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Characterization of implant displacement and deformation in gynecologic interstitial brachytherapy

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ABSTRACT

PURPOSE: To determine the uncertainties in implant position during multifraction gynecologic interstitial brachytherapy, we analyzed the interfraction displacements and deformations of gynecologic interstitial implants.

METHODS AND MATERIALS: Fourteen gynecologic patients treated with multifraction high-dose-rate interstitial brachytherapy received two CT scans each at the time of implantation and 48–72 h later. Rigid fusions on the pubic symphysis were performed. This analysis included catheter shifts in the cranial (CR), caudal (CA), anterior, posterior, left, and right directions; template shifts; the change in the catheter length measured along the path from catheter tip to catheter connector (offset); the change in relative distances between catheters (deformations); and changes in rectum and bladder D_{2cc} and tumor D_{90}.

RESULTS: Of the 198 catheters analyzed, the number of catheter shifts (%) and mean ± standard deviation were 43% CA (5.0 ± 2.0 mm), 22% CR (7.9 ± 4.0 mm), 14% anterior (6.3 ± 2.1 mm), 48% posterior (8.7 ± 3.1 mm), 7% left (4.8 ± 0.4 mm), and 9% right (5.4 ± 0.9 mm). Catheter offsets were 3% CA (7.2 ± 6.3 mm) and 11% CR (6.1 ± 2.6 mm). Template shifts were 43% CA (5.2 ± 1.6 mm) and 14% CR (6.6 ± 4.0 mm). Deformations were 10 shrinkages (4.7 ± 0.9 mm) and 32 expansions (4.7 ± 0.5 mm). Dosimetric changes were 5.2% ± 10.8% for rectum D_{2cc}, −1.1% ± 18.5% for bladder D_{2cc}, and −5.1% ± 6.7% for tumor D_{90}.

CONCLUSIONS: On average, less than 1 cm displacements and deformations of the implant occurred over the course of treatment. Proper quality assurance methodologies should be in place to detect shifts that can potentially result in inadvertent insertion into normal tissue.

Keywords: Brachytherapy; Gynecologic; Interstitial; Displacement; Uncertainty; Catheter

Introduction

The use of interstitial brachytherapy for the treatment of advanced and recurrent gynecologic malignancies with significant vaginal and/or sidewall extensions increases local control with an acceptable risk of morbidity compared with external beam alone (1). Multiple implantation methodologies for gynecologic interstitial brachytherapy have been described in the literature (2–6). Templates with preset hole patterns are used for needle placement and to help with guidance and quality assurance (QA). The corners of the template are sutured to the perineal skin for stability. The two most common template systems are the Syed-Neblett template (SNT) (2) and the Martinez Universal Perineal Interstitial Template (MUPIT) (3). Plastic catheters and hollow titanium needles (4) have been used. Custom-made templates and catheters inserted "free hand (FH)" into the patient may also be used. Catheters can be secured in place with a variety of anchoring techniques, such as buttons or liquid adhesive. Most multifractionated interstitial brachytherapy treatments require the hospitalization of the patient for the duration of the treatment; some ambulatory techniques have been proposed and used for gynecologic treatments (5). A single implant can be used for a treatment that extends from 1 to 5 days. Significant uncertainties may exist related to the catheter/needle anchorage to the template or the patient's skin, the stability of the template, and deformations of the patient anatomy.

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An assessment of the interfraction variability of catheter location is essential to understand the uncertainties in multifraction gynecologic interstitial brachytherapy and can be used to inform planning and QA policies. A substantial literature exists (7–14) on implant displacements for interstitial prostate brachytherapy. However, insights that prostate literature may provide for gynecologic applications may be limited. Differences in tumor invasion into organ structures, imaging methodology, and applicators used in prostate and gynecologic interstitial brachytherapy procedures may result in significant differences in implant geometry, stabilization, and deformation.

Implant displacement has been studied for gynecologic ambulatory procedures (15) and for cervical cancer patients receiving interstitial brachytherapy through a MUPIT (16). In this work, we analyze the variability of gynecologic interstitial implants recently performed according to the standard practice in our clinic. To our knowledge, this is the first detailed investigation of implant displacements and deformations in gynecologic interstitial brachytherapy using SNT.

Methods and materials

A data set of 28 CT scans from 14 patients treated from March 2011 to December 2011 with high-dose-rate (HDR) interstitial gynecologic brachytherapy in our institution was retrospectively analyzed with institutional review board approval. All patients received a CT scan immediately after implantation and again 2 (n = 11 patients) or 3 (n = 3) days after implantation. All patients had vaginal extension of gynecologic malignancy necessitating interstitial treatments. One patient did not have a rectum because of a history of rectal cancer.

Implants

All patients were implanted under general anesthesia. Three implantations were performed using real-time MRI guidance from a 3 T wide-bore unit, with a CT scan acquired immediately after implantation. All the other implantations were performed in a CT brachytherapy suite under CT guidance.

A vaginal obturator (VO) was inserted through the center of an SNT (Best Medical International Inc., Springfield, VA) (Fig. 1). Plastic ProGuide catheters (Nucletron, an Elekta company, Elekta AB, Stockholm, Sweden) were implanted with a central stainless steel removable insert to ensure stability during the insertion. Of the 198 total catheters implanted in all patients, 7 were inserted FH, 75 through grooves in the central VO, and 112 through holes in the SNTs. In 4 patients with an intact uterus, a central tandem was inserted.

After the implant, the central VO and the VO and SNT catheters were secured to the template using a sterile liquid adhesive, and the template was sutured in four corners to the perineal skin. FH catheters were secured to the patient's skin through buttons when possible. The extent of each catheter's entry into the template or the patient body was marked on the catheter for pretreatment visual inspection.

All patients received one fraction on the day of implantation and an additional four to eight fractions twice daily. The doses from the brachytherapy and prior radiation were summed via the EQD2 (equivalent dose 2 Gy) formalism. Dose optimization and fractionation scheme selection had the goal of achieving a combined clinical target volume (CTV) D_{90} between 70 and 80 Gy, while respecting limits on the combined D_{2cc} metrics for bladder (<90–95 Gy), rectum (<70–75 Gy), and sigmoid (<70–75 Gy). The fractionation schemes were prescribed by the physician on a patient-by-patient basis based on tumor, normal tissue, and patient factors and are reported in Table 4.

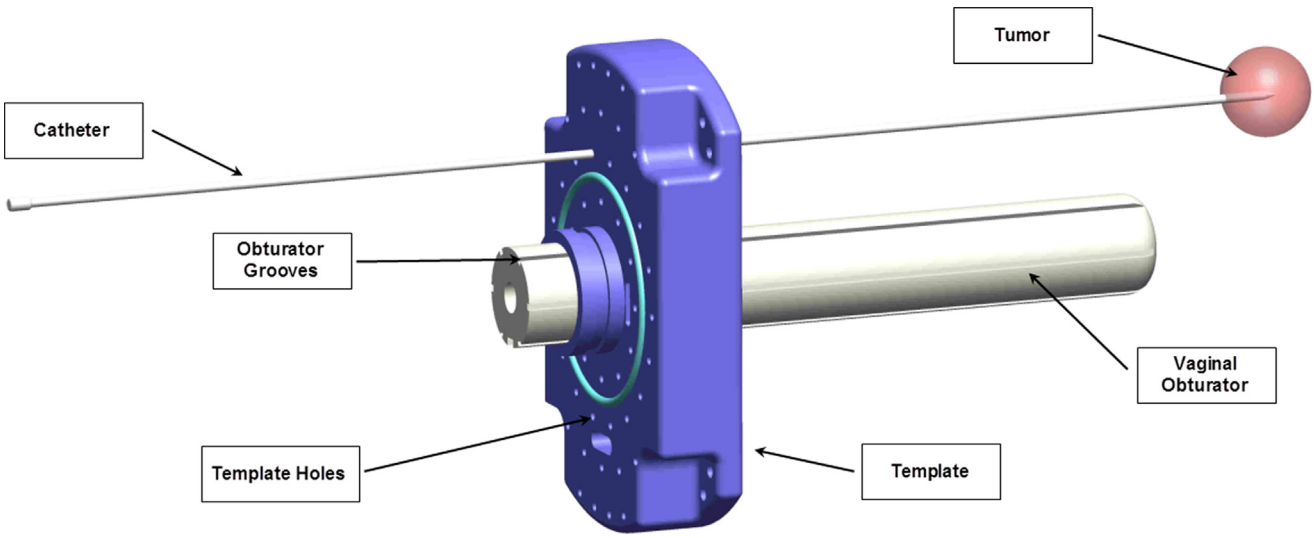

Fig. 1. Graphical representation of a Syed-Neblett template with holes for catheter insertion, vaginal obturator with grooves for catheter insertion, and catheter inserted into a tumor.