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Do changes in interfraction organ at risk volume and cylinder insertion geometry impact delivered dose in high-dose-rate vaginal cuff brachytherapy?

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ABSTRACT

PURPOSE: Within a multifraction high-dose-rate vaginal cuff brachytherapy course, we determined if individual variations in organ at risk (OAR) volume and cylinder insertion geometry (CIG) impacted dose and whether planned minus fractional (P − F) differences led to a discrepancy between planned dose and delivered dose.

METHODS AND MATERIALS: We analyzed vaginal cuff brachytherapy applications from consecutive patients treated with three fractions of 5 Gy after each undergoing a planning CT and three repeat fractional CTs (fCTs). Rectal and bladder D_{2ccs} and volumes were recorded in addition to the x (in relationship to midplane) and y (in relationship to the table) angles of CIG. Paired t-tests and multiple regression analyses were performed.

RESULTS: Twenty-seven patients were identified. In comparing the planning CT vs. mean fCT rectal volumes, bladder volumes, x angles, and y angles, only bladder volume was significantly different (planned volume higher, $t = 2.433$, $p = 0.017$). The cumulative mean planned OAR D_{2cc} vs. delivered D_{2cc} was only significantly different for the bladder (planned dose lower, $t = -2.025$, $p = 0.053$). Regression analysis revealed planned rectal D_{2cc} ($p < 0.0003$) and a positive (posterior) y insertion angle ($p = 0.015$) to significantly impact delivered rectal D_{2cc}. Additionally, P − F rectal volume ($p = 0.037$) was significant in determining rectal delivered dose.

CONCLUSIONS: A more posterior y angle of insertion was found to increase rectal D_{2cc} leading us to believe that angling the vaginal cylinder anteriorly may reduce rectal dose without significantly increasing bladder dose. Although attention should be paid to OAR volume and CIG to minimize OAR dose, the clinical significance of P − F changes remains yet to be shown.

Keywords: Vaginal cuff brachytherapy; HDR vaginal brachytherapy; Cylinder insertion geometry; Organ at risk volume; Interfraction dose variance

Introduction

In the United States, endometrial cancer represents the fourth leading cause of cancer in women (1). In 2015, an estimated 54,870 new cases will be diagnosed and approximately 10,170 women will die from this disease (2). Although the standard-of-care initial management for endometrial cancer has remained total abdominal hysterectomy and bilateral salpingo-oophorectomy with or without pelvic and para-aortic lymph node dissection (3−5), the recommendation for adjuvant therapy continues to be individualized based on disease stage and recurrence risk stratification. In cases necessitating adjuvant radiation, vaginal cuff brachytherapy (VBT) has become an essential component of treatment (6).

The National Comprehensive Cancer Network guidelines for endometrial carcinoma outline patient-selection criteria and indications for VBT (7), and these are endorsed by the American Brachytherapy Society (ABS). The most recent guidelines from ABS for postoperative VBT provide

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details regarding treatment timing, applicator selection, dose fractionation and prescription, and implementation technique (8). Although VBT most commonly consists of multiple high-dose-rate (HDR) fractions delivered via a vaginal cylinder, the guidelines do not specifically recommend a separate treatment plan for each fraction because of cost and the assumption that implant geometry remains the same for each insertion. As a result, common clinical practice has used performing a planning CT (pCT) and using the singular generated plan for the subsequent treatment fractions.

Within this context, authors have examined various aspects of cylinder insertion in VBT including 2D vs. 3D planning, the dosimetric effects of organ at risk (OAR) filling and air pockets, and the use of single vs. multichannel applicators (9–18). Additionally, two studies explored the dosimetric effects of cylinder insertion angles, and another study examined the dosimetric and financial utility of replanning before each fraction (17, 19, 20). Nonetheless, there remains a paucity of data regarding the technical implementation of VBT.

The purpose of our study is to examine whether changes in OAR volume and cylinder insertion geometry (CIG) impact delivered dose (DD) in a multifraction HDR VBT course. Although much attention has been paid to the issue of fractional replanning for VBT, very few have studied CIG and its dosimetric consequences. OAR filling and CIG geometry represent two avenues by which dose to OARs could be reduced leading potentially to improved clinical outcomes. Additionally, we assess whether planned minus fractional (P − F) differences in OAR volume and CIG contribute to a significant discrepancy between planned dose (PD) and DD. Within this context, we aim to identify individual predictors for increased OAR DD so that we may accordingly adjust our implementation technique.

Methods and materials

Twenty-seven consecutive patients with endometrial carcinoma who underwent total abdominal hysterectomy and bilateral salpingo-oophorectomy followed by external beam radiation therapy (EBRT) to the pelvis and subsequent VBT were included in this study. EBRT consisted of 45 Gy, and VBT consisted of three fractions of 5 Gy prescribed to a 0.5-cm depth delivered with HDR via a single-channel vaginal cylinder. The vaginal treatment length was the upper two-thirds of the vagina based on institutional practice at that time. Patients who underwent monotherapy with VBT after surgery and those who did not receive pelvic EBRT were not included as they would have typically received a five-fraction course at our institution.

All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008. Approval from our institutional review board was obtained for the conduction of this study. The risks, benefits, and logistics of both EBRT and VBT were discussed with each patient after which informed consent for treatment was obtained. For the pCT, the patient was assisted into the dorsal lithotomy position after which the vaginal vault was sized by the examining physician. Then, the largest-sized cylinder that the patient could comfortably tolerate was inserted until the domed tip was flush with the vaginal cuff. The cylinder was inserted in a ''neutral'' position consistent with the patient's anatomy and as parallel to the table as possible and then secured with an external immobilization device. The patient's legs were then extended out of lithotomy position for patient comfort and better dosimetry (21). A localization CT was performed to ensure adequate positioning of the cylinder with no significant air gaps after which the pCT with 2.5 mm thickness was obtained from midpelvis to below the full length of the applicator. No rectal or bladder contrast was used. The images were then transferred to our brachytherapy treatment planning software (Oncentra Brachy by Nucletron/Elekta). After the bladder and rectum were contoured on the pCT and reviewed by two physicians, a treatment plan was generated with dose-volume histograms (DVHs) that allowed us to extract and record the minimum dose to the highest irradiated 2 cc (D_{2cc}) of the rectum and bladder. The rectal and bladder volumes were measured and recorded in addition to the x angle (in relation to patient midplane) and y angle (in relation to the table). A positive x angle indicated that the proximal portion of the cylinder was inserted to the patient's left, and a positive y angle indicated that the proximal portion of the cylinder was inserted posteriorly; Figure 1 shows one set of these measurements. The cylinder diameter and vaginal treatment length were also recorded.

For each of the three treatments, the patient was positioned similarly and again the cylinder was inserted in neutral position and secured. A CT scan was obtained before each treatment fraction (fCT); the rectum and bladder were contoured and reviewed by two physicians. The initial planning parameters were applied to each fCT to generate DVHs and corresponding rectal and bladder D_{2ccs} for each fraction. Given that the plan was overlain on the fCT that had the patient in their actual position of treatment, the generated DVHs provided us with the DDs to the OARs. The rectal and bladder volumes were measured for each fraction as well as the x and y cylinder insertion angles.

All statistical tests were performed using SPSS V21.0 (SPSS Inc., Chicago, IL), and $p \leq 0.05$ was considered statistically significant for this study. After tabulating the acquired information, paired t-tests were run to compare the pCT parameters (OAR D_{2ccs}/volumes and cylinder insertion x/y angles) to the corresponding fCT parameters. They were also used to compare the PD to cumulative DD over three fractions. P − F values were also computed for the differences in OAR volumes and x/y angles. Cylinder diameter, treatment length, rectal volume, bladder volume,