THE IMPACT OF PRONE POSITION WITH BELLY-BOARD DEVICE ON THREE-DIMENSIONAL CONFORMAL RADIOTHERAPY OF PROSTATE CANCER: DECREASING THE RECTUM COMPLICATION PROBABILITY

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Background and Purpose : To investigate the impact of supine position versus prone position with belly-board on prostate radiotherapy by evaluation the geometric parameter change between internal organs and treatment dose-volume histograms (DVHs).

Materials and Methods : Fifteen patients with prostate cancer underwent pelvic CT scan in position of both prone with belly-board device and supine without immobilization. Four-field box three-dimensional conformal radiotherapy (3DCRT) treatment planning was planned for each patient in both positions. Geometric change including diameter of rectum, distant between critical organs and treatment DVHs were investigated. Wilcoxon signed-rank test was used for statistical analysis.

Results : Patients in prone treatment position had both larger anterio-posterior diameters and transverse diameter of rectum ($p = 0.003$ and $p = 0.031$), and larger distance between the centers of prostate and rectum ($p=0.002$) than those of patients in supine position. In regard to the DVHs data, prone treatment position resulted in larger rectal volume ($p = 0.015$), lower mean rectal dose ($p = 0.002$) and smaller rectal volume receiving high radiation dose ($p = 0.001$).

Conclusions : Patients in prone treatment position with belly-board immobilization had both larger anterio-posterior diameters, transverse diameter of rectum, and larger distance between the centers of prostate and rectum than those of patients in supine position. Prone treatment position with belly-board device can reduce rectum dose, which may in turn decrease the risk of radiation-induced complications.

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Key words: Prostate cancer, Three-dimensional conformal radiotherapy, Treatment position, Belly-board, Dose-Volume Histogram.

INTRODUCTION

The capability of 3D conformal radiotherapy (3DCRT) in increasing radiation dose to the prostate and reducing dose to the adjacent normal organs has been well established in patients with localized prostate cancer [1, 5, 11, 12, 15, 13, 18]. The optimal treatment position

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in patients with prostate cancer however is still controversial. Several studies have demonstrated that prone position can reduce the irradiated volume of small bowel [4, 7, 14]. Zelefsky *et al.* [20] found that a prone position was associated with a significant reduction in the dose to the rectum and the small bowel compared with supine position. However, there was no significant reduction of the dose to the bladder wall. In contrast, Bayley *et al.* [2] demonstrated that a supine position could significantly improve the dose in small bowel, rectal wall and bladder.

The difference of organ motion and positioning errors in the different treatment positions is well documented [2, 3, 6, 8, 9, 16, 17] but again controversial. Stroom *et al.* [18] demonstrated that prone position with belly-board device was associated with smaller random but somewhat larger systematic variations. The estimated planning margins to account for the geometrical uncertainties were therefore similar for the two treatment position. Also in this respect, Bayley *et al.* [2] found a significant reduction of prostate motion in the supine treatment position, and demonstrated that the prone position with a Hip-Fix immobilization device required a larger planning target volume (PTV) and resulted in higher dose to critical organ.

Given the lack of consensus regarding the optimal treatment position for patients with localized prostate cancer, we conducted a study to evaluate the effects of prone and supine positioning on dose distributions. In addition, the diameter of rectum and the distance between the center of rectum and prostate were measured in both supine and prone position with belly-board.

METHODS AND MATERIALS

Fifteen consecutive patients with localized prostate cancer, (T2-T3a, Gleason's score >6, PSA > 20 ng/ml) were treated with 3DCRT. The clinical treatment consisted of whole pelvic irradiation in prone position up to a total dose of 45 Gy in 25 fractions in 5 weeks, followed by prostate boost irradiation 27 Gy in 15 fractions in 3 weeks. CT simulation in prone position with belly-board device was performed first for the initial pelvic irradiation. Another CT simulation in supine position without immobilization device was performed again for the boost treatment after 3 weeks of pelvic irradiation (Fig. 1.). The patients were instructed to have full bladder and empty rectum in both supine and prone treatment positions. Virtual treatment plans were generated for these 15 pairs of CT simulations in

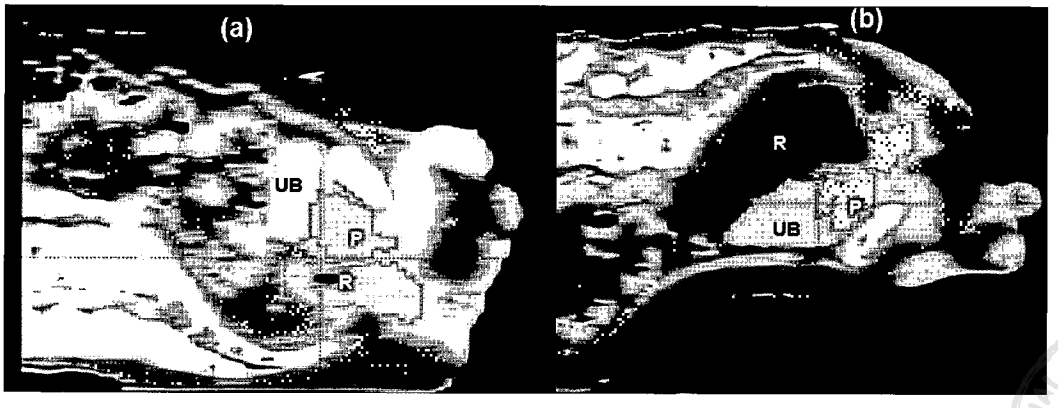

Fig 1. (a) CT scan image of patient in supine position without any immobilization device and (b) patient in prone position with belly-board device

prone and supine position in order to evaluate the impact of treatment positioning on the dose volume histograms (DVHs).

The 3D treatment planning system was "Render Plan 3-D 2.71, Precision Therapy, FL". All volumes, including prostate, bilateral seminal vesicles, rectum and urinary bladder were outlined by a single investigator to minimize potential inter-observer variations. The rectum was registered from 2 cm above superior border of prostate down to 2 cm below inferior border of the prostate. The PTV consisted of prostate with 7-mm margin in posterior direction and 10-mm margin in other directions. A simple four-field box technique (anterio-posterior, posterio-anterior, lateral opposing portals) was planned in both supine and prone position. PTV was covered by the 95% isodose curve, normalized to the isocenter.

Analysis of rectum diameters

Transverse and anterio-posterior (AP) diameters of rectum (Dia-T, Dia-AP), distance between the anterior wall of rectum and the posterior surface of prostate (Dis-PRw), and distance between the center of prostate and the center of rectum (Dis-PRc) were measured on every axial slice of CT scan of in both positions (Fig. 2.). Mean diameter and distance values were calculated by averaging the measured data on all axial CT images. The equivalent diameter of rectum from DVHs (Dia-Eq) was calculated as follows:

$$\text{Dia} - \text{Eq of Rectum} = \sqrt{\frac{4 \times \text{Rectum volume}}{\pi \times \text{Rectum length}}}$$

Analysis of dose-volume histograms

Prostate, rectum and bladder volumes in both prone and supine positions were recorded for every patient to look for potential changes in these parameters relative to different treatment positions. Cumulative DVHs for PTV, rectum, and bladder were analyzed. Mean radiation dose (D-mean), percentage of volume that receive 95% prescribed dose (V95%), and absolute volume that receive more than 65 Gy (V65 Gy) were also recorded from the DVHs in both supine and prone positions.

Statistical analysis

Diameter change and treatment DVHs of critical organs were recorded and calculated for evaluation. Difference between supine and prone treatment position was analyzed by testing the equality of values using Wilcoxon signed-rank test.

RESULTS

Rectum diameters and rectum-prostate distance

The average data of rectal diameters and the relative distances between rectum and prostate were tabulated as Table 1.

The transverse and AP diameters of

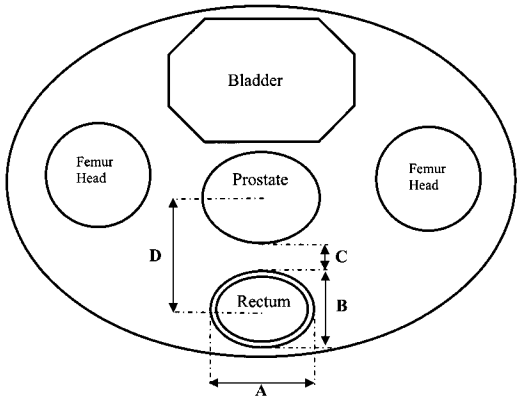

Fig 2. Schematic graph for definition of various rectal diameters and rectum-prostate distances:
A: Transverse diameters of rectum (Dia-T)
B: Anterio-posterior (AP) diameters of rectum (Dia-AP)
C: Distance between the anterior wall of rectum and the posterior surface of prostate (Dis-PRw),
D: Distance between the center of prostate and the center of rectum (Dis-PRc)

Table 1. Average rectal diameters and rectum-prostate distances (cm).

	Supine position	Prone position	p - Value
Dia-AP	3.3 ± 0.9	4.4 ± 1.1	0.003
Dia-T	3.5 ± 1.4	4.2 ± 1.5	0.031
Dia-Eq	3.4 ± 1.0	3.4 ± 1.1	0.814
Dis-PRw	0.4 ± 0.2	0.5 ± 0.2	0.334
Dis-PRc	3.5 ± 0.5	4.3 ± 0.6	0.002

Dia-AP as anterio-posterior diameter of rectum.
Dia-T as transverse diameter of rectum.
Dia-Eq as diameter of rectum from DVH and length of rectum.
Dis-PRw as distance between posterior surface of prostate and anterior wall of rectum
Dis-PRc as distance between center of prostate and center of rectum

Table 2. Dose, volume of rectum and urinary bladder by treatment positions.

		Supine	Prone	p - Value
Rectum	Volume (ml)	63.1 ± 37.5	98.8 ± 52.6	0.015
	D-mean (Gy)	56.4 ± 4.6	49.1 ± 8.0	0.002
	V95% (%)	19.9 ± 6.0	12.4 ± 6.9	0.001
	V65Gy (ml)	21.2 ± 6.2	13.0 ± 6.9	0.001
Urinary bladder	Volume (ml)	149.2 ± 64.8	182.8 ± 116.4	0.173
	D-mean (Gy)	32.0 ± 14.3	29.3 ± 15.3	0.470
	V95% (%)	14.5 ± 8.2	13.3 ± 8.9	0.532
	V65Gy (ml)	14.8 ± 8.4	15.6 ± 9.4	0.820

D-mean as mean dose
V95% as percentage of critical organ volume receiving 95% of the prescribed dose
V65Gy as actual volume of critical organ receiving dose more than 65Gy

rectum in prone position were larger than those in supine position in 73% and 87% of patients, respectively. The average transverse and AP diameters of rectum in prone position were greater than the corresponding values in supine position of the same patient (p = 0.031, p = 0.003).

The distance between center of prostate and center of rectum in prone position was 4.3 ± 0.6 cm, which was significantly larger than the recorded distanced of 3.5 ± 0.50 cm in supine position (p = 0.002). However, there was no obvious difference in the average distance between the anterior wall of rectum and the posterior wall of prostate (0.5 ± 0.2 cm vs. 0.4 ± 0.2 cm, p = 0.334) and in equivalent rectum diameter (3.4 ± 1.1 vs. 3.4 ± 1.4 cm, p = 0.814).

The distance between centers of prostate and rectum and the distance between the anterior wall of rectum and the posterior wall of prostate were larger in prone position than the corresponding data in supine position in 87% and 67% of patients, respectively.

DVH of rectum

The DVHs of rectum in supine and prone positions are presented in Table 2 and Fig. 3. The study demonstrated that a larger rectum volume (98.8 ± 52.6 ml vs. 63.1 ± 37.5 ml, p = 0.015), a lower mean rectal dose (49.1 ± 8.0 Gy vs. 56.4 ± 4.6 Gy, p = 0.002), a lower percentage

of rectal volume that received 95% prescribed dose (12.4 ± 6.9 % vs. 19.9 ± 6.0 %, $p = 0.001$), and a smaller rectal volume that received more than 65 Gy (13.0 ± 6.9 ml vs. 21.2 ± 6.2 ml, $p = 0.001$) were found in prone position compared with those in supine position. According to these data, prone positioning achieved a better rectal sparing than supine positioning did.

DVH of urinary bladder

The DVHs of urinary bladder in supine and prone positions are presented in Fig. 4. The bladder volumes in supine and prone positions were not significantly different from each other (182.8 ± 116.4 ml vs. 149.2 ± 64.8 ml, $p = 0.173$). No significant differences of the mean bladder dose, volume of bladder exposed to 95% of prescription dose (V95%), and volume receiving at least 65 Gy (V65 Gy) were found between the prone and supine positions (Table 2).

DISCUSSION

Geometric analysis of rectum

Enlarged rectal and bladder volumes in prone position were observed by Weber *et al.* [19]. The rectal volume change may lead to reduction of mean rectal dose and decreased percentage of rectal volume receiving high dose. In this study, we found that there was statistically significant difference in AP diameter and transverse diameter of rectum between the two different treatment positions ($p<0.05$) in favor of the prone position. It was assumed that the air from lower colon displaced to rectum in prone position enlarging its volume.

A larger distance between prostate/seminal vesicles and rectum in the prone position compared to the supine position was observed by Mclaughlin et al. [10]. The authors suggested that an observed increase of the rectum-prostate distance was the result of an anterior shift of prostate in prone position and could therefore reduce the rectal volume receiving high radiation dose. In contrast, we could not detect a significant change in the distance between posterior wall of prostate and anterior wall of rectum between different treatment position ($p = 0.334$). However, a marked increase in distance between the center of prostate and the center of rectum was found in prone position ($p = 0.002$). This is probably associated with volume change of rectum from air displacement.

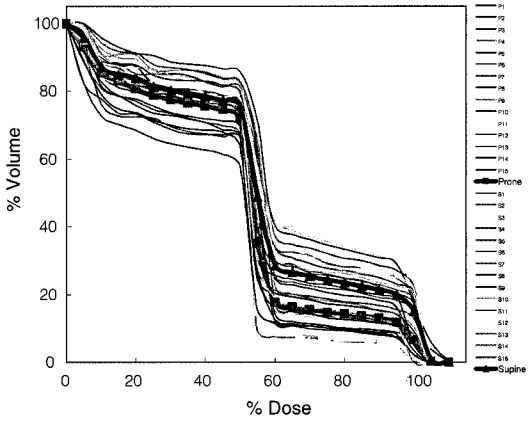

Fig 3. DVH chart of rectum in different treatment positions. (s-) is the DVH for patients with supine position, (p-) is the DVH for patients with prone position with belly board.

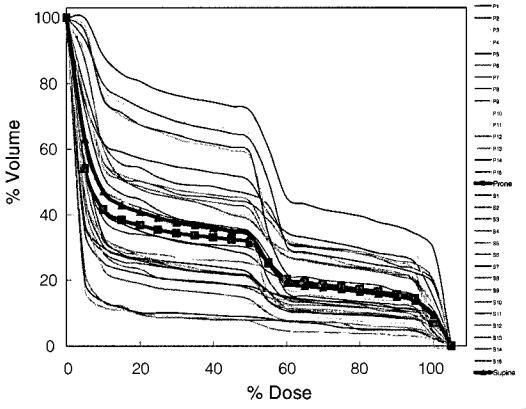

Fig 4. DVH chart of urinary bladder in different treatment positions (s-) is the DVH for patients with supine position, (p-) is the DVH for patients with prone position with belly board.

Geometric analysis of seminal vesicles

The variability of the position of the seminal vesicles plays an unclear role in the relationship between treatment position and rectal sparing. The seminal vesicles are freely mobile. Zelefsky *et al.* [20] noted that the seminal vesicles tend to drop backwards wrapping in part the anterior rectal wall in supine position. This adverse geometrical relationship would inevitably lead to an increased volume of rectum exposed to high dose of radiation.

Dose-volume histogram analysis

A significant advantage of prone positioning was observed in terms of the average rectal wall dose and V95% (volume of rectal wall receiving at least 95% of the prescription dose) [3]. Similar results were found in the present study. There were marked improvements in mean dose, V95%, V65Gy of rectum when patients treated in prone position ($p < 0.05$). Although IMRT might lead to a further improvement, a simple change in positioning in high dose 3DCRT could lead to a better sparing as can be seen from our DVH studies.

The mean bladder volumes for the supine and prone position were not significantly different from each other in this study ($p = 0.173$). There were no difference in mean bladder dose, V95%, and V65 Gy of bladder in both positions. It may be explained in part by the tight attachment of prostate and bladder. Therefore the impact of treatment positioning on bladder dose is limited.

In conclusion, Patients in prone treatment position with belly-board immobilization had both larger anterio-posterior diameters and transverse diameter of rectum and, and larger distance between the centers of prostate and rectum than those of patients in supine position. Prone treatment position with belly-board device is associated with significant reduction of rectum dose in radiotherapy of prostate cancer. The advantage in DVH may decrease the risk of radiation-induced complications.

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腹板及俯臥姿勢對於攝護腺癌直腸照射劑量之影響

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背景和目的：比較使用 Belly board（腹板）之俯臥位是否優於仰臥位式攝護腺癌放療，並計算直腸的直徑變化、直腸與攝護腺間距及評估治療劑量與體積直方圖（DVH）之關係。
材料與方法：15 例攝護腺癌患者分別進行兩組骨盆電腦斷層掃描，分別是使用 Belly board 之俯臥位及沒有固定的仰臥位。每個病人在兩種擺位下的治療計劃皆使用 4-field box technique（方盒治療技術）三維適形放療（3DCRT）。使用 Wilcoxon signed-rank test 作統計分析，分析項目包括: 直腸的幾何變化、直腸與攝護腺間距及重要器官的治療劑量與體積直方圖（DVH）分析。
結果：患者於俯臥姿勢加腹板治療相對於患者在仰臥位置有較大的直腸前後徑和橫向徑為（p 值 = 0.003 和 p = 0.031），和較大的攝護腺和直腸的中心間的距離（p 值 = 0.002）。關於 DVHs 數據，患者於俯臥治療導致治療部位的直腸體積較大（P = 0.015），意味著較低直腸劑量（p= 0.002）和較小的直腸體積接受高輻射劑量（p = 0.001）。
結論：攝護腺癌病人治療時使用 Belly board（腹板）之俯臥位之固定方式對直腸直徑（前後向及橫斷面）都有顯著的增大（相較於仰臥位的固定方式），在直腸與攝護腺中心點間的距離也是使用 Belly board（腹板）之俯臥位之固定方式有較大的距離，在劑量與體積的直方圖也顯示使用Belly board（腹板）之俯臥位之固定方式有較低的直腸輻射劑量可以降低放療引起的併發症。
[放射治療與腫瘤學 2013; 20(2): 107-114]

關鍵詞：攝護腺癌、三維適形放療、治療姿勢、腹板、劑量與體積的直方圖