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Preoperative treatment planning with intraoperative optimization can achieve consistent high-quality implants in prostate brachytherapy

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ABSTRACT

Advances in brachytherapy treatment planning systems have allowed the opportunity for brachytherapy to be planned intraoperatively as well as preoperatively. The relative advantages and disadvantages of each approach have been the subject of extensive debate, and some contend that the intraoperative approach is vital to the delivery of optimal therapy. The purpose of this study was to determine whether high-quality permanent prostate implants can be achieved consistently using a preoperative planning approach that allows for, but does not necessitate, intraoperative optimization. To achieve this purpose, we reviewed the records of 100 men with intermediate-risk prostate cancer who had been prospectively treated with brachytherapy monotherapy between 2006 and 2009 at our institution. All patients were treated with iodine-125 stranded seeds; the planned target dose was 145 Gy. Only 8 patients required adjustments to the plan on the basis of intraoperative findings. Consistency and quality were assessed by calculating the correlation coefficient between the planned and implanted amounts of radioactivity and by examining the mean values of the dosimetric parameters obtained on preoperative and 30 days postoperative treatment planning. The amount of radioactivity implanted was essentially identical to that planned (mean planned radioactivity, 41.27 U *vs.* mean delivered radioactivity, 41.36 U; $R^2 = 0.99$). The mean planned and day 30 prostate V100 values were 99.9% and 98.6%, respectively. The mean planned and day 30 prostate D90 values were 186.3 and 185.1 Gy, respectively. Consistent, high-quality prostate brachytherapy treatment plans can be achieved using a preoperative planning approach, mostly without the need for intraoperative optimization. Good quality assurance measures during simulation, treatment planning, implantation, and postimplant evaluation are paramount for achieving a high level of quality and consistency.

Introduction

Transperineal interstitial permanent prostate brachytherapy is a routinely used treatment modality for men with localized prostate cancer.[1] Advances in brachytherapy treatment planning systems have allowed the brachytherapist to model the radiation dose to target volumes and organs at risk more rapidly than ever before. This evolution has created a dichotomy in brachytherapy treatment planning: the opportunity for brachytherapy to be planned intraoperatively as well as preoperatively.

Typically, there are 2 generally accepted methods to prostate brachytherapy treatment planning.[2–5] In the first method, intraoperative or real-time treatment planning, all procedures are carried out in the operating room on the day of the implant. These procedures include setting up the patient, determination of the prostate volume, treatment planning, and implantation of the patient with preordered radioactive sources. In the second method, namely preplanning, the prostate implant process is broken up into 2 stages. In the first stage, the patient undergoes an ultrasound simulation sometimes also referred to as *volume study*. The simulation consists of setting up the patient in an identical position to that in the actual implant, determination of the prostate volume and other prostate dimensions, evaluation for pubic bone interference, and overall evaluation to decide whether the patient is a candidate for prostate brachytherapy. Upon completion of their simulation, the patient is discharged home and returns for the implant at a later scheduled date, typically within 2–4 weeks. During this period, a treatment plan is generated and seeds are ordered based on the treatment plan needle loading pattern. Quality

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assurance is performed on the seeds, which are stranded, placed into needles, and sterilized. In the second stage of the preplanning method, patients are set up in the operating room in an identical position to that in their simulation and implanted based on the treatment plan.

The relative advantages and disadvantages of each approach have been the subject of extensive debate.[2–5] Proponents of the preplanning technique cite that the technique is more cost-effective because treatment planning and quality assurance is performed outside the operating room. Having a plan before the implant procedure saves valuable operating room time and allows for the use of preloaded needles, which entail little or no seed waste. Commonly cited advantages of intraoperative treatment planning over preoperative planning include improved accuracy of prostate volume studies, elimination of the need for a preplan volume study, and the ability to adjust to unanticipated operative findings. Proponents of the intraoperative approach suggest that these advantages result in improved consistency and quality, as assessed by postimplant dosimetry.[6] At our institution, we have adopted a hybrid approach in which the treatments are planned on the basis of preoperative imaging, but modern brachytherapy treatment planning software is on hand in the operating room in case variation from the predefined treatment plan is necessary (intraoperative optimization). The goal of preoperative planning is to ensure an optimal treatment plan, whereas intraoperative optimization functions as a quality control step when needed. The purpose of this study was to evaluate our quality assurance process in patients treated using our approach by comparing the total radioactivity planned with the total radioactivity implanted. Furthermore, we sought to determine whether high-quality implantation results, as determined by postimplant dosimetry parameters, could be consistently achieved at our center using our planning approach.

Materials and Methods

We reviewed the medical records of 100 consecutive patients with intermediate-risk prostate cancer who had been treated prospectively at the University of Texas M.D. Anderson Cancer Center on an institutional review board–approved protocol. Patients received treatment from 2006 through 2009. All patients received permanent prostate brachytherapy as monotherapy with iodine-125 (I-125) seeds (Oncura, Plymouth Meeting, PA). Stranded seeds with a radioactivity of 0.497 U/seed were used in all cases to obtain a prescribed dose of 145 Gy to the target volume.

All patients underwent evaluation for prostate brachytherapy, including a detailed history and physical examination, laboratory testing, and pelvic computed tomography (CT) or magnetic resonance imaging (MRI). CT scans were obtained to evaluate the patients for potential pubic bone interference with needle insertion. Eligibility criteria for participation in the protocol included the following: clinical tumor stage T1 or T2; no evidence of gross extracapsular extension, regional node involvement, or metastatic disease; and either a maximum Gleason score ≤7 and prostate-specific antigen (PSA) score <10 ng/mL or a Gleason score ≤6 and a PSA score between 10 and 15 ng/mL. In addition, patients could not have received hormone therapy.

All patients underwent scanning for treatment simulation in the dorsal-lithotomy position with a urinary catheter in place approximately 3–4 weeks before the implant procedure. Simulation scanning consisted of transrectal ultrasonography to determine the prostate volume and CT to determine pubic arch interference. Ultrasound images of the prostate were captured at 5-mm intervals and transferred to the VariSeed treatment planning system (Varian Medical Systems, Milpitas, CA); the prostate, seminal vesicles, rectum, urethra, and bladder were contoured on these images. A planning target volume with a margin of 3 mm around the prostate was generated, except posteriorly, where there was no margin. A treatment plan was then generated for each patient using the following planning parameter guidelines: prostate volume receiving at least the prescription dose (V100) >95%, prostate volume receiving at least 150% of the prescription dose (V150) <60%, prostate volume receiving at least 200% of the prescription dose (V200) <20%, and prescription dose that covers 90% of the prostate volume (D90) >100%; urethra volume receiving at least 200% of the prescription dose (U200) = 0%; and rectum volume receiving at least 100% of the prescription dose (R100) <1 cm^3. The amount of radioactivity, number and position of seeds, and loading pattern were optimized to meet these parameters. Two additional sterilized needles (1 with 2 stranded seeds and the other with 3) were purchased for each patient in addition to the planned stranded seeds. The extra I-125 stranded seeds were reserved for use at the treating physician's discretion in case intraoperative optimization planning indicated they were needed.

The physician who performed the simulation reproduced the patient position in the operating room. Radioactive sources were inserted into the prostate under ultrasound guidance according to the preoperative treatment plan. A coronal fluoroscopic image was obtained when the planned sources had been placed but before the implant procedure was concluded; these images were compared with those used in treatment planning to confirm the optimal source distribution. On the rare occasions when the planned implant seed positions or dose distribution did not match with the delivered seed positions or dose distributions, the implant was optimized in the operating room and additional stranded seeds were implanted to ensure complete target coverage while also ensuring both V150 <60% and R100 <1 cm^3. This intraoperative optimization was performed using intraoperative ultrasound images and the VariSeed software to fully assess the necessity and consequences of any changes to the original plan. The number of patients for which intraoperative optimization adjustments were made was documented.

After the procedure, all patients underwent immediate CT to evaluate prostate coverage and determine the postimplant day 0 (day of implant) dosimetric values. All patients underwent repeat CT on day 30 to evaluate the postimplant D30 (1 month after implant) dosimetry so that dosimetric data could be reevaluated. Postoperative dose distributions and dosimetric values were determined on the basis of the day 30 CT scans. The postimplant structures were delineated on the day 30 CT images, with the prostate volume referenced to that on the preoperative planning sonogram. The target volume's position was determined relative to the base plane and the prostate-rectum interface, as determined at the time of strand placement.[7]

The planned dosimetry parameters were compared with the postimplant CT-based measurements taken on day 30. The amount of radioactivity planned was compared with the radioactivity actually implanted in terms of both amount of radioactivity and number of seeds. Correlations between the amount of activity planned and the amount of activity implanted were generated by calculating R^2 values. R^2 is the coefficient of determination that is a statistical measure of how well the regression line approximates the real data points. R^2 provides the goodness of fit of the data with an R^2 value of 1.0, indicating that the regression line fits the data perfectly.

Results

The amount of radioactivity implanted was essentially identical to the amount of radioactivity predicted by the preoperative plan (Fig. 1). The average numbers of seeds planned and implanted were 83.04 (mean activity, 41.27 U) and 83.22 (mean activity, 41.36 U), respectively. Intraoperative adjustments were made for only 8 of the 100 patients (8%) whose records were reviewed. The mean planned prostate D90 value was 186.3 Gy (range 160–200 Gy; SD 6.2 Gy) and the mean day 30 prostate D90 value was 185.1 Gy (range 140–220 Gy; SD 14.4 Gy). The planned and postimplant prostate V100 values were similar (Fig. 2): The mean planned prostate V100 value was 99.9% (range 99%–100%; SD 0%) and the mean day 30 prostate V100 value was 98.6% (range 90%–100%; SD 1.5%). The intended rectal dose constraint R100 was also routinely achieved, without significant deviation from the planned value (Fig. 3): The mean planned R100 value was 0.40 cm^3 (range 0–0.9 cm^3; SD 0.23 cm^3) and the mean day 30 R100 value was 0.31 cm^3 (range 0–2.3 cm^3; SD 0.42 cm^3).

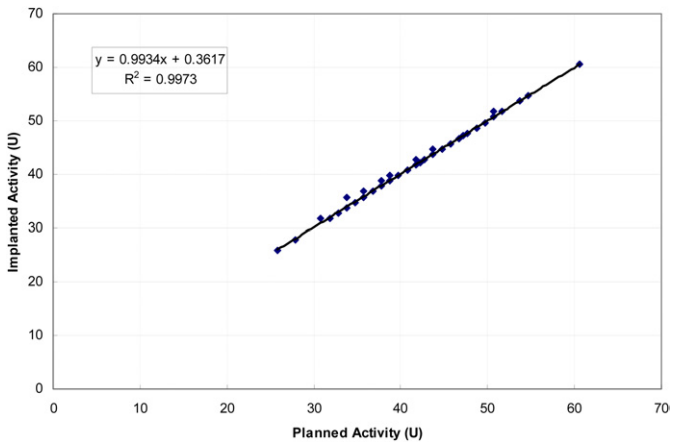

Fig. 1. Amount of radioactive planned *vs.* amount of radioactivity implanted and results of the correlation analysis.