BRACHYTHERAPY

Brachytherapy ■ (2014) ■

Placement of empty catheters for an HDR-Emulating LDR Prostate Brachytherapy technique: Comparison to standard intraoperative planning

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ABSTRACT

PURPOSE: We sought to determine whether placing empty catheters within the prostate and then inverse planning iodine-125 seed locations within those catheters (High Dose Rate-Emulating Low Dose Rate Prostate Brachytherapy [HELP] technique) would improve concordance between planned and achieved dosimetry compared with a standard intraoperative technique.

METHODS AND MATERIALS: We examined 30 consecutive low dose rate prostate cases performed by standard intraoperative technique of planning followed by needle placement/seed deposition and compared them to 30 consecutive low dose rate prostate cases performed by the HELP technique. The primary endpoint was concordance between planned percentage of the clinical target volume that receives at least 100% of the prescribed dose/dose that covers 90% of the volume of the clinical target volume (V_{100}/D_{90}) and the actual V_{100}/D_{90} achieved at Postoperative Day 1.

RESULTS: The HELP technique had superior concordance between the planned target dosimetry and what was actually achieved at Day 1 and Day 30. Specifically, target D_{90} at Day 1 was on average 33.7 Gy less than planned for the standard intraoperative technique but was only 10.5 Gy less than planned for the HELP technique ($p < 0.001$). Day 30 values were 16.6 Gy less vs. 2.2 Gy more than planned, respectively ($p = 0.028$). Day 1 target V_{100} was 6.3% less than planned with standard vs. 2.8% less for HELP ($p < 0.001$). There was no significant difference between the urethral and rectal concordance (all $p > 0.05$).

CONCLUSIONS: Placing empty needles first and optimizing the plan to the known positions of the needles resulted in improved concordance between the planned and the achieved dosimetry to the target, possibly because of elimination of errors in needle placement.

Keywords: Brachytherapy; LDR; Low dose rate; Prostate

Introduction

Prostate brachytherapy as monotherapy is regarded as a highly efficacious and convenient treatment option of low and low intermediate risk prostate cancer. Since the introduction of the modern era of prostate brachytherapy in the early 1980s, the original transperineal percutaneous ultrasound- and template-guided seed implant (1−3) has evolved in terms of implant philosophy, technique, treatment planning algorithms, and imaging technologies. Advances in treatment planning now allow for inverse planning, real time image−guided needle placement, and automatic isotope delivery. These advances continue to help increase the quality of implants and lessen the learning curve associated (4) with performing high-quality implants, which are already proven to be a highly effective treatment for prostate cancer (5−7).

Received 10 December 2013; received in revised form 17 January 2014; accepted 28 January 2014.

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1538-4721/$ - see front matter

http://dx.doi.org/10.1016/j.brachy.2014.01.009

Over the past several years, intraoperative planning techniques have emerged as a viable option as compared with the original two-staged preplan approach. Intraoperative techniques help to remove the uncertainties of patient repositioning and errors associated with matching the operative prostate volume to the preplan volume at the time of the actual implant. Removing positioning as a potential confounding variable has been demonstrated to improve the dosimetric metrics of the implant (8, 9). Dosimetric variable such as percentage of the clinical target volume that receives at least 100% of the prescribed dose (V_{100}) and dose that covers 90% of the volume of the clinical target volume (D_{90}) have been associated with improved biochemical progression−free survival (10) after implant. Focusing on techniques associated with a higher probability of achieving consistently improved V_{100s} and D_{90s} may lead to a higher probability of long-term biochemical control.

One of the limiting factors affecting the concordance between the intended and executed implant remains the seed placement accuracy, which is greatly affected by proper needle placement. Several factors contribute to the accuracy of needle placement such as the brachytherapist's skill level, imaging and equipment quality, and the degree of prostate immobilization and mobility. Another prostate treatment modality, high dose rate (HDR) brachytherapy, mostly circumvents the issue of inexact needle placement by modeling the needle position in the treatment planning system after they are implanted into the patient. This strategy for better geometric concordance has been adapted to low dose rate (LDR) prostate brachytherapy and is the object of this article.

Inverse treatment planning techniques were made available for HDR brachytherapy and subsequently LDR brachytherapy, such as the inverse planning simulated annealing (IPSA) algorithm (11, 12). Beaulieu *et al.* (4) have published on the use this state-of-the-art technology, through its incorporation into the commercially available FIRST treatment planning system (Nucletron, an Elekta company, Elekta AB, Stockholm, Sweden), as a way to help decrease the learning curve associated with high-quality prostate brachytherapy implants. They concluded that both new and seasoned brachytherapy teams could obtain excellent postimplant dosimetry.

This article compares two differing LDR prostate brachytherapy planning and delivery methods, both using the commercially available FIRST (Nucletron) system that includes inverse treatment planning and automatic seed delivery. The key difference in the HELP method is that it consists of first implanting the needles into the patient and subsequently registering the needle locations in the treatment planning system, as is done in HDR prostate brachytherapy. This has the potential to greatly reduce the disparity between planned and executed needle location, which can be a limiting factor in the first method that forces the brachytherapist to deliver the needle in the planned location. This article compares dosimetric quality metrics for implants using our standard approach and the newer HELP method of implant.

Methods and materials

Patient selection

A total of 60 consecutive patient cases were analyzed. The first 30 were treated with a standard intraoperative planning approach, and the remaining 30 were treated with a method that is similar to HDR planning and was referred to as "HDR-Emulating LDR Prostate (HELP) Brachytherapy." The patient baseline characteristics are summarized in Table 1, which shows no significant difference in makeup, including age, clinical stage, prostate-specific antigen, and gland volume. This retrospective study was approved by the Dana-Farber/Harvard Cancer Center Institutional Review Board.

All patients underwent an ultrasound volume study before the procedure to quantify their prostate volume (for radioactive seed ordering) and assess any pubic arch interference.

Image acquisition

In the operating room, a *flex* Focus 400 (BK Medical Systems, Inc., Peabody, MA) ultrasound system with a biplanar axial/sagittal transducer (model #8848A, BK Medical) was used to acquire the ultrasound images. This probe is mounted to a stepper and can be rotated along its axis for longitudinal image acquisition through the FIRST (Nucletron) treatment planning software-controlled motor. During image acquisition, the software captures live images every 0.5° as the motor rotates the probes along its 140° sweep. These images are the input for a three-dimensional image reconstruction, which provides axial, sagittal, and transverse planes of the acquired volume. A Foley catheter is

Table 1
Patient characteristics for both treatment techniques

Characteristics	Standard technique (range)	HELP technique (range)	p Value
Prostate volume (cm^3)	33.1 (16.1−66.2)	34.3 (19.6−62.6)	0.68
Age	62.1 (54−73)	64.8 (55−77)	0.08
Caucasian (percent of patients)	80	93	0.13
Prostate-specific antigen	5.1 (0.6−11.9)	5.7 (2.0−12.0)	0.33
Gleason score	6.2 (6−7)	6.2 (6−7)	0.76
Number of cores positive	2.7 (1−7)	3.4 (1−10)	0.18
Maximum percent core positive	26 (5−90)	35 (5−90)	0.20
Perineural invasion (percent of patients)	16.7	20.0	0.74
HRT (number of patients)	4	1	0.17
cT1C (number of patients)	27	26	0.69
cT2A (number of patients)	3	4	

HELP = High Dose Rate-Emulating Low Dose Rate Prostate; HRT = hormone replacement therapy.