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Dosimetric quality and evolution of edema after low-dose-rate brachytherapy for small prostates: Implications for the use of newer isotopes

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ABSTRACT

PURPOSE: To characterize prostate swelling and dosimetry in patients with small prostate volumes (PVs) undergoing brachytherapy.

METHODS AND MATERIALS: We studied 25 patients with PV <25 cc (range, 15.1–24.8) and 65 patients with PV ≥25 cc (range, 25.0–66.2) based on three-dimensional ultrasound contours who underwent brachytherapy monotherapy with intraoperative planning. Postoperative Days 1 and 30 dosimetry was done by CT–MRI fusion.

RESULTS: Small PVs had greater Day 1 swelling than large PVs (32.5% increase in volume vs. 23.7%, $p = 0.04$), but by Day 30, swelling was minimal and not significantly different ($p = 0.44$). Small PVs had greater seed and needle densities at implant ($p < 0.001$). Rectal and urethral doses were nearly identical by Day 30 (small PV rectum receiving 100% of the prescription dose [145 Gy] [V_{100}] = 0.32 cc; large PV rectum $V_{100} = 0.33$ cc, $p = 0.99$; small PV urethra receiving 150% of the prescription dose [145 Gy] [V_{150}] = 0.20, large PV urethra $V_{150} = 0.20$, $p = 0.91$). Swelling at Day 1 created some cool implants (rate dose that covers 90% of the prostate volume [D_{90} <140 Gy = 12.0% and 9.4% for the small and large PV groups, respectively, $p = 0.71$), but Day 30 planning target volume coverage was excellent (rate D_{90} <140 Gy = 0% for both groups).

CONCLUSIONS: Although smaller prostates have greater Day 1 swelling, good Day 30 dosimetry can be achieved, making them excellent candidates for ^{125}I seeds (half-life [$t½$] = 60 days). Smaller prostates may be suboptimal for shorter $t½$ sources such as ^{131}Cs ($t½ = 9.7$ days), in which the majority of the dose may be delivered to an edematous gland, unless the planning is adjusted to anticipate the edema.

Keywords: Prostate brachytherapy; Low dose rate; Small prostate; ^{125}I seeds

Introduction

Transperineal interstitial prostate brachytherapy with low-dose-rate (LDR) seed implantation is a commonly used treatment modality for localized prostate cancer. Although this technique is sometimes contraindicated in larger prostates because of anatomic variants such as pubic arch interference, there is debate regarding the implantation of small prostates. In some studies, prostates less than 25 cc have been found to have increased swelling and more suboptimal implants (1, 2). Other studies have shown that prostates as small as 20 cc have acceptable dosimetry (3) and prostate cancer–specific mortality (4). The duration of swelling is

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also somewhat variable across studies with some reporting minimal swelling 30 days after implant (5), whereas others indicate potential residual swelling 30 days after implant (6).

Furthermore, although ^{125}I implants are the most common free seeds used for prostate brachytherapy, there is increasing interest in the use of ^{131}Cs because of its shorter half-life ($t½$ = 9.7 days vs. 60 days for ^{125}I) (7). If swelling in small prostates is indeed greater in the short-term postimplant period, there is a risk of underdosing tumor in smaller prostates which would be especially evident with ^{131}Cs implants.

To better understand these potential implications, we conducted a retrospective study assessing prostate size with relation to both short-term and long-term swelling and dosimetry in patients who underwent brachytherapy at our institution.

Methods and materials

Between October 2009 and May 2012, 102 patients with early-stage, localized prostate cancer were treated with prostate brachytherapy alone at the Brigham and Woman's Hospital in Boston, MA. All patients received three-dimensional transrectal ultrasound with contoured prostate volumes (PVs) before the procedure. Brachytherapy was performed transperineally by one brachytherapist (PLN) under ultrasound guidance with intraoperative planning using loose ^{125}I LDR seed implants to a prescription dose of 145 Gy. All patients received CT and MRI scans 1 day (Day 1) and 30 days (Day 30) postoperatively for dosimetric study. MRI was used to contour the prostate and was fused with the CT for dosimetry using a seed-to-seed fusion technique.

Patients' baseline characteristics were obtained from the medical record (Table 1). Patients who received androgen deprivation therapy with luteinizing hormone–releasing hormone agonists or antiandrogen therapy before brachytherapy were excluded as this has been shown to be an independent marker of increased prostate swelling (8). Eight patients were excluded from the study because they did not have a contoured volume study volume before the implantation. Three patients included in the study (all in the large PV group) did not have Day 30 CT and MRI scans and were excluded in Day 30 analysis. The final study population consisted of 25 patients with small PV defined as PV less than 25 cc and 65 patients with PV 25 cc or greater based on the pretreatment volume study performed.

PVs and dosimetry were calculated using the Nucletron SPOT Pro contouring software (Nucletron, an Elekta company [Elekta AB, Stockholm, Sweden]). Prostate edema was calculated as defined by Liu *et al.* (2) as a change in volume from the volume study to the Day 1 or 30 scans divided by the volume study volume. Needle and seed densities were obtained by dividing the total number of seeds and needles used by the volume study PV. All dose volume–histogram parameters were obtained on Days 1 and 30 and included dose that covers 90% of the prostate volume (D_{90}), prostate receiving 100%, 150%, and 200% of the prescription dose (145 Gy) (V_{100}, V_{150}, and V_{200}), urethra receiving 125% and 150% of the prescription dose (145 Gy) (V_{125}) and (V_{150}), and rectum receiving 100% of the prescription dose (145 Gy) (V_{100}). Quality of implant was analyzed at Days 1 and 30 by percentage of implants reaching a goal of prostate D_{90} >140 Gy, prostate V_{100} >90%, prostate V_{150} <70%, urethra V_{150} <0.25 cc, and rectum V_{100} < 1 cc. All differences were analyzed via the student's *t* Test and *F* test using Microsoft Excel (Microsoft Corp., Redmond, WA), R version 2.12.2 (R Development Core Team, www.r-project.org), and PSPP version 0.7.9 statistics analysis software (GNU project, http://www.gnu.org/software/pspp/). This study was approved by the Dana-Farber Harvard Cancer Center Institutional Review Board.

Results

Clinical characteristics of the patients

The mean PV of all patients was 33.9 cc (range, 15.1–66.2 cc). Eighty-seven percentage of the overall study population was Caucasian with similar rates in the small and large PV groups. Age, Gleason score, and percentage of cores positive did not differ between the small and the large prostate groups, but there was a trend

Table 1
Patient and tumor characteristics

Characteristics	Small PV (range)	Large PV (range)	*p*
Mean PV (cc)	21.5 (15.1–24.8)	38.6 (25.0–66.2)	<0.001
Mean age, yr	64.7 (55–74)	64.7 (49–77)	0.99
Caucasian (% of patients)	80	89	0.25
Mean PSA	4.9 (0.6–9.0)	5.6 (1.6–14.0)	0.20
Mean Gleason score	6.4 (6–7)	6.3 (6–7)	0.54
Mean number of cores positive	3.2 (1–10)	2.9 (1–10)	0.58
Mean maximum percent of core positive	30.2 (5–80)	27.8 (5–90)	0.69
Perineural invasion (% of patients)	16.0	16.9	0.92
cT1c (number of patients)	20	60	0.10
cT2a (number of patients)	5	5	

PV = prostate volume; PSA = prostate-specific antigen.