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Clinical evaluation of the impact of rectal and bladder filling on prostate position during hypofractionated radiotherapy for prostate cancer

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Abstract

Objective: To evaluate the impact of rectal and bladder filling on prostate position during hypofractionated radiotherapy for prostate cancer.

Methods: Three gold fiducials were implanted into the prostate in 25 patients. Each patient underwent CT scanning under four different conditions: full rectum and bladder, full bladder and empty rectum, full rectum and empty bladder, and empty rectum and bladder (primary image). The other three scans were aligned with the primary image by pelvic bone, then by the implanted fiducials. Prostate displacements were determined by computing the difference between these two alignments. The magnitude and directions of displacement were analyzed.

Results: A full rectum shifted the prostate most significantly in the anterior (0.93 ± 0.31 cm) and superior directions (0.48 ± 0.30 cm). A full rectum was associated with anterior shifts ≥0.5 cm in 92.0% of the patients, ≥1 cm in 44.0%, while superior shifts ≥0.5 cm were observed in 48.0% and ≥1 cm in 8.0%. A full bladder shifted the prostate mildly in the superior direction (0.19 ± 0.30 cm). A full rectum and full bladder shifted the prostate more in the anterior (1.19 ± 0.37 cm) and superior directions (0.49 ± 0.50 cm). 100% and 56.0% had ≥0.5 cm of anterior and superior displacements. 68.0% and 16.0% had ≥1 cm of anterior and superior shift.

Conclusions: Our study demonstrated that a full rectum shifted the prostate mainly anterosuperiorly. The rectal volume's impact on prostate movement is much larger than that of the bladder.

Keywords: Bladder filling; rectum filling; prostate cancer; prostate motion; hypofractionation; radiotherapy.

Introduction

Hypofractionated precise radiotherapy is increasingly used for prostate cancer treatment [1, 2]. With increases in the fractional dose, a stable and position-fixed target is necessary for the sake of target accuracy and normal tissue safety. Inter- and intrafractional prostate motions are not neglectable during external beam radiotherapy, as prostate position is influenced by surrounding organs such as the rectum and bladder [3-5]. Rectal and bladder volume have been found to correlate with extent of prostate displacement [6, 7]. To understand the magnitude and direction of prostate motion under different rectal and bladder conditions during hypofractionated radiotherapy, we prospectively carried out this analysis of prostate motion under controlled rectum and doctor-directed patient-controlled bladder fillings (comfortably full or void).

Methods

Patients and fiducials implantation

This is subsidiary work of an online registration clinical trial (Online registration number: ChiCTR-ONC-12001895). From January 2015 to August 2018, twenty-five patients with pathologically confirmed prostate cancer were enrolled. Median patient age was 72 years (range, 48–86 years). The patients

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were staged T1–3aN0M0, according to the American Joint Committee on Cancer staging system, with a median Gleason score of 6 (range, 5–8). The median pretreatment PSA level was 11.3 ± 7.1 ng/ml (range, 2–40 ng/ml), and only patients with a World Health Organization performance status of 0–1 were eligible to enter the trial. According to the D'Amico risk group classification [8], five, sixteen, and four patients were in the low-risk, intermediate-risk, and high-risk groups, respectively. The ethics committee of our institution approved the trial (NCC2016YZ-34), and all eligible patients provided written informed consent before enrollment.

Two weeks before CT simulation, three gold fiducials (MT-JZ cylindrical gold seeds 0.8 x 4 mm, Beijing Zhongkanglian Medical Equipment, Beijing, China) were transrectally implanted into the prostate with an 18-gauge needle (Chiba, 18G X 20cm, U/S, Argon Medical Devices, Inc, TX, USA) under ultrasound guidance: one to the right base, one to the left base, and one to the apex of the prostate.

CT scans under different rectal and bladder volume statuses

Two weeks after fiducial implantation, the patients underwent a series of four computerized tomography (CT) scans under a CT simulator (Brilliance CT, Philips Medical Systems Inc, USA). All patients underwent CT simulation in the supine position with thermoplastic pelvic immobilization. One hour before the simulation, patients were directed to evacuate their rectum and bladder, drink 1000 ml water, and wait for a comfortably full bladder. To empty the rectum completely, glycerin enemas were sometimes required. A rectal balloon (RT-4415PT, Pro-Tekt Endorectal Balloon, USA) was placed in the rectum and inflated with 60 ml air to produce a full rectum. During CT simulations, scanning was performed in 3 mm increments, from the superior border of the fourth lumbar vertebra to 5 cm below the ischial tuberosities. CT scans were performed under four different controlled rectum and bladder volume statuses: scan 1 (S1) was performed with a full bladder ("comfortably full") and full rectum (rectum distended with the air-inflated balloon); scan 2 (S2), with a full bladder and empty rectum (rectal balloon removed); scan 3 (S3), with an empty bladder (bladder evacuated) and full rectum; and scan 4 (S4), with an empty bladder and empty rectum.

CT data were transferred to the Pinnacle planning system (Philips, Netherlands), and relevant structures were outlined, including the fiducials, prostate, bladder, rectum, and pelvic bones (pubis, acetabulum, and femoral heads). The prostate was outlined from the base to the apex (not including the seminal vesicle). The rectum was contoured from the recto-sigmoid junction to the ischial tuberosities, including the lumen. The bladder was contoured in its entirety. Bladder and rectal volumes were recorded. The CT scan performed with an empty rectum and empty bladder was set as the primary image (S4). The other three scans were first matched with the primary image (S4) by alignment of pelvic bones to eliminate positioning errors. We recorded the parameters as P1. After that, the other three CT scans were aligned with the primary scan using the implanted fiducials in the prostate as P2. Displacements of the prostate were determined by computing the difference between P1 and P2. Vector analysis ("-" or "+") represented the direction of movement. The magnitude and direction of prostate motion related to rectal and bladder statuses were analyzed.

Statistical analysis

The displacement magnitudes of X (left–right), Y (anterior–posterior), and Z (superior–inferior) under different rectum and bladder volume statuses were compared using the paired-samples t-test and one-way ANOVA. Statistical significance was defined as $P < 0.05$. SPSS 19.0 software was employed in the data analysis.

Results

The volume of the full bladder condition for the 25 patients was 386.2 ± 195.2 ml (mean ± SD), and the volume of the empty bladder condition was 130.5 ± 85.9 ml ($P < 0.001$). The rectal balloon was inflated with 60 ml air, so the full rectal volume was 60 ml. Rectal emptiness referred to the absence of stool and gas residue after the removal of the balloon.

A full rectum shifted the prostate in the right, anterior, and superior directions by 0.10 ± 0.16 cm, 0.93 ± 0.31 cm, and 0.48 ± 0.30 cm (mean ± SD), respectively. With a full rectum, no patients showed more than 0.5 cm left–right displacement, while anterior displacement of more than 0.5 cm was seen in 92.0% and more than 1 cm in 44.0%; superior displacement of more than 0.5 cm was seen in 48.0% and more than 1 cm in 8.0%. A full bladder shifted the prostate in the left, anterior, and superior directions by 0.03 ± 0.10 cm, 0.03 ± 0.21 cm, and 0.19 ± 0.30 cm, respectively. No patients showed more than 0.5 cm displacement in the left–right or anterior–posterior directions under full bladder status, whereas 24.0% showed more than 0.5 cm superior displacement of the prostate. A full rectum and full bladder shifted the prostate in the right, anterior, and superior directions by 0.07 ± 0.18 cm, 1.19 ± 0.37 cm, and 0.49 ± 0.50 cm, respectively. Only 1 patient showed more than 0.5 cm of rightward shift, but 100% and 56.0% had more than 0.5 cm anterior and superior displacements, respectively, and 68.0% and 16.0% of patients had more than 1 cm of anterior and superior shift.

The distribution of prostate position shifts under different rectum and bladder fillings are shown in (Figure 1). It is obvious that the prostate displacement was greater with full rectum/empty bladder and full rectum/full bladder conditions than with a full bladder/empty rectum, especially in the Y (anterior–posterior) and Z (superior–inferior) directions. A full rectum and full bladder caused the prostate to move in the anterior and superior directions, whereas a full bladder only caused a small superior prostate shift. Distribution of X\Y\Z shifts under different rectum and bladder filling statuses are listed in (**Table 1**). The integrated prostate position shifts are displayed graphically in (**Figure 2**).

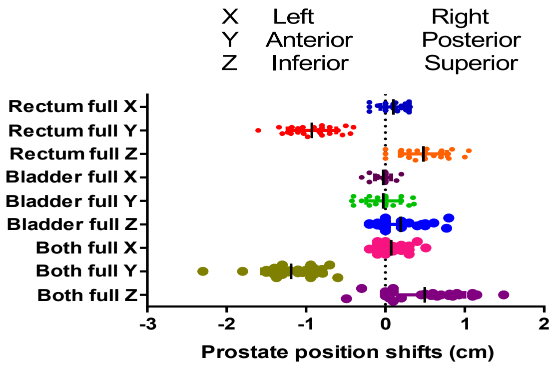

Fig. 1: The impact of empty or full bladder and rectum on the motion of prostate

Figure 1: *The impact of empty or full bladder and rectum on prostate motion.*

Table 1: *Distribution of probabilities of X, Y, and Z shifts under different rectum and bladder filling statuses in comparison with the primary status (empty bladder and empty rectum).*

Shift directions	Full rectum			Full bladder			Full rectum and full bladder		
	<0.5cm (%)	5-1cm (%)	≥1cm (%)	<0.5cm (%)	0.5-1cm (%)	≥1cm(%)	<0.5cm (%)	0.5-1cm (%)	≥1cm (%)
X	25 (100)	0 (0)	0 (0)	25 (100)	0 (0)	0 (0)	24 (96.0)	1 (4.0)	0 (0)
Y	2 (8.0)	12 (48.0)	11 (44.0)	25 (100)	0 (0)	0 (0)	0 (0)	8 (32.0)	17 (68.0)
Z	13 (52.0)	10 (40.0)	2 (8.0)	19 (76.0)	6 (24.0)	0 (0)	11 (44.0)	10 (40.0)	4 (16.0)

X, Left–Right; Y, Anterior–Posterior; Z, Superior–Inferior

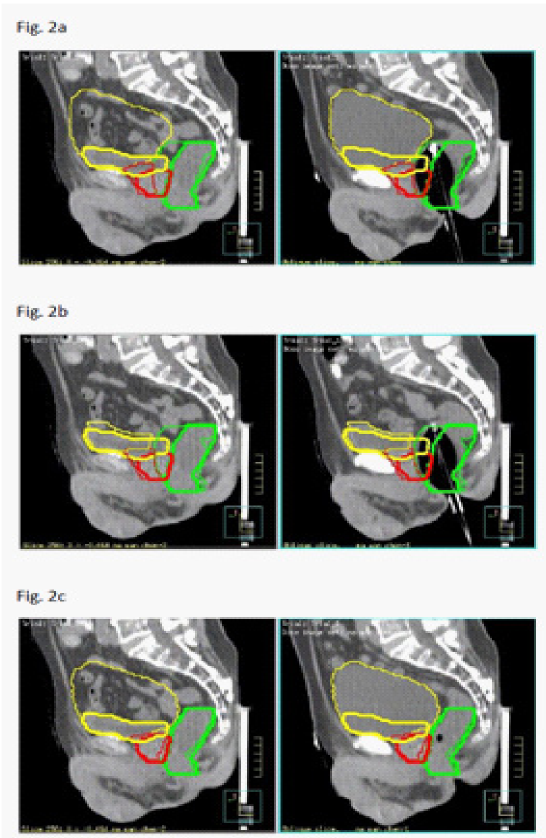

Figure 2a: *Full bladder and full rectum (thin line) & empty bladder and empty rectum (thick line) after pelvic bone alignment.*
Figure 2b: *Full rectum and empty bladder (thin line) & empty bladder and empty rectum (thick line) after pelvic bone alignment.*
Figure 2c: *Full bladder and empty rectum (thin line) & empty bladder and empty rectum (thick line) after pelvic bone alignment. Illustrations: Yellow: bladder; Green: rectum; Red: prostate*

Discussion

Compared with conventional fractionation radiotherapy, hypofractionated radiotherapy has the therapeutic advantage of fewer and larger fractions with equivalent or better biochemical control without a significant increase in late toxicity [9-11]. However, prostate motion, patient positioning errors and range uncertainties may alter the target dose and increase exposure of neighbouring organs at risk [12]. Knowledge about the magnitude and direction of prostate motion related to rectum and bladder filling is of great importance, especially in the era of hypofractionated and high-dose radiation therapy [7]. Although there have been some reports on the effects of rectal and bladder filling on prostate position [13-15], there have been very few prospective studies using bladder and rectum volume-controlled conditions. Our study is a prospective, simultaneous analysis of the effects of bladder and rectal filling on prostate position. The rectum volume was artificially controlled, and the bladder was self-controlled by the patient under the direction of the physician. The results of this trial demonstrate that a full rectum or a full rectum and full bladder primarily shift the prostate in the anterior–superior direction. A full bladder only shifted the prostate superiorly by a small amount. The rectal volume's influence on prostate motion is much larger than that of the bladder volume. The knowledge of the magnitude and direction of prostate displacement due to rectum and bladder volumes' change may help us understand the importance of monitoring and controlling rectum and bladder volume during hypofractionated radiotherapy of prostate cancer.

From our study's results, the rectal volume's impact on prostate position is obvious and much larger than that of the bladder. A full rectum alone or a full rectum combined with a full bladder can shift the prostate anteriorly by more than 1 cm, and superiorly by nearly 0.5 cm. The magnitude of prostate motion under rectal volume's impact remained highly significant in our study. This result was consistent with previously published data [15-18]. Antolak et al. [16] measured the mobility of the clinical target volume (CTV) in prostate radiotherapy with respect to the pelvic anatomy in 17 patients and showed that prostate mobility was not significantly correlated with bladder volume. However, the mobility of both the prostate and seminal vesicles was very significantly correlated with rectal volume. Poli et al. [6] evaluated the influence of rectal volume on prostate motion during three-dimensional conformal radiotherapy (3D-CRT) for prostate cancer and found that a baseline rectal volume greater than 70 cm3 had a significant influence on prostate motion in the anteroposterior axis. Both Schild et al. [19] and Dawson et al. [20] reported that distension of the rectum shifted the prostate anteriorly; deviations as large as 15 mm were seen in prostate position. Therefore, rectal filling was definitely an important factor for prostate moving forward, whereas the effect of bladder was not obvious.

The anterosuperior shift of the prostate seen under an extended rectum in our study could be attributed to specific factors. First, the prostate is closely adjacent to the rectum, and the sacrococcyx limits posterior displacement of the rectum. Therefore, a distended rectum will force the prostate to move forward into the retropubic space. Second, the pelvic floor musculature and structures limit the inferior movement of the prostate, so that distention of the middle and distal rectum or contraction of the pelvic floor musculature under a filled rectum and/or full bladder will move the prostate superiorly [21, 22]. After all, there is more potential space in the superior direction. The magnitude and direction of target shifting demonstrated by the data could have an impact on the accuracy of treatment delivered to the prostate. In order to improve tumor control and avoid radiation-induced toxicity to surrounding organs at risk, correcting the target position displacement before irradiation delivery and monitoring the prostate position during radiation therapy become essential in the era of IMRT of prostate cancer [5]. In addition, our study indicates that it is not reasonable to extend CTV margins evenly in all directions.

A full bladder only shifted the prostate superiorly to a small degree in our study, and no any other trends of prostate position-shifting were observed. This is in accordance with other authors' reports. Pinkawa et al. [13] evaluated prostate position variability in 30 prostate patients under full bladder (FB) and empty bladder (EB) conditions. They concluded that despite a larger variability of bladder filling was observed, prostate position stability was the same with FB and EB conditions. Their latter report indicated that significant bladder wall displacements were only found at the anterior and superior borders when FB was compared with EB [23]. Both Antolak et al. [16] and Van Herk et al. [18] also reported that prostate mobility was not significantly correlated with bladder volume. We speculate that this is due to the fact that bladder's position is above the symphysis pubis where posterior and inferior expansion is restricted by the rectum and sacrococcygeal structures behind and the prostate and the pelvic floor musculature below, but there is greater potential space for expansion in the anterior and superior directions (refer to Figure 2c).

Most studies [15, 16, 23] scanned and treated patients in the supine position, just as we did. When patients are scanned in the supine position, Pinkawa et al. showed that the mean bladder wall displacement remained <5 mm at the inferior, lateral, and posterior borders – compared with 15 and 21 mm at the anterior and superior borders – with bladder volume change [23]. Some studies, however, have reported a significant influence of bladder filling on prostate position when patients were in a prone position [7, 14]. In a prone position, the body weight can press through the bladder onto the prostate and cause significant displacement in the posterior and inferior directions [13]. So we prefer the supine position for hypofractionated radiotherapy for prostate cancer.

Our study had some limitations. First of all, it included a limited number of patients, and it lacked accurate control of the bladder volume. Secondly, we did not evaluate the position of the seminal vesicles under different rectal and bladder filling statuses. Finally, we did not evaluate the rotation variability. Thus more research work is warranted.

Conclusions

Our results suggest that we should require more generous margins in the anterior and superior directions around the CTV and that the use of bone registration for irradiation delivery to the prostate is not precise enough. We should routinely use image-guided techniques via the prostate to deliver precise radiotherapy for prostate cancer, especially with hypofractionated therapy. Finally we further confirmed the importance of controlling the rectal volume status during prostate cancer radiotherapy. These findings will help to improve the accuracy of hypofractionated radiotherapy for prostate cancer.

Competing interests: All the authors declare that they have no competing interests.

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References

1. Yin Z, You J, Wang Y, et al. Moderate hypofractionated radiotherapy vs conventional fractionated radiotherapy in localized prostate cancer: a systemic review and meta-analysis from Phase III randomized trials. Onco Targets Ther. 2019; 12:1259-1268.

2 Arcangeli G, Arcangeli S, Pinzi V, Benassi M, Strigari L. Optimal scheduling of hypofractionated radiotherapy for localized prostate cancer: A systematic review and metanalysis of randomized clinical trials. Cancer Treat Rev. 2018; 70:22-29.

3. Tong X, Chen X, Li J, et al. Intrafractional prostate motion during external beam radiotherapy monitored by a real-time target localization system. J Appl Clin Med Phys. 2015; 16(2):5013.

4. Badakhshi H, Wust P, Budach V, Graf R. Image-guided radiotherapy with implanted markers and kilovoltage imaging and 6-dimensional position corrections for intrafractional motion of the prostate. Anticancer Res. 2013; 33(9):4117-4121.

5. Munoz F, Fiandra C, Franco P, et al. Tracking target position variability using intraprostatic fiducial markers and electronic portal imaging in prostate cancer radiotherapy. Radiol Med. 2012; 117(6):1057-1070.

6. Poli AP, Dias RS, Giordani AJ, Segreto HR, Segreto RA. Strategies to evaluate the impact of rectal volume on prostate motion during three-dimensional conformal radiotherapy for prostate cancer. Radiol Bras. 2016; 49(1):17-20.

7. 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. Radiother Oncol. 1999; 50(2):225-234.

8. D'Amico AV, Whittington R, Malkowicz SB, et al. Biochemical outcome after radical prostatectomy, external beam radiation therapy, or interstitial radiation therapy for clinically localized prostate cancer. JAMA. 1998; 280(11):969-974.

9. Shaikh T, Li T, Handorf EA, et al. Long-Term Patient-Reported Outcomes From a Phase 3 Randomized Prospective Trial of Conventional Versus Hypofractionated Radiation Therapy for Localized Prostate Cancer. Int J Radiat Oncol Biol Phys. 2017; 97(4):722-731.

10. Arcangeli G, Saracino B, Gomellini S, et al. A prospective phase III randomized trial of hypofractionation versus conventional fractionation in patients with high-risk prostate cancer. Int J Radiat Oncol Biol Phys. 2010; 78(1):11-18.

11. Incrocci L, Wortel RC, Alemayehu WG, et al. Hypofractionated versus conventionally fractionated radiotherapy for patients with localised prostate cancer (HYPRO): final efficacy results from a randomised, multicentre, open-label, phase 3 trial. Lancet Oncol. 2016; 17(8):1061-1069.

12. 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. Int J Radiat Oncol Biol Phys. 1995; 33(5):1321-1329.

13. Pinkawa M, Asadpour B, Gagel B, Piroth MD, Holy R, Eble MJ. Prostate position variability and dose-volume histograms in radiotherapy for prostate cancer with full and empty bladder. Int J Radiat Oncol Biol Phys. 2006; 64(3):856-861.

14. Melian E, Mageras GS, Fuks Z, et al. Variation in prostate position quantitation and implications for three-dimensional conformal treatment planning. Int J Radiat Oncol Biol Phys. 1997; 38(1):73-81.

15. Beard CJ, Kijewski P, Bussiere M, et al. Analysis of prostate and seminal vesicle motion: implications for treatment planning. Int J Radiat Oncol Biol Phys. 1996; 34(2):451-458.

16. Antolak JA, Rosen, II, Childress CH, Zagars GK, Pollack A. Prostate target volume variations during a course of radiotherapy. Int J Radiat Oncol Biol Phys. 1998; 42(3):661-672.

17. Artignan X, Rastkhah M, Balosso J, Fourneret P, Gilliot O, Bolla M. [Quantification of prostate movements during radiotherapy]. Cancer Radiother. 2006; 10(6-7):381-387.

18. Van Herk M, Bruce A, Kroes AP, Shouman T, Touw A, Lebesque JV. Quantification of organ motion during conformal radiotherapy of the prostate by three dimensional image registration. Int J Radiat Oncol Biol Phys. 1995; 33(5):1311-1320.

19. Schild SE, Casale HE, Bellefontaine LP. Movements of the prostate due to rectal and bladder distension: implications for radiotherapy Med Dosim. 1993; 18(1):13-15.

20. Dawson LA, Mah K, Franssen E, Morton G. Target position variability throughout prostate radiotherapy. Int J Radiat Oncol Biol Phys. 1998; 42(5):1155-1161.

21. Crook JM, Raymond Y, Salhani D, Yang H, Esche B. Prostate motion during standard radiotherapy as assessed by fiducial markers. Radiother Oncol. 1995; 37(1):35-42.

22. Ten Haken RK, Forman JD, Heimburger DK, et al. Treatment planning issues related to prostate movement in response to differential filling of the rectum and bladder. Int J Radiat Oncol Biol Phys. 1991; 20(6):1317-1324.

23. Pinkawa M, Asadpour B, Siluschek J, et al. Bladder extension variability during pelvic external beam radiotherapy with a full or empty bladder. Radiother Oncol. 2007; 83(2):163-167.