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Can MRI-only replace MRI-CT planning with a titanium tandem and ovoid applicator?

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ABSTRACT

PURPOSE/OBJECTIVE(S): To evaluate dosimetric differences between MRI-only and MRI-CT planning with a titanium tandem and ovoid applicator to determine if all imaging and planning goals can be achieved with MRI only.

MATERIALS/METHODS: We evaluated 10 patients who underwent MRI-CT-based cervical brachytherapy with a titanium tandem and ovoid applicator. High-risk clinical target volume and organs at risk were contoured on the 3D T2 MRI, which were transferred to the co-registered CT, where the applicator was identified. Retrospectively, three planners independently delineated the applicator on the axial 3D T2 MRI while blinded to the CT. Identical dwell position times in the delivered plan were loaded. Dose-volume histogram parameters were compared to the previously delivered MRI-CT plan.

RESULTS: There were no significant differences in dose to D_{90} or D_{98} of the high-risk clinical target volume with MRI vs. MRI-CT planning. MRI vs. MRI-CT planning resulted in mean $D_{0.1cc}$ bladder of 8.8 ± 3.4 Gy vs. 8.5 ± 3.2 Gy ($p = 0.29$) and D_{2cc} bladder of 6.2 ± 1.4 Gy vs. 6.0 ± 1.4 Gy ($p = 0.33$), respectively. Mean $D_{0.1cc}$ rectum was 5.7 ± 1.2 Gy vs. 5.3 ± 1.2 Gy ($p = 0.03$) and D_{2cc} rectum 4.0 ± 0.8 Gy vs. 4.2 ± 1.0 Gy ($p = 0.18$), respectively. Mean $D_{0.1cc}$ sigmoid was 5.2 ± 1.3 Gy vs. 5.4 ± 1.6 Gy ($p = 0.23$) and D_{2cc} sigmoid 3.9 ± 1.0 Gy vs. 4.0 ± 1.1 Gy ($p = 0.18$), respectively.

CONCLUSION: There were no clinically significant dosimetric differences between the MRI and MRI-CT plans. This study demonstrates that cervical brachytherapy with a titanium applicator can be planned with MRI alone, which is now our clinical standard. © 2018 Published by Elsevier Inc. on behalf of American Brachytherapy Society.

Keywords: MRI brachytherapy; CT brachytherapy; Cervical cancer; Brachytherapy

Introduction

Brachytherapy is an integral component of curative management for locally advanced cervical cancer (1–3). Historical systems prescribed dose using milligram-radium hours or point-based systems with two-dimensional planar imaging (4–6). Three-dimensional treatment planning with CT or MRI demonstrates superior local control and decreased toxicity when compared with two-dimensional treatment planning (7). MRI has the benefit of superior soft tissue delineation compared with CT, which allows for more accurate delineation of the target volume (8). The most commonly prescribed volume with MRI-based brachytherapy planning is the high-risk clinical target volume (HR-CTV) comprising the gross tumor volume, cervix, and gray zones of peritumoral disease regression (9,10).

Performing MRI-based brachytherapy with an applicator in situ poses several challenges. The applicator must be MRI safe or MRI conditional and tested under specific conditions for patient safety. There is uncertainty in applicator reconstruction, especially titanium applicators, due to known spatial distortions from the applicator in the MRI

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Conflict of interest: Dr. Harkenrider has served on Varian Brachytherapy Advisory Board. The authors report no proprietary or commercial interest in any product mentioned or concept discussed in this article.

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(11−13). Digital reconstruction of the applicator is more certain when performed on CT. There are also uncertainties that accompany co-registration of images such as CT and MRI (14). MRI-based brachytherapy is also time, labor, and resource intensive. The use of multiple imaging modalities adds cost to the procedure as well (15).

Our department transitioned to an MRI-based brachytherapy program in 2014 and performed MRI and CT with the applicator in situ for treatment planning. There are many steps in this process, and with experience, we hoped to become more efficient and eliminate unnecessary steps without sacrificing quality and safety of the treatment. The role of CT in addition to MRI is controversial, and its utility is highly dependent on the applicator used, material of the applicator, and use of a solid applicator library in planning, which all impact the ability to identify the source positions within the applicator (16). There are limited data on the dosimetric impact of omission of CT in an MRI brachytherapy program with a titanium applicator, especially at ≥1.5 Tesla (T). The goal of this study was to evaluate the dosimetric differences between MRI-only and MRI-CT applicator identification and treatment planning with a titanium tandem and ovoid (T&O) applicator to determine if CT can be eliminated from the treatment workflow.

Material and methods

Loyola University Medical Center began an MRI-based cervical brachytherapy program in 2014, and we accrued patients on a prospective institutional study (LU206907). Our procedures and outcomes have been previously reported (17,18). Briefly, patients were treated with external beam radiotherapy and concurrent weekly cisplatin 40 mg/m^2, followed by brachytherapy to deliver a goal of 2 Gy equivalent dose to 90% of the HR-CTV of 85−95 Gy. When starting the program, we placed the applicator under general anesthesia with intraoperative orthogonal X-rays to verify proper applicator placement, recovered the patient, obtained an MRI with the applicator in situ, obtained a treatment planning CT, and then performed treatment planning and treatment delivery. The patient stayed overnight in the hospital for each application, and the second fraction was delivered the morning of Day 2. The applicator was then removed, and the patient was discharged. After 1−2 weeks, the procedure was repeated and another two fractions of cervical brachytherapy administered.

All patients were treated with an MRI conditional Fletcher-Suit-Delclos (FSD) T&O applicator (Varian Medical Systems, Palo Alto, CA). No interstitial needles were placed in these applications. Testing of this applicator in the MRI was performed before initiation of the program, and those results have been previously reported (18). Three-dimensional T2 MRI was performed along with 2D T2 sagittal, paraxial, and paracoronal sequences (where "para" indicates orientations relative to the cervix). For treatment planning, the MRI co-registration was performed to align the applicator using the axial oblique T2-weighted sequences as the source image and CT data as the target image. The physician used 3D T2 MRI for delineation of target volumes and organs at risk (OARs), whereas the medical physicist used CT for digital reconstruction of the applicator (Fig 1). For this study, we hypothesized that

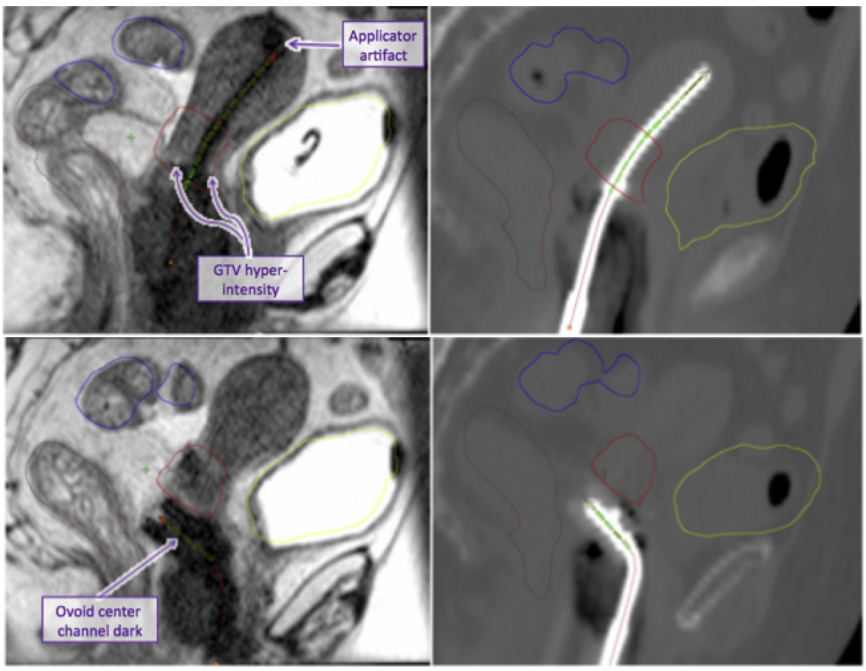

Fig. 1. Top row: MRI only showing OARs and tandem with a blooming artifact at the tip (left). CT showing MR-registered OARs and tandem (right). Bottom row: MRI only showing OARs and ovoid with darkened channel (left). CT showing MR-registered OARs and ovoid (right). (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)