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Comparing organ-at-risk doses for high−dose rate vaginal brachytherapy between three different planning workflows

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ABSTRACT

PURPOSE: The aim of this study was to compare the organ-at-risk doses to the rectum and the bladder in postoperative endometrial cancer patients who receive high−dose rate vaginal brachytherapy (HDR-VB), when using three different methods of treatment planning: (*Workflow A*) individualized treatment planning before every fraction, (*Workflow B*) individualized treatment planning for first fraction only), and (*Workflow C*) using a template plan based on applicator choice and prescription specifics without patient-specific imaging or planning (standardized template approach).

METHODS AND MATERIALS: Alternative plans were retrospectively created using workflows B and C for 22 patients who previously received postoperative HDR-VB using a vaginal cylinder and planned using Workflow A for endometrial cancer. The rectum and bladder were contoured on the CTs used for each fraction for dose comparison between the three methods. D_{50}, D_{2cc}, D_{1cc}, $D_{0.1cc}$, and V_{100} of the bladder and the rectum were compared using the two-sided Wilcoxon signed-rank test.

RESULTS: A total of 123 fractions were available for comparison. For Workflow A vs. Workflow B, there was no significant difference for any rectal or bladder dosimetric parameter. For Workflow A vs. Workflow C, Workflow A delivered a significantly higher median dose to the rectum than Workflow C for D_{50}, D_{2cc}, D_{1cc}, and V_{100}. Workflow C delivered a significantly higher dose to the bladder than Workflow A: D_{2cc}, D_{1cc}, $D_{0.1cc}$, and V_{100}. However, the magnitudes of the differences were small; the dose index difference was >75 cGy for only two fractions.

CONCLUSION: Plan standardization in HDR-VB may result in considerable time and cost savings with minimal organ-at-risk dose differences.

Keywords: Vaginal brachytherapy; Endometrial cancer; HDR vaginal brachytherapy; Organ-at-risk doses

Introduction

Endometrial carcinoma is the most common cancer of the female gynecologic tract in the United States, with an estimated incidence of 60,050 and 10,470 predicted deaths in 2016 (1). It represents 6.77% of all female malignancies. Approximately 75−80% of patients present with stage I and II endometrial cancer. Although surgery is the primary treatment modality for early-stage endometrial cancer, adjuvant radiotherapy is often administered (2). The decision to give adjuvant radiation is determined by prognostic factors, such as patient age, depth of myometrial invasion, histologic tumor grade, pathologic subtype, cervical involvement, lymphovascular invasion, and stage (2).

Adjuvant radiotherapy for endometrial cancer reduces the risk of recurrence by 43−75% (3). The most common site of recurrence in patients with early-stage endometrial cancer is the vaginal cuff (4). The Postoperative Radiation Therapy in Endometrial Carcinoma II study randomized stage I or IIA endometrial cancer patients to pelvic external beam radiation therapy (EBRT) or vaginal brachytherapy (VB). At a median followup of 45 months, the rate of vaginal cuff recurrence was similarly low between patients receiving EBRT vs. those undergoing VB, 1.6% and 1.8%, respectively (5). Furthermore, those randomized to receive VB were less likely to experience gastrointestinal side effects and reported improved quality of life.

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VB planning is often performed with fluoroscopic or CT imaging before each fraction, allowing customized treatments plans based on real-time patient anatomy. This method confirms proper applicator position and documents the dose delivered to the patient at each fraction (6). This may also limit overtreatment or undertreatment of the vaginal cuff, based on interfraction variability (7). However, creating a customized treatment plan for each fraction is onerous for patients and physicians alike, increases health care costs, and may have little impact on patient outcomes (2).

The purpose of this study was to compare various rectal and bladder dosimetric parameters in postoperative endometrial cancer patients receiving high−dose rate vaginal brachytherapy (HDR-VB), between three different methods of planning/delivery: (*Workflow A*) fractional re-imaging (FRI) approach—CT-based planning before each fraction with an individualized treatment plan created for every fraction; (*Workflow B*) first-fraction imaging (FFI) approach—applying the individualized treatment plan for the first fraction to subsequent CT simulation images for the following fractions; (*Workflow C*) standardized template (ST) approach—using an ST plan based on applicator choice and prescription specifics without patient-specific imaging or planning.

Methods and materials

With institutional review board approval, 24 patients treated with postoperative HDR-VB at The University of Nebraska Medical Center between 2007 and 2010 were evaluated. A total abdominal hysterectomy with bilateral salpingo-oophorectomy and lymph node dissection was initially performed on each patient. For this study, 24 patients treated consecutively were evaluated. Two patients were excluded because of variation between cylinder diameter and the vaginal length to which dose was prescribed between fractions, respectively. Each patient received three or four fractions at a dose of 500−700 cGy/fraction, prescribed to the surface or 0.5-cm depth. The dose was prescribed to the surface in three cases; dose was prescribed to 0.5-cm depth in the remaining 19 cases. A total of 74 fractions were treated for these 22 patients, with 22 initial fractions (fraction 1) and 52 repeated fractions (fractions 2, 3, and 4). Single-channel cylinders (25−35 mm) were used to treat the upper 35−55 mm of the vagina. Within each patient plan, the same length of vagina was treated according to the physician's prescription; at the time of treatment, 14 patients received three fractions of HDR-VB and 8 patients received four fractions of HDR-VB.

Before each fraction, CT imaging and treatment planning were completed. The rectum and the bladder were contoured on CT images using BrachyVision software (Varian Medical Systems, Palo Alto, CA). Before the first treated fraction, a customized treatment plan was created. Before each subsequent fraction, new CT imaging was performed after applicator placement and a customized treatment plan was re-created and an updated dose-volume histogram (DVH) was generated. The doses to the bladder and rectum were recorded from each fraction and tracked over the full treatment course. After plan quality assurance, the treatment was delivered for each fraction using a VariSource HDR remote afterloader (Varian Medical Systems).

For our study, three distinct planning modalities were used retrospectively to compare organ-at-risk (OAR) doses delivered to the rectum and bladder.

1) Workflow A (FRI approach): This was the method used to plan and treat the 22 women included in the study. Before each fraction, a CT scan was obtained, adjacent structures were contoured using the BrachyVision software, and a customized treatment plan was completed. During the planning, the dwell positions and time were manually optimized by experienced physicists. The optimization considerations were to ensure a uniform dose distribution along the prescription reference line either at the applicator surface or at 0.5-cm depth from the surface along the prescribed treatment length and to minimize OAR doses. In general, the dose was within 3% of prescription dose along the reference line except at the top of the applicator where a lower dose was planned because of applicator geometry; the OAR ICRU point doses and the volume maximum doses were watched so that a plan yielded a low dose to the OARs while ensuring the prescription dose uniformity described earlier. In our investigation, Workflow A was retrospectively compared with two alternative workflows described as follows.
2) Workflow B (FFI approach): A patient-specific plan was created for each patient based on the fraction 1 CT scan. After accounting for decay, fractions 2−4 were re-planned with the same dwell times and positions as fraction 1 to model the dosimetry of fraction 1. This model is then applied to subsequent fractions without repeat CT planning.
3) Workflow C (ST approach): patient-specific CT-based treatment planning is not required for this workflow. Instead, a treatment plan based on applicator size and prescription specifics is selected from an institution-established library of standardized plans. The template plan is used with proper decay corrections for all subsequent fractions. The ST plan was then applied to the CT simulation acquired before each fraction as in Workflow A to retrospectively calculate predicted OAR doses.

As the initial fraction treatment planning would be identical for workflows A and B, only fractions 2, 3, and 4 were compared between the 2 workflows. The cylinder length was constant for 21 of the 22 patients. For 1 patient, multiple cylinder sizes were used to improve patient comfort, accounting for 3 of the 52 available fractions. These 3 fractions were, therefore, excluded from the comparison.