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A feasibility study of using advanced external beam techniques to create a vaginal cuff brachytherapy-like endometrial boost plan

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ABSTRACT

The purpose of this study was to explore the feasibility of using advanced external beam radiation therapy (EBRT) planning techniques for creating plans that could be used as a possible alternative for high-dose rate (HDR) vaginal cuff brachytherapy (VCBT) boost in treating endometrial cancer. The computed tomography (CT) images of a total of 4 female patients who had endometrial cancer treated with HDR-VCBT were selected for this study. A typical HDR-VCBT target volume, 0.5-cm-thick shell volume around the cylinder applicator in the prescribed treatment length was contoured and used as the planning target volume (PTV) in both the HDR VCBT and the EBRT VCBT-like plans. HDR-VCBT plans were made based on the clinical protocol, 6 Gy given at the cylinder surface. The EBRT plans were generated using either a 7-field intensity-modulated radiation therapy (IMRT) or a 2-arc volumetric-modulated arc therapy (VMAT) techniques for different cylinder sizes and treatment lengths, with the prescription dose of 5 Gy. Organs at risk (OARs) such as bladder, femoral heads, rectum, and sigmoid were also contoured and used in dosimetric evaluations. Dose-to-target metrics included mean dose, the dose covering 90% of target volume (D90) and the percentage of target volume covered by 90% of prescription dose (V90 or V13.5 Gy). Dose to OAR metrics included the maximum dose received by 0.1 cc (D0.1cc), 1.0 cc (D1.0cc), and 2.0 cc (D2.0cc) of OARs. These metrics were calculated and compared between all techniques. After the EBRT plans were normalized to achieve a comparable mean dose to target as HDR-VCBT, the EBRT plans were found to have superior target coverage and increased dose homogeneity compared with HDR-VCBT. V90s of EBRT plans were 95%, compared with 50% to 58% of the HDR plans. However, D0.1cc, D1.0cc, and D2.0cc of OARs were 2% to 38% lower in HDR-VCBT than in EBRT. Although HDR-VCBT plans demonstrated superior normal tissue sparing, both EBRT and HDR-VCBT plans produce plans that met clinical dose constraints on normal tissues. Advanced EBRT techniques such as IMRT and VMAT are capable of making plans, which closely resemble HDR-VCBT. Although the doses of OARs are greater

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in EBRT than in HDR-VCBT, the prescription dose coverage and dose homogeneity of the EBRT plans are greater than that of HDR-VCBT plans at the similar mean dose, and the OAR dose is still acceptable with EBRT plans. The detailed dosimetric approaches are provided in the study.

Introduction

The efficacy of intra-cavitary vaginal cuff brachytherapy (VCBT) alone has been demonstrated in both randomized and nonrandomized experiences, and is increasingly used in the adjuvant treatment of patients with early-stage endometrial cancer.[1,2] For reasons of efficacy, convenience, and safety, high-dose rate (HDR) brachytherapy has replaced low-dose rate brachytherapy in this setting. Consequently, in the majority of radiation oncology departments, adjuvant vaginal cuff HDR brachytherapy has become the standard of care for many patients with early-stage endometrial cancer, either combined with external beam radiation or delivered as monotherapy.[3] It was reported that the VCBT reduces the risk of recurrence at the vaginal cuff and is associated with significantly less toxicity when compared with whole-pelvic external beam radiation therapy (EBRT).[3,4]

However, not every radiation oncology clinic has an HDR unit to carry out such an advantageous treatment for the patients with endometrial cancer, mainly because of the limit of the cost (HDR unit and a dedicated brachytherapy physicist) and brachytherapy patient load to the relevant clinics. In recent years, the EBRT planning techniques have advanced with the rapid development of smaller multileaf collimators and improved dose rate modulation techniques, particularly the advent of volumetric-modulated arc therapy (VMAT) and intensity-modulated radiation therapy (IMRT) techniques, which have improved the dose conformity to the target volume and reduced the doses to the organs at risk (OARs). It is now possible to deliver doses to the target with greater conformity and subsequently reduce doses to the normal structures. Considering the recent progress of EBRT techniques, now it has become feasible to make a comparable EBRT plan for endometrial boost similar to HDR VCBT. In the literature, the idea of using EBRT techniques for making brachytherapy-like plans has already been checked by some researchers. Aydogan *et al.*[5] tested it with IMRT techniques in 2006 and Amendola *et al.*[6] explored the feasibility using the VMAT technique in 2012. They concluded EBRT can make a clinically acceptable alternative VCBT-like plan. The advantages of brachytherapy have been identified as the delivery of localized high doses while sparing normal surrounding tissues. Our objective is to quantify the extent to which those features are maintained when using EBRT under the particular circumstances. This work expands the exploration in 3 ways. First, in this study we investigate the effect of treatment length on OAR dose metrics. Second, we combine analysis for both IMRT and VMAT VCBT-like plans for the same set of patients. Finally, we take a different approach to dose prescription and EBRT treatment planning. The approach to HDR VCBT prescription described by the American Brachytherapy Society[7,8] is to prescribe dose either to the vaginal surface or to a depth of 5 mm, with a highly nonuniform dose distribution between the vaginal surface and the depth of 5 mm. The 2 previously cited studies both designed EBRT plans to achieve a high degree of uniformity, and defined planning target volumes (PTVs) to achieve similar coverage of 95% of prescription dose (whether dose is prescribed to the surface or at depth). In this way, the 2 previously cited studies would demonstrate lower average dose to the volume surrounding the cylinder from EBRT than from the comparable HDR plans. This work differs from the previous works in that we do not impose any goal of dose uniformity to the target volume. Our heterogeneous stereotactic body radiation therapy-like dose distribution more closely approximates the nonuniform dose distribution of HDR VCBT. Because of the challenge of comparing different nonuniform dose distributions, rather than prescribing equivalent levels of coverage, we prescribe equivalent average dose to the target in order to approximate equivalent tumor cell killing. To demonstrate the advantages and disadvantages of EBRT VCBT-like plans, the dosimetric parameters from EBRT VCBT-like and HDR VCBT plans were compared side by side, the pros and cons of each technique were evaluated, and the dosimetric differences between all techniques were discussed.

Methods and Materials

Patient selection

A total of 4 female patients with gynecological endometrial cancer were retrospectively chosen for this study. All the patients received EBRT followed by a HDR VCBT boost. The patients were treated with HDR with American Brachytherapy Society-recommended clinical protocol.[7,8] In this study, the cylinder sizes ranged from 2.0 to 3.0 cm in diameter. In our clinical protocol, a prescription dose of 45 Gy (1.8 Gy × 25 fractions) was used for each initial EBRT treatment, and a dose of 18 Gy (6.0 Gy × 3 fractions) to the surface