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3-T MRI-based adaptive brachytherapy for cervix cancer: Treatment technique and initial clinical outcomes

Jordan Kharofa[1], Natalya Morrow[1], Tracy Kelly[1], Jason Rownd[1], Eric Paulson[1], Janet Rader[2], Denise Uyar[2], William Bradley[2], Beth Erickson[1,*]

[1]*Department of Radiation Oncology, Medical College of Wisconsin, Milwaukee, WI*
[2]*Department of Gynecologic Oncology, Medical College of Wisconsin, Milwaukee, WI*

ABSTRACT

PURPOSE: To report the techniques and initial clinical outcomes for MRI-based adaptive brachytherapy (MRIB-ABT) using 3-T MRI.

METHODS AND MATERIALS: All patients who underwent MRIB-ABT between January 2008 and June 2012 for cervical cancer using 3-T MRI for at least three fractions were retrospectively reviewed. The institutional standard for initiation of brachytherapy planning was 100% of dose at point A and 160% at the vaginal surface with five fractions of 500−550 cGy at Point A. The dose distribution was modified to enhance coverage of the high-risk clinical target volume (HR-CTV) and to spare the organs at risk (OAR) by altering dose specification distances around the tandem and the percentage of the Point A dose around the ring or ovoids.

RESULTS: Eighteen patients (FIGO stages IB = 4, II = 12, III = 1, and IVA = 1) underwent eighty-two 3-T MRI-based insertions. All patients received 3D conformal, external beam radiation (45−50.4 Gy). The median gross tumor volume pretreatment was 38 cm^3 (2−165 cm^3) compared with 4.8 cm^3 (1−9 cm^3) at the first high−dose rate fraction with a median volume reduction of 88%. Dose specification at the level of Point A was altered in 51% of 3-T MRI fractions from the standard 20 mm (range, 14−18 mm) and in 8% at the ring surface to optimally cover the HR-CTV and spare the OAR. The 2-year local control, disease-specific survival, and overall survival are 100%, 100%, and 93%, respectively.

CONCLUSIONS: MRIB-ABT using 3-T MRI for treatment of cervix cancer allows for customized alterations in dose specification that minimize dose to the OAR and maximize coverage of the HR-CTV.

Keywords: MRI-based brachytherapy; 3-T MRI; Cervical cancer

Introduction

Brachytherapy is an important component in the successful definitive treatment of cervical carcinoma. With modern imaging and planning techniques, brachytherapy has evolved from a point-based to a volume-based dose specification process. CT-based planning allows for dose-volume histogram assessment of the vital organs at risk (OAR; e.g. bladder, rectum, sigmoid) at the time of insertion. Use of CT-based techniques alone, however, does not allow one to assess the dose distribution throughout the tumor and its extensions. With MRI-based techniques, the target and the OAR can be readily visualized and the dose distribution more completely understood. Recommendations for volume-based parameters for the target and the OAR using these techniques have been developed and validated by the gynecologic GEC-ESTRO (Groupe Européen de Curiethérapie−European Society of Therapeutic Radiation Oncology) working group (1−3).

In an effort to transition from point-based specification to volume-based specification, the use of MRI-based adaptive brachytherapy (MRIB-ABT) offers several advantages. MRIB-ABT allows for improved soft tissue contrast delineation to enable contouring of target structures and of OAR. When performed during a brachytherapy insertion, the dose specification may be adapted to enhance coverage of the high-risk clinical target volume

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* Corresponding author. Department of Radiation Oncology, Medical College of Wisconsin, 9200 West Wisconsin Avenue, Milwaukee, WI 53226. Tel.: +1-414-805-4462; fax: +1-414-805-4369.

E-mail address: berickson@mcw.edu (B. Erickson).

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(HR-CTV) and limit dose to the OAR (4). Previous reports using lower strength magnets have revealed impressive rates of local control and toxicity with this approach (5). The objective of this study is to report the techniques and initial clinical outcomes for MRIB-ABT using higher strength, 3-T MRI with particular interest in the regression of tumor during treatment and adherence to dose constraints for the HR-CTV and OAR.

Methods and materials

All patients who underwent MRIB-ABT using a tandem and ring or tandem and ovoids between January 2008 and June 2012 for cervical cancer using 3-T MRI for at least three fractions were retrospectively reviewed through an IRB-approved protocol at the Medical College of Wisconsin. The current series is not a consecutive series of patients. For patients with bulky lesions after external beam radiation, distal vaginal involvement, or altered anatomy, our institutional preference is for a template-based interstitial technique. All patients were staged with positron emission tomography (PET) imaging and an MRI scan of the pelvis at diagnosis and were assessed at a multidisciplinary gynecologic tumor board. Insertion of the applicators, under IV sedation, was performed in a brachytherapy suite located in the Radiation Oncology Department. This was followed by CT simulation followed by a pelvic MR, both of which were located within the department in close proximity to the insertion suite.

MRI acquisition

Patients were imaged in treatment position on a Siemens 3-T Verio scanner (Siemens AG, Munich, Germany) with MR-compatible, plastic, and carbon fiber tandem-ring or ovoid applicators (Nucletron, an Elekta Company; Elekta AB, Stockholm, Sweden) in place. Catheters filled with 0.9% normal saline (Best Medical International, Inc., Springfield, VA) were inserted into the applicator lumen to enable treatment planning directly on MRI. To confirm application positioning, a 3-plane two-dimensional (2D) T2 HASTE (half-acquired single-shot turbo spin echo [field of view: 40, matrix: 256, echo time: 91 ms, repetition time: 2000 ms, TH/skip: 2/0.6 mm]) sequence was acquired to obtain a scout view of the applicator in relation to the uterus and cervix. Axial, nonfat-suppressed T2-weighted images with 1-mm^3 voxels were then acquired using a 3D SPACE (sampling perfection with application optimized contrasts using different flip-angle evolution [field of view: 384 mm^2, matrix: 384^2, echo time: 186 ms, repetition time: 2500 ms, Slice thickness/Inter-slice spacing: 1/0 mm]) sequence and commercial phased-array radiofrequency (RF) coils (6). Immediately before imaging, 0.5 mg of glucagon was administered intravenously to reduce bowel motion.

Contouring and treatment planning

The gross tumor volume (GTV) and HR-CTV were contoured for each fraction according to the GEC-ESTRO guidelines (3) as were the bladder, rectum, and sigmoid as outlined in Fig. 1. The GTV at diagnosis was contoured on pretreatment diagnostic (multislice 2D turbo spin echo) T2-weighted, 3-T MRI, and on the subsequent 3-T MRI scans at brachytherapy, when visible, to determine the regression over the course of external beam radiation and during the course of brachytherapy. During CT-only fractions, only the OAR were contoured without contouring of the HR-CTV. The MRIs from the prior fractions were used to guide dose specification in these infrequent non-MR fractions. All patients received 45−50.4 Gy to the whole pelvis using external beam radiation. Four patients (22%) were treated to an extended field, which included the para-aortics lymph nodes using the intensity-modulated radiation therapy. Five patients (28%) received an additional 5.4 Gy as a parametrial boost. Brachytherapy was initiated after completion of whole pelvis

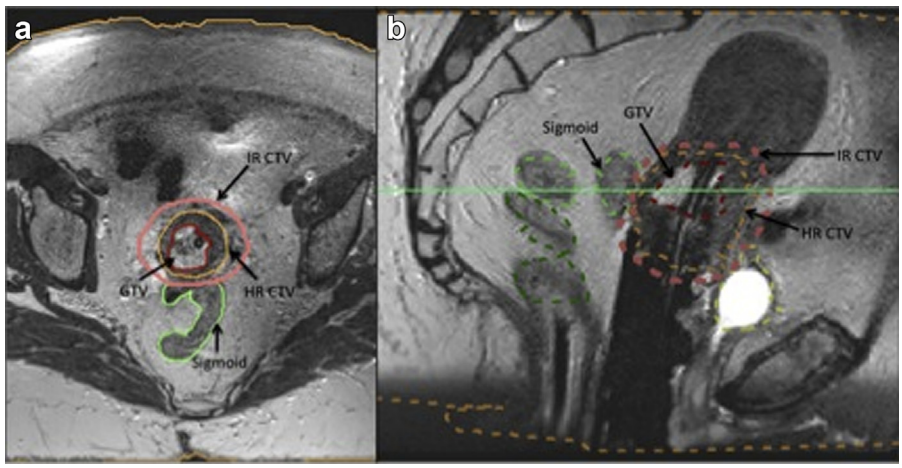

Fig. 1. Contours at Fraction 1 for the HR-CTV, GTV, and OAR according to the GEC-ESTRO guidelines using MRI-based adaptive brachytherapy using 3-T MRI. HR-CTV = high-risk clinical target volume; IR-CTV = intermediate risk volume; GTV = gross tumor volume; OAR = organs at risk.