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BRACHYTHERAPY

Sector analysis of dosimetry of prostate cancer patients treated with low-dose-rate brachytherapy

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ABSTRACT

PURPOSE: Brachytherapy is an effective single treatment modality for low- and intermediate-risk prostate cancer. Here, we compare the radiation doses in different prostate sectors between the preimplant planning images and the postimplant dosimetry.

METHODS AND MATERIALS: Two hundred fifteen consecutive patients treated for prostate cancer by ^{125}I seed brachytherapy were assessed. Pretreatment plans using transrectal ultrasound images of the prostate were compared with the dose calculated on posttreatment MRI and CT scans obtained 1 month after seed implantation. Twelve sectors were generated by dividing the prostate base, midgland, and apex into four quadrants each. Pretreatment and posttreatment dosimetry were compared between the 12 different sectors of the prostate.

RESULTS: Average V_{100} (percentage of prostate volume that receives 100% of the prescribed dose) in the preimplant planning images of the prostate was 99.9 ± 0.25% compared with postimplant V_{100} of 94.8 ± 3.77% ($p < 0.0001$). Prostate V_{100} in the postimplant dosimetry was >91% in all sectors, except the anterior base sector, in which it was 64.87 ± 20.96%. Average 1-month D_{90} (the dose to 90% of the prostate volume) was 114.5 ± 10.55%. D_{90} at 1 month compared with preimplant planning was lower in the prostate base and higher in the prostate apex ($p < 0.001$).

CONCLUSIONS: Our results show that in ^{125}I seed brachytherapy, prostate base receives a lower dose and apex receives a higher dose compared with preimplant planned dose coverage.

Keywords: Sector analysis; Prostate; Dosimetry; Cancer

Introduction

Low-dose-rate (LDR) brachytherapy is an established treatment modality for low- and intermediate-risk prostate cancer (1−3). In high-risk prostate cancer, combination of LDR brachytherapy and external beam radiation is extensively used (4, 5). The radioactive seed implant technique uses a transperineal approach for inserting the seeds, which is performed with transrectal ultrasound (TRUS) guidance. Planning TRUS is usually performed before the seed implantation, either in the operation room (6, 7), or days to weeks before the implantation procedure (8).

While planning usually provides uniform coverage of the prostate, posttreatment dosimetry is usually different from the preimplant planning, although adequate coverage is mostly attained (9−12). Factors that play a role in the discrepancy between preplan and postimplant prostate dose coverage include prostatic edema, difficulty to precisely implant the seeds in the operation room, measures taken by the implanting physician to spare the bladder wall, urethra, or rectum, and postoperative seed displacement.

Sector analysis is a method in which the organ is divided into different sectors according to anatomic locations (13, 14). Sector analysis of the prostate allows dose calculations not only to the whole prostate but also to the specific parts of it (13, 14). Pre- and post-implant treatment plans are compared for patients treated with ^{125}I prostate brachytherapy at Princess Margaret Cancer Centre to find if there is a predictable pattern of variance.

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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 215 consecutive men with prostate cancer attending the Princess Margaret Cancer Centre from March 2009 to December 2012 and who met the eligibility criteria for inclusion in the study. One hundred seventy patients with low-risk prostate cancer (T1 or T2a, Gleason 6, and prostate-specific antigen (PSA) of <10 ng/mL) and 45 patients with intermediate-risk prostate cancer (T2b−T2c, Gleason 7, or PSA of 10−20 ng/mL) were included in the study. Eligibility criteria for the study were age 18 years or older, histologically confirmed prostate cancer, no evidence of metastases, pretreatment planning using TRUS, implant procedure with ^{125}I, 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 prescribed dose was 145 Gy (15). The planning target volume was defined as the prostate with an anterior and lateral margins of 3 and a 5 mm margin in the cranial and caudal directions with removal of the expansion into bladder wall. 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 V_{100} of >99%, D_{90} (the dose to 90% of the prostate volume) of 120−125%, and V_{150} (percentage of prostate volume that receives 150% of the prescribed dose) of 55−62%. The urethra was identified using aerated gel in urethra during the preplan ultrasound mapping. 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 (16). For rectal wall, RV_{100} (rectal wall volume that receives 100% of the prescribed dose) was aimed to be kept under 1 cm^3.

Implantation procedure

Permanent seed implantation was performed under general anesthesia. Patients were positioned in lithotomy in the exact position as during 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.

Postimplant dosimetry

Postimplant dosimetry, using CT−MRI fusion, was performed 30 days after the implant. Axial CT images were taken in the supine position with Aquilion ONE Toshiba CT scanner (Toshiba America Medical Systems, Inc., Tustin, CA). 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 thickness was 3 mm with no interslice gap. CT spatial resolution was 0.4−0.6 mm, and MRI spatial resolution was 0.7−1.0 mm. CT−MRI fusion was performed manually by the brachytherapy dosimetrist, relying on the brachytherapy seeds as fiducial markers. Seed location was determined in VariSeed on the CT images, and the number of seeds was verified against seeds counted on pelvic X-ray images. All relevant soft tissue structures were contoured on the MR images, except the urethra, which was contoured on CT images. Review of pre- and postimplant contouring and the implant procedures were carried out by the same experienced physician (EPS). Critical organ contouring and dosimetry were performed as per the American Brachytherapy Society guidelines (16).

Sector analysis

The prostate was delineated on pretreatment TRUS images and CT−MR fusion images obtained 1 month after seed implant. Twelve prostate sectors were generated by dividing the craniocaudal prostate axis into three equal parts: base, midgland, and apex and each of the three parts into four quarters: anterior, posterior, right lateral, and left lateral (Fig. 1). Evaluation of radiation coverage in each of the 12 sectors was performed for both pretreatment plan and postimplant dosimetry. Sector volume, V_{100}, and D_{90}, were calculated and compared.

Statistical analysis

Sector analysis parameters are reported as mean ± standard deviation (SD). Statistical analysis was performed using the Student *t* test, and the statistical software programs Microsoft Office Excel 2007 (Microsoft Corporation, Redmond, WA) and GraphPad Prism version 4.1 (GraphPad Software, Inc., La Jolla, CA).

Results

Prostate sectors volumes

Average prostate volume (±SD) in the preimplant planning was 42.4 ± 13.1 cm^3 vs. 42.6 ± 12.0 cm^3 in the