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PHYSICS CONTRIBUTION

EFFECT OF EDEMA ON POSTIMPLANT DOSIMETRY IN PROSTATE BRACHYTHERAPY USING CT/MRI FUSION

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Purpose: To investigate the time course of prostatic edema and the effect on the dose–volume histograms of the prostate for patients treated with brachytherapy.

Methods and Materials: A total of 74 patients with prostate cancer were enrolled in this prospective study. A transrectal ultrasound-based preplan was performed 4 weeks before implantation and computed tomography/magnetic resonance imaging fusion-based postimplant dosimetry was performed on the day after implantation (Day 1) and 30 days after implantation (Day 30). The prostate volume, prostate volume covered by 100% of the prescription dose (V_{100}), and dose covering 90% of the prostate (D_{90}) were evaluated with prostatic edema over time.

Results: Prostatic edema was greatest on Day 1, with the mean prostate volume 36% greater than the preplan transrectal ultrasound-based volume; it thereafter decreased over time. It was 9% greater than preplan volume on Day 30. The V_{100} increased 5.7% from Day 1 to Day 30, and the D_{90} increased 13.1% from Day 1 to Day 30. The edema ratio (postplan/preplan) on Day 1 of low-quality implants with a V_{100} of <80% was significantly greater than that of intermediate- to high-quality implants (>80% V_{100}; $p = 0.0272$). The lower V_{100} on Day 1 showed a greater increase from Day 1 to Day 30. A V_{100} on Day 1 of >92% is unlikely to increase >0% during the interval studied.

Conclusion: Low-quality implants on Day 1 were highly associated with edema; however, such a low-quality implant on Day 1, with significant edema, tended to improve by Day 30. If a high-quality implant (V100 >92%) can be obtained on Day 1, a re-examination is no longer necessary. © 2007 Elsevier Inc.

Prostate brachytherapy, Postimplant dosimetry, Edema, Computed tomography/magnetic resonance imaging fusion, CT/MRI fusion.

INTRODUCTION

Transperineal prostate implants with ^{125}I have rapidly become a popular treatment option for localized prostate cancer. The American Brachytherapy Society has published guidelines that include a recommendation for postimplant quality assurance (1, 2). The relationship between prostatic edema and improvement in the dose–volume histograms (DVHs) after prostate brachytherapy has been well documented (3–10). In general, prostatic edema is the greatest on Day 0–1; thereafter, it gradually decreases in size, with the DVHs then showing strong improvement. In several previous studies, prostatic edema was assessed using computed tomography (CT) scans. Polo *et al*. (11) reported the median prostate volume in 21 patients to be 30% greater when measured by CT than by CT/magnetic resonance imaging (MRI) fusion image in the postimplant setting (11). Taussky *et al*. (4) and Reed *et al*. (12) analyzed 20 and 30 patients for edema using the CT/MRI fusion method, respectively. Although their implant qualities (prostate volume covered by 100% of the prescription dose [V_{100}]) were excellent (Taussky *et al*. [4], 93.6% on Day 1; Reed *et al*. [12], 95% on Day 0; and in our series, 85.2% on Day 1), a substantial range in the implant quality is commonly observed at many centers. The mean prostate volumes of their populations were relatively larger than that of our population (Taussky *et al*. [4], 34.9 cm^3; Reed *et al*. [12], 33 cm^3; and in our series, 17.7 cm^3). They included no patients who had received neoadjuvant hormonal therapy. The aim of the present study was to investigate the course of prostatic edema in patients treated with brachytherapy according to the effects of the

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DVHs of the prostate using the CT/MRI fusion method with a larger number of patients.

METHODS AND MATERIALS

The study population consisted of 74 patients with early-stage adenocarcinoma of the prostate treated with low-dose-rate brachytherapy in our hospital. The only selection criterion for the study was that the patients were required to reside relatively close to the hospital to avoid problems caused by the need for excessive travel to undergo the extra scans. All patients provided written informed consent to participate in this prospective study. Of the 74 patients, 26 underwent prostate brachytherapy with 145 Gy alone (prostate-specific antigen [PSA] ≤10 ng/mL, Gleason score ≤6), and 48 underwent external beam radiotherapy 30 days after brachytherapy with 104 Gy (PSA >10 ng/mL or Gleason score ≥7). The mean age was 66.3 ± 5.6 years, and the mean number of seeds used was 55.2 ± 15.1. The mean initial PSA level was 8.4 ± 4.5 ng/mL. Of the 74 patients, 48 underwent neoadjuvant hormonal therapy, 8 received a short course of ≤4 months of androgen deprivation therapy for cytoreduction, and 40 received an extended course of >4 months of androgen deprivation therapy for poor prognosticators. In all hormonally manipulated patients, androgen deprivation therapy was initiated before implantation, which consisted of luteinizing hormone-releasing hormone agonist and antiandrogens.

All patients were treated with loose ^{125}I radioactive seeds (Oncoseed, Nihon Mediphysics, Tokyo, Japan) using a Mick applicator (Mick Radio-Nuclear Instruments, Bronx, NY). The source strength was 0.34 mCi for all patients. A baseline transrectal ultrasound (TRUS) scan was performed by an experienced urologist. All patients underwent TRUS-based preplanning 4 weeks before implantation. The preplan was determined using TRUS images taken at 5-mm intervals from the base to the apex of the prostate with the patient in the dorsal lithotomy position. The updated American Association of Physicists in Medicine Task Group 43 formula was used in the planning and calculation of the final dosimetry.

On the day after implantation (Day 1) and 29.7 ± 2.5 days (range, 23–35) after implantation (Day 30), a chest radiograph (anteroposterior view), kidney-urinary bladder radiograph, and pelvic radiograph were all taken to check for any possible seed migration (13, 14).

Computed tomography and MRI sets were also obtained on Days 1 and 30. A postimplant CT scan was obtained using a CT scanner with 16 detector arrays (LightSpeed Ultra 16, GE Medical Systems, Milwaukee, WI). Axial CT images of 3 mm thickness were obtained. A field of view of 15 cm, a 512-square matrix, and a standard reconstruction algorithm were used. No intravenous contrast material was used. The patients' urethra was catheterized for the CT and MRI scans to improve the visualization of the urethra on Day 1, but it was not catheterized on Day 30. MRI scans were obtained with a five-channel-sense cardiac coil under easy breathing with a slice thickness of 3 mm and no intersectional gap (Intera Achieva 1.5T, Pulsar, Philips Medical Systems, Eindhoven, The Netherlands). The MRI sequence was contrast-enhanced T_1-weighted spin-echo (repetition time/echo time, 607 ms/12 ms) with 2 mL/kg body weight of gadopentetate dimeglumine (Magnevist, Schering, Berlin, Germany) administered. Contrast-enhanced T_1-weighted images were used, because this method was more effective for detecting the seeds and prostate than was T_1-weighted spin-echo (607/12), T_2-weighted fast spin-echo (3,000/80), fat-suppressed T_2-weighted fast spin-echo (2,800/75), or contrast-enhanced fat-suppressed T_1-weighted spin-echo (729/12) imaging (15, 16). The CT and MRI scans were electronically registered using a manual fusion procedure of the Variseed fusion system, version 7.1 (Varian Medical Systems, Palo Alto, CA) to perform CT/MRI fusion-based dosimetry. More than 10 seeds were used as fiducial markers for fusion, because fusion guidance using surrounding structures such as the pubic bone is not reliable when gas is in the rectum. Seed detection using CT/MRI fusion-based dosimetry was automatically performed with the Variseed system, and the contouring of organs was performed manually with the guidance of the MRI scan.

A radiation oncologist contoured the prostate volumes according to the fusion image. The volumes and DVH-related parameters were calculated using the contours of the prostate and the Variseed system. For each postimplant dosimetry, DVHs for the prostate were generated. The prostate volume covered by 100% of the prescription dose (V_{100}) and the dose covering 90% of the prostate (D_{90}) for scans take on Days 1 and 30 were evaluated. The relationship between the resolution of edema and an increase in the DVH-related parameters was evaluated by comparing the incidence of edema and the increase in prostate V_{100} and D_{90}. Factors (*i.e.,* age, initial PSA level, preplan volume, hormonal therapy, number of seeds, and treatment method) potentially predictive of edema on Day 1 were assessed singly using a standard regression coefficient. Group comparisons for the volumes and dosimetric parameters were performed using the *t* test. All tests were two-sided, and $p \leq 0.05$ was considered statistically significant.

Table 1. Time course of prostate volume and DVHs ($n = 74$)

		Postplan day	
Variable	Preplan	1	30
Prostate volume (cc)	17.7 ± 7.2	24.2 ± 9.9	19.4 ± 7.7
Prostate V100 (%)	96.4 ± 3.0	85.2 ± 10.8	90.9 ± 7.1
Prostate D90 (%)	123.7 ± 14.4	94.8 ± 19.1	107.9 ± 22.4

Abbreviations: Preplan = values estimated from preplan transrectal ultrasound images; Postplan Days 1 and 30 = values estimated from postimplant computed tomography/magnetic resonance imaging fusion-based dosimetries on Days 1 and 30; V_{100} = prostate volume covered by 100% of prescription dose; D_{90} = dose covering 90% of prostate.

Data presented as mean ± standard deviation.

RESULTS

Seed migration

Seed migrations were found in 15 of 74 patients during the first 30 days. However, only 2 of 15 patients had seed migration found on the Day 1 radiograph. The average seed loss per implant was 0.26 (range, 0–2).

Prostate volume and DVHs

Table 1 shows that the time course of the prostate volumes and DVH-related parameters. The prostate volume increased on Day 1 with respect to baseline and had decreased on Day 30 with respect to Day 1. The V_{100} and D_{90} were both lower on Day 1 and improved on Day 30. The V_{100} increased by 5.7% from Day 1 to Day 30, and the D_{90} increased by 13.1% from Day 1 to Day 30. Figure 1 shows the correlation of Day 1 to Day 30 regarding the V_{100} and D_{90}. Figure 2 shows the relationship of edema to the DVHs on Day 1. A greater level of edema was weakly associated with a lower V_{100} and D_{90}.