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Regional treatment margins for prostate brachytherapy

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ABSTRACT

PURPOSE: This study quantified the treatment margin (TM) around the prostate that received 100% of the prescribed dose and analyzed postimplant dosimetry in different regions of the prostate for ^{125}I seed implants.

METHODS AND MATERIALS: An average target volume (ATV) was created from postoperative MRI scan contours drawn independently by five radiation oncologists in 40 patients. The MRI was fused with the postoperative CT for dosimetry purposes. The TM, defined as the radial distance between the ATV and the 100% isodose line, was measured at 16 points at the base, midgland, and apex. The ATV was divided into four quadrants: anterior–superior, posterior–superior, anterior–inferior, and posterior–inferior quadrants. The values of the dose that covers 90% of the ATV (D_{90}) and the percentage of the ATV receiving the prescribed dose (V_{100}) received by the whole prostate and its four quadrants were documented.

RESULTS: The range of the mean TM, in millimeter, was −8.88 to 3.68, 1.12 to 10.42, and 6.27 to 18.25 at the base, midgland, and apex, respectively. The mean D_{90} was 135.8, 162.8, 191.0, and 194.6 Gy for the anterior–superior, posterior–superior, anterior–inferior, and posterior–inferior quadrants, respectively.

CONCLUSIONS: Despite having a relatively uniform preoperative planning target volume, this study identified variable TMs postoperatively in different regions of the prostate. In particular, the anterior base is most underdosed, whereas the lateral regions of the midgland and apex have generous TMs. Postimplant dosimetric parameters were lowest in the anterior–inferior quadrant.

Keywords: Prostate brachytherapy; Treatment margin; Postimplant dosimetry

Introduction

The utilization of prostate brachytherapy in the treatment of patients with organ-confined prostate cancer has rapidly expanded over the past two decades (1). Brachytherapy is a technical procedure that requires special skills, with multiple recommendations available to guide patient selection and assessment of implant quality. Both the American Brachytherapy Society and the Groupe Européen de Curiethérapie and the European Society for Therapeutic Radiology and Oncology guidelines recommend using postimplant dosimetry as a component of implant evaluation (2, 3). Analysis of different parameters is recommended, but both guidelines agree that the prostate D_{90} and V_{100} dose–volume metrics are considered the primary criteria determining implant quality. Each of these quantities has been reported to correlate with freedom from biochemical failure (4, 5). However, these findings have not been reproduced by a number of other reports. It has been suggested that these parameters may be poor surrogates of dose

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delivered to the cancer because of their inability to reflect the dose distribution within the prostate or the adequacy of dose coverage to extraprostatic tissue (EPT) (6, 7).

It has been shown that treatment margin (TM), defined as the distance between the prostatic edge and the prescription isodose line, is an independent predictor of biochemical control in patients with prostate cancer (8). This suggests that the ability to encompass EPT is an important constituent of an adequate brachytherapy treatment. Therefore, indicators of sufficient coverage of the EPT would complement postimplant dose evaluation. Data show that in 99% of patients undergoing radical prostatectomy, the radial distance of extraprostatic extension is usually within a 3- to 5-mm margin (9). Although a uniform margin of 3–5 mm is typically used to generate the planning target volume (PTV), actual implants exhibit a nonuniform dose margin around the prostate. In this study, we quantify the TM at different planes of the prostate gland and in multiple directions within each plane. We also document D_{90} and V_{100} values received by the whole prostate and its four quadrants. This work will provide the preliminary data that are necessary for expanded indications for brachytherapy in the future, in which focal or targeted brachytherapy is considered.

Methods and materials

Patient population

Forty patients with biopsy-proven organ-confined prostate cancer eligible for brachytherapy were included in this prospective study that was approved by our local research ethics board. Patients signed a study-specific consent describing the scope and the details of the study. The baseline characteristics of this cohort are summarized in Table 1.

Brachytherapy procedure

Preloaded ^{125}I seeds of strength 0.389 mCi were used. The needles were placed in a modified peripheral loading pattern with the aim to deliver 145 Gy to the PTV. This was defined as the prostate gland plus a 3-mm margin anteriorly and laterally and 5-mm margin caudally. The details of the implant technique have been previously described (10).

Table 1
Clinical characteristics of patient population

Variables	*N* (%)
Median age (range in y)	64 (51–79)
Median pretreatment PSA (range in ng/mL)	6.3 (2.0–14.0)
Gleason score	
≤5	2 (5)
6	36 (90)
7	2 (5)
Clinical stage	
T1c	24 (60)
T2a	9 (22)
T2b	7 (18)
Risk group	
Low risk	26 (65)
Intermediate risk	14 (35)

PSA = prostate-specific antigen.

Imaging and contouring

All patients underwent CT and 1.5T MRI scans on Day 28 postoperatively, in which axial 3-mm thick CT slices and axial and coronal 3- to 4-mm thick T2-weighted MRI images were acquired. A Variseed treatment planning system (Varian Medical Systems, Inc., Palo Alto, CA) was used for image delineation. The scans were made anonymous and were randomized. Prostate volumes were defined by five radiation oncologists who had experience in prostate radiation therapy and had completed a prostate contouring workshop. To account for intraobserver variability, a set of 12 cases were randomly selected to be contoured twice by some of the physicians. The details of the imaging techniques and contouring process have been previously described (11).

Data analysis

The contouring information was exported from the Variseed treatment planning system (Varian Medical Systems, Inc.) in Digital Imaging and Communications in Medicine (DICOM) format, and purpose-written Matlab software (The Mathworks, Inc., Natick, MA) was used to generate contour measurements for each image set. The information obtained from the contours from the five radiation oncologists for each patient was then averaged to create an average target volume (ATV) that was used as the reference prostate volume. The ATV contours were then imported back into the Variseed treatment planning system (Varian Medical Systems, Inc.) where measurements were obtained.

A detailed precursory analysis was done on the first 10 patients. For each patient, the ATV axial slices were serially numbered, starting with the most cranial slice. Seven different planes were defined to represent different regions of the prostate, namely the prostate base, midgland, and apex, and these are shown in Fig. 1a. The TM was defined as the distance between the ATV and the 100% isodose line (IL-100). At each plane, as shown in Fig. 1b, 16 vectors (V1–V16) spaced at an angle of 22.5° from each other were defined. At each plane, after magnifying the image five times to improve the accuracy of the recordings, TM measurements were manually recorded at the 16 vectors and then converted back into true millimeters. The TM value was determined based on the extent of the IL-100 in relation to the ATV (Fig. 1b). The superior margin was measured as the distance between the most cranial slice containing an ATV contour and the slice containing the most superior extent of IL-100, and the inferior margin was measured similarly. The statistical analysis of the data