To prospectively assess the effects of prone vs. supine treatment position on the dose to the rectum and bladder in prostate cancer patients treated with intensity modulated radiotherapy (IMRT).

Materials and Methods: Thirteen patients with prostate cancer (7 post radical prostatectomy and 6 intact prostate) were prospectively treated with curative radiotherapy in Ramathibodi hospital between January 2013 and June 2013. All patients underwent a planning CT scan in both prone and supine treatment positions. The planning target volumes (PTV) and organ at risks (OARs) were delineated in both positions. IMRT plans were generated on each patient. A minimum of 95% of the PTV must receive 100% of the prescription dose, and the maximum dose should not exceed 107%. Dose-volume histograms (DVHs) were analyzed to evaluate rectal and bladder doses in both prone and supine positions.

Results: Mean, minimum and maximum PTV doses were not different between supine and prone position. Rectal volume in prone position were significantly larger than in supine position (p = 0.01). Mean rectal doses were slightly lower in prone position but were not statistically significant. Bladder volume in prone position were significantly larger than in supine position (p = 0.0007). Mean bladder doses were statistically significant lower in prone position.

Conclusions: From this study, rectal doses were not statistically different between the 2 positions, but bladder doses were lower in prone position. However, this is a result of larger bladder volume from more bladder filling. Due to more set up uncertainty and patient discomfort, we still use supine position in prostate cancer patient treated with IMRT.

Keyword: Intensity-Modulated Radiotherapy, prostate, treatment position

Introduction

Prostate cancer is the most common cancer among men in the United States and is a significant source of morbidity and mortality[1]. In 2009 prostate cancer was the 5th leading site of cancer in Thai male[2]. External beam radiation has been widely used in treating prostate cancer. Advanced radiotherapy techniques available today, including intensity-modulated radiotherapy (IMRT), are remarkably effective[3,4]. These technologies had allowed considerably higher doses of radiation to be delivered to the target with relatively lower doses to the organs at risk (OARs) and surrounding normal tissues. However, delivering adequate doses of radiotherapy to target position near OARs remains a challenging task because the tolerance dose of OARs is an important dose-limiting factor. The target is not well separated physically from OARs. Theoretically, the best way to deliver adequate doses to the target with relatively lower doses to the OARs is to increase the distance between the target and the OARs. It is possible that optimizing the dose distribution by changing the treatment position from supine to prone may further decrease the dose to normal tissue.

Materials and methods

Thirteen patients with prostate cancer (7 post radical prostatectomy and 6 intact prostate) were prospectively treated with curative radiotherapy in RAMATHIBODI hospital between January 2013 and June 2013. All patients underwent a planning CT scan in both supine and prone positions. CT simulation was performed by a GE CT simulation system, using 1400 kv and 400 mA. Simulation images were obtained every 2 mm interval from above the iliac crest down to the perineum in both treatment positions. As a patient immobilization device, Vac-Lock™ cushion was used to immobilize the patents' legs in supine and belly board in prone position. Each patient was prescribed laxative drugs in the evening prior to CT simulation. Approximately 30 minutes prior to the initial treatment CT scan, the patients were instructed to void then drink 500 ml of water. The supine scan position was performed followed immediately by prone position within less than 10 minutes. The CT scans were transfered to the Eclipse® radiotherapy treatment planning system version 8.9

Structures delineation

Clinical target volumes (CTV) and OARs, such as the rectum and bladder were delineated by the author. Then 3-4 months later, the author performed target delineation again to evaluate intraobserver variation. The CTV for intact prostate consisted of the prostate gland plus the seminal vesicles. The CTV for post radical prostatectomy was contoured according to the RTOG contouring atlas[5]. The planning target volume (PTV) includes the CTV plus an 8-mm margin, except at the prostate gland–rectum interface, where a 5-mm margin was used to decrease the risk of rectal toxicity. The external wall of the rectum and bladder were contoured. The craniocaudal rectal extension was defined as the first CT slice above the anal verge (caudal border), and the cranial limit was defined as the first slice below the sigmoid flexure. The bladder was contoured in its entirety [6,7]. Pelvic lymph nodes were not treated in this study.

Treatment Planning

IMRT plans were generated by the Eclipse® radiotherapy treatment planning system version 8.9 using the beam data of Clinac iX. Two treatment plans were generated for each patient (supine IMRT and prone IMRT). For the IMRT plans, a nine-field coplanar with segmental multileaf collimation delivery technique using 10 MV X-ray was used. Plans were optimised using an inverse planning module, which uses a gradient optimisation algorithm that permits real-time modification of the optimisation parameters and encourages user interactivity to minimise the overall optimisation time. Our plan acceptance criteria for prostate IMRT were as follows. A minimum of 95% of the PTV must receive 100% of the prescription dose, and maximum dose was always less than 107%. Prescribed dose for intact prostate was 76-78 Gy delivered in 38-39 fractions and prescribed dose for post radical prostatectomy was 66-70 Gy delivered in 33-35 fractions [8,9]. Rectal constraints must be met such that no more than 30% of the rectal volume may receive 65 Gy (V65<30%), and no more than 70% of rectal volume may receive 40 Gy (V40<70%). For the bladder, no more than 25% of the bladder volume may receive 75 Gy (V75<25%) and no more than 80% of the bladder volume may receive 40 Gy (V40<80%). The rectal and bladder volumes on the prone and supine scans were compared in each case.

Data collection

The data were collected case by case using Eclipse planning system and compare dose to rectum and bladder based on dose-volume histogram (DVH).

Statistical data analysis

The DVH of the rectum and bladder of the prone and supine treatment positions between post radical prostatectomy and intact prostate were compared for each patients. Dose-volume end points used to compare the supine and prone plans included the mean dose and dose constraint. The statistical difference was determined by a two-sided paired t-test. Differences with $p < 0.05$ was considered significant.

STATA 12.0 (StataCorp, College Station, Texas, USA) was used for all statistical analyses.

Informed consent

The study was approved by the ethics review committee on research involving human subject of Ramathibodi Hospital, Mahidol university. Informed consent was obtained from each patient before enrollment. The study was supported by the Faculty of Medicine, Ramathibodi Hospital.

Results

From January 2013 to June 2013, thirteen patients (7 post radical prostatectomy and 6 intact prostate patients) were treated with curative IMRT. All thirteen patients were scanned in both treatment positions. There was no significant difference in volumes of the PTV, bladder and rectum between the first and second contouring (Table 1).

Planning target volumes (PTV)

In post radical prostatectomy group, the mean PTV for the supine was 253 cm^3 and prone was 269 cm^3 ($p = 0.31$). In intact prostate group, the mean PTV for the supine was 169.9 cm^3 and prone was 169.8 cm^3 ($p = 0.98$). Mean, minimum and maximum PTV doses between two positions were not significantly different (Table 2).

Rectum volume and dose

Post radical prostatectomy group

The mean rectal volumes were 56.87 cm^3 and 83.22 cm^3, in supine and prone respectively, which were statistically different ($p = 0.01$). The DVH analysis of average rectal dose between two positions in post radical prostatectomy group showed no statistically significantly difference but tended to be lower in low rectal dose constraint (V30 – V50). In higher dose constraint (V60-V70) supine position was superior to prone position (Table 3).

Table 1. The variation in contouringvolume of PTV, rectum and bladder

	Prone		p-value	Supine		p-value
	First time	Second time		First time	Second time	
PTV (cm^3)	223.2	224.2	0.05	214.6	213.6	0.28
Rectum (cm^3)	85	84.8	0.74	62.9	62.5	0.35
Bladder (cm^3)	308.4	306.2	0.06	189.9	188.6	0.36

Table 2. The PTV dose in supine and prone position.

Dose (Gy)	Post RP		*p*-value	Intact prostate		*p*-value
	Prone	Supine		Prone	Supine	
Mean PTV volume (cm3)	269	253	0.31	169.8	169.9	0.98
Average of mean PTV dose (%)	102.9	103	0.8	103	103	0.19
Average of min PTV dose (%)	89	90	0.31	90	89	0.6
Average of max PTV dose (%)	107	106	0.4	106	107	0.44

Intact prostate group

The mean rectal volumes were 70.1 cm^3 and 87.15 cm^3, in supine and prone respectively, which were not statistically significantly different ($p = 0.07$). The DVH analysis of average rectal dose between two positions in intact prostate group showed no statistically significantly difference. In high rectal dose (V75) supine position was tended to be lower than prone position (Table 4).

Bladder volume and dose

Post radical prostatectomy group

The mean bladder volumes were 181.4 cm^3 and 328.4 cm^3, in supine and prone, respectively, which were statistically different ($p = 0.0007$). The DVH

Table 3. The rectal dose in supine and prone position in post radical prostatectomy group.

	Prone	Supine	*p*-value
Average of mean rectal dose (cGy)	3975	4073	0.77
Mean V30	63.8%	67.2%	0.58
Mean V40	47.2%	52.5%	0.37
Mean V50	38.5%	39.6%	0.78
Mean V60	25.9%	25.2%	0.82
Mean V65	18.0%	16.4%	0.57
Mean V70	2.7%	2.3%	0.26

Table 4. The rectal dose in supine and prone position in intact prostate group.

	Prone	Supine	*p-value*
Average of mean rectal dose (Gy)	3410	3709	0.34
Mean V30	49.3%	55.5%	0.17
Mean V40	37.4%	43.2%	0.17
Mean V50	28.4%	34.4%	0.08
Mean V60	21.0%	24.1%	0.34
Mean V65	17.6%	20.0%	0.46
Mean V70	14.5%	15.8%	0.53
Mean V75	10.9%	7.2%	0.18

Table 5. The bladder dose in supine and prone position in post radical prostatectomy group.

	Prone	Supine	*p-value*
Average of mean bladder dose (cGy)	3568	4383	0.03
Mean V40	47%	59%	0.23
Mean V55	31.2%	40.8%	0.06
Mean V60	27.7%	36%	0.06
Mean V70	7.35%	8.41%	0.61

Table 6. The bladder dose in supine and prone position in intact prostate group.

	Prone	Supine	*p-value*
Average of mean bladder dose (cGy)	2987	3823	0.07
Mean V40	33.5%	45.4%	0.045
Mean V55	21%	30.5%	0.03
Mean V60	18.3%	27.4%	0.03
Mean V70	13.8%	21.8%	0.02
Mean V75	11.3%	18.7%	0.03
Mean V80	4.6%	10.8%	0.04

Figure 1. DVH of rectum in post radical prostatectomy group.

(Δ = prone position, □ = supine position)

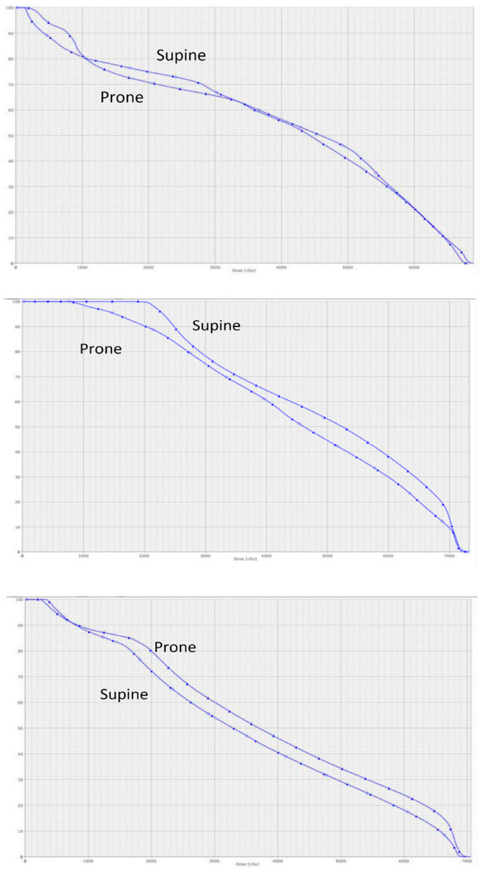
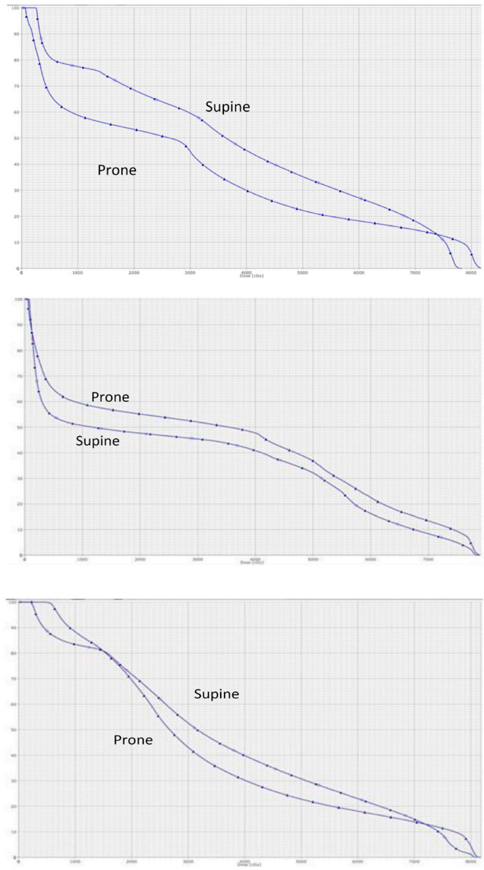


Figure 2. DVH of rectum in intact prostate group.

(Δ = prone position, □ = supine position)



analysis of average bladder dose between two positions in post radical prostatectomy group demonstrated marginally lower in prone position (V55 and V60). In V40 and V70 mean bladder dose between two positions were not statistically significantly different (Table 5).

Intact prostate group

The mean bladder volumes were 200 cm^3 and 285.2 cm^3, in supine and prone respectively which were statistically different ($p = 0.02$). The DVH analysis of average bladder dose between two positions in intact prostate group showed statistically significantly lower in prone position (Table 6).

Distance between seminal vesicles to rectum

In localized prostate cancer patients, the median distance between seminal vesicles to rectum in prone position was 0.79 cm and was 0.47 cm in supine position.

Discussion

The purpose of this study was to evaluate the effect of treatment position on rectal and bladder dose in IMRT. Based on dose-volume histogram comparision, this study found that in both groups of patients (post radical prostatectomy and intact prostate), there were no difference in rectal dose between prone and supine position. In post radical prostatectomy group, the rectal dose was not different but tended to be lower in low dose constraint (V30-V50). However, in higher dose constraint (V60-V70) supine position was superior to prone position in terms of rectal sparing. In intact prostate patients, all rectal dose constraints tended to decrease in prone position except in the highest dose constraint (V75). We confirmed that rectal doses were not different between prone and supine position in both post radical prostatectomy and intact prostate patients but tended to be lower in prone position. In patients with intact prostate the effect of prone position was more pronounced. Few previous studies demonstrated that prone position was superior in decreased rectal dose [9,10]. Zelefsky et al.[9] assessed anteriorly prostate shifting in prone position which affected on seminal vesicles positioning and increasing in the distance between PTV and rectum. In our study, we observed that distances between seminal vesicles and rectum were not significantly different between supine and prone position but in two patients also seen the effect as in the previous study. Kato et al.[10] compared rectal dose reduction between prone 3D-CRT, supine 3D-CRT and supine IMRT for prostate cancer. They found that prone 3D-CRT resulted in more rectal sparing than supine 3D-CRT and IMRT in most cases. The author suggested that improve rectal sparing was due to the anatomical advantage in prone position. The puborectalis muscle pulls lower portion of rectum in anterior direction causes upper portion of the rectum highly mobile. Prone position tends to displace the upper portion of the rectum posteriorly also the result from increased pressure from abdominal content in prone position. O'Neill et al[11] suggested that rectum sparing in prone position was better than supine position due to increasing distance between PTV and rectum, which from the reason that in the prone position gravity caused the prostate to fall anteriorly which reducing the overlap of PTV and rectum. In that study, their protocol was not using rectum preparation, no patient immobilization but they instructed patients to have full bladder prior to CT simulation. McLaughlin et al. [12] showed that the prone position with jack-knife angulation is inferior in rectal DVH compared to prone flat position. The mechanism was related to passive displacement of the rectum by abdominal contents in prone position.

In this study we also studied the effect of treatment position in post radical prostatectomy patients, which the imaging from CT showed that the rectum moved posteriorly and dilated due to anatomical effect. However in this study has shown that the different in mean rectal volume, which significantly larger in prone position in all patients, this finding suggested that dose to rectum was also reduced by the effect of increasing rectal volume in both intact prostate and post RP patients. The large rectal volume also had effect in IMRT planning, causing relatively lower rectal dose as shown in planning (Figure 1 and 2).This study suggested that the reduction of rectal dose in some patients resulted from the anatomical advantage of prostate, seminal vesicles mobility and shifting as well as the large rectal volume.

The bladder dose in this study was significantly decreased in prone position due to position, shape and size of the bladder. Due to the larger bladder volume in prone position, the bladder doses were lower. As observed in CT images, in prone position, bladders were pulled anteriorly due to gravity and position. Bladder volume in this study was significantly different in prone position, even the time between supine and prone position was within 10 minute. The larger bladder volume in prone position was due to the urinary incoming flow. The result in this study was corresponding to previous study by Weber et al.[13] that larger volume of rectum and bladder were correlated with lower dose to bladder. Whereas other study by Koelbl et al.[14] suggested that prone position using belly board reduced the median dose to bladder and small bowel in rectal cancer patient who treat with 3D-CRT. That study showed that the superior in dosimetry of bladder and rectum in prone position were associated with larger volume. In previous study by Pinkawa et al.[15] determined the prostate variability and DVH with full and empty bladder. No special protocol for bladder volume control was applied. The patients' feeling of full bladder was the only criterion. The study demonstrated that radiotherapy with a full bladder has advantages reducing the dose to bladder and bowel. The empty bladder can increase the bladder volume in high dose region. They also noted that the bladder volume was stable during the course of RT.

The disadvantage of prone position is set up uncertainty. Bayley et al [16] showed that supine position caused less prostate movement than prone position but no difference in isocenter positioning error or total positioning error. Weber et al.[13] retrospectively evaluated treatment position reproducibility without immobilization devices. The isocenter shifts during treatment in prone position were more than supine position about 83% and 50%, which reflected a lack of reproducibility related to patient discomfort. Further study to evaluate accuracy and reproducibility of patient set-up during beam delivery in both positions should be done.

Conclusion

From this study, rectal doses were not statistically different between the 2 positions, but bladder doses were lower in prone position. However, this is a result of larger bladder volume from more bladder filling. Due to more set up uncertainty and patient discomfort, we still use supine position in prostate cancer patient treated with IMRT.

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