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Dosimetric evaluation of clinical target volume in the postimplant analysis of low-dose-rate brachytherapy for prostate cancer

Nicola J. Nasser[1,2,†], Joshua Sappiatzer[1,†], Yinkun Wang[3], Jette Borg[3], Elantholi P. Saibishkumar[1,2,*]

[1]*Department of Radiation Oncology, Radiation Medicine Program, Princess Margaret Cancer Centre, Toronto, Ontario, Canada*
[2]*Faculty of Medicine, University of Toronto, Toronto, Ontario, Canada*
[3]*Department of Radiation Physics, Radiation Medicine Program, Princess Margaret Cancer Centre, Toronto, Ontario, Canada*

ABSTRACT

PURPOSE: Brachytherapy is an effective single treatment modality for low- and intermediate-risk prostate cancer. In this study, we defined a clinical target volume (CTV) and evaluated its dosimetry 1 month after the low-dose-rate brachytherapy procedure.

METHODS AND MATERIALS: One hundred ninety-eight consecutive patients treated for prostate cancer by iodine-125 seed brachytherapy were assessed. Prostate dosimetry was stratified according to British Columbia Cancer Agency criteria, with good implants having both V_{100} (percentage of target volume that receives 100% of the prescribed dose) > 85% and D_{90} (percentage of the prescribed dose received by 90% of the target volume) > 90%, suboptimal implants with V_{100} of 75–85%, or D_{90} 80–90%, whereas poor implants were defined as those with V_{100} < 75 or D_{90} < 80%. CTV dosimetry stratification was performed according to the same dose coverage criteria, albeit to the CTV.

RESULTS: One hundred ninety-two patients (97%) had good prostate radiation coverage, whereas only 165 patients (83%) had good postimplant CTV dosimetry. Patients with suboptimal vs. good CTV dosimetry had prostate edema of 7.8 ± 0.2% vs. 0.2 ± 0.1%, respectively ($p = 0.001$).

CONCLUSIONS: Prostate seed implants with optimal dosimetry to prostate may still have suboptimal D_{90} and V_{100} for the CTV, especially in the presence of postimplant edema. A consensus is needed for definition and evaluation of CTV in postimplant setting for low-dose-rate prostate brachytherapy.

Keywords: Clinical target volume; Prostate; Dosimetry; Cancer

Introduction

Low-dose-rate (LDR) brachytherapy is widely used for treatment of low- and intermediate-risk prostate cancer (1–4). Extracapsular extension can occur in low- and intermediate-risk prostate cancer but is mostly confined within 3–5 mm (5). Hence, clinical target volume (CTV) in LDR brachytherapy should include the whole prostate and a margin around the prostate to account for possible extracapsular extension (6). Moreover, including a margin around the prostate allows for at least partial compensation for prostate edema, which usually occurs as a result of seed insertion (7–10).

Preimplant planning usually ensures adequate coverage to the prostate CTV, whereas posttreatment dosimetry is usually limited to the prostate, rectum, and urethra, and prostate CTV dosimetry is not routinely performed. Moreover, there are no clear guidelines to evaluate the quality of CTV dosimetry. Recently, we have shown that there are significant differences in dose coverage of different sectors of the prostate between preplan and postimplant dosimetry (11).

In the present study, preimplant treatment plans and postimplant dosimetry are compared for patients treated with iodine-125 prostate brachytherapy at Princess Margaret Cancer Centre (PMCC) to evaluate radiation dose coverage to the prostate and the prostate CTV.

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* Corresponding author. Department of Radiation Oncology, Princess Margaret Cancer Centre/University of Toronto, Toronto M5G 2M9, Ontario, Canada. Tel.: +1-416-946-2919; fax: +1-416-946-6561.

E-mail address: saibish.elantholi@rmp.uhn.on.ca (E.P. Saibishkumar).

† These authors contributed equally to this manuscript.

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Methods and materials

Patients

This retrospective analysis was approved by the University Health Network Research Ethics Board. The study group consisted of 198 consecutive men with prostate cancer attending the PMCC from March 2009 to October 2012 and who met the eligibility criteria for inclusion in the study. One hundred sixty-nine patients with low-risk prostate cancer (T1 or T2a, and Gleason 6, and prostate-specific antigen [PSA] <10 ng/mL) and 29 patients with intermediate-risk prostate cancer (T2b–T2c, or Gleason 7, or PSA 10–20 ng/mL) were included in the study. High-risk prostate cancer (T3, or Gleason 8–10, or PSA ≥20 ng/mL) was not included in this study. Eligibility criteria for the study were age 18 years or older, histologically confirmed prostate cancer, no evidence of metastases, pretreatment planning using transrectal ultrasound (TRUS), implant procedure with iodine-125, prescribed dose of 145 Gy (12), and postimplant dosimetry at 1 month based on MRI and CT pelvic scans.

Pretreatment planning

Prostate mapping was performed 2–4 weeks before implantation by TRUS using a BK ProFocus (BK Medical ApS, Herlev, Denmark) at 9 MHz. Images were recorded every 5 mm and downloaded to the VariSeed, version 7.2 or 8.0, treatment planning system (Varian Medical Systems, Inc., Palo Alto, CA). The CTV was defined as the prostate with anterior and lateral margins of 3 mm, and a 5 mm margin in the cranial and caudal directions with the removal of the expansion into the bladder wall (6). No posterior margin was added at the rectal interface. For patients with Gleason 7 prostate cancer, lateral margins were 5 mm on the prostate side involved with the Gleason 7 tumor. Pretreatment plan aimed for a prostate CTV $V_{100} > 99\%$, D_{90} 120–125%, and V_{150} 55–62%. Pretreatment plans aimed to deviate the 150% isodose to the prostate areas that harbored biopsy cores positive for malignancy. Pretreatment plans were designed to keep UD_5 (dose to 5% of the urethral volume) < 150% and UD_{30} (dose to 30% of the urethral volume) < 125% of the prescribed dose (13). RV_{100} (rectal wall volume that receives 100% of the prescribed dose) was aimed to be kept under 1 cm^3. Seeds activity was ~0.3 mCi.

Implantation procedure

Permanent seed implantation was performed under general anesthesia. Patients were positioned in lithotomy as close to the exact position possible as at the time of the mapping session. Under TRUS guidance, transperineal insertion of seeds using template and needles was performed according to the pretreatment plan. During the procedure, serial x-ray imaging of prostate was obtained after each row of seeds implanted, to assess the quality of seed insertion and facilitate intraoperative decision making regarding necessary modifications of the preplan to achieve better dose coverage of the prostate. These modifications if done, were mainly adding one or two seeds at the end of the implantation procedure if deemed necessary, after assessment at the operation room, in terms of accuracy of placement, fluoroscopic images showing any significant displacement, and so on.

Postimplant dosimetry

Postimplant dosimetry, using CT–MRI fusion, was performed 30 days after the implant (Fig. 1). Axial CT images were taken in the supine position with Aquilion ONE Toshiba CT scanner (Toshiba America Medical Systems, Inc., Tustin, CA) after insertion of an urethral Foley catheter. Slices were obtained at 2.5-mm intervals without an interslice gap. Axial MR scans were obtained using 3T IMRIS/Siemens MRI scanner (IMRIS, Winnipeg, MB, Canada) and were obtained immediately after the CT. The slice

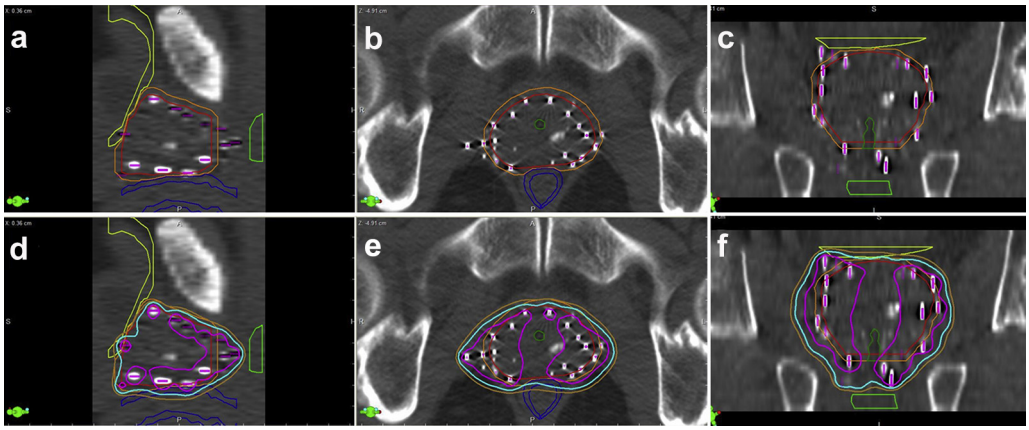

Fig. 1. Prostate dosimetry postimplant scans. Structures were contoured on MR and fused with CT scan to identify the brachytherapy seeds. First row shows (a) sagittal, (b) axial, and (c) coronal views of pelvis. Prostate (red), bladder (yellow), rectum (blue), prostate clinical target volume (bronze). Second row shows the same (d) sagittal, (e) axial, and (f) coronal views of pelvis with isodoses overlaid (yellow 80%, blue 100%, and pink 150%). (For interpretation of references to color in this figure legend, the reader is referred to the web version of this article.)