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Evaluation of interfractional variation of organs and displacement of catheters during high-dose-rate interstitial brachytherapy for gynecologic malignancies

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ABSTRACT

PURPOSE: To investigate the dosimetric effects due to interfractional changes in catheter position and variation in patient's anatomy during the course of interstitial high-dose-rate (HDR) brachytherapy.

METHODS AND MATERIALS: A total of 15 patients with either cervical or vaginal cancer underwent interstitial HDR brachytherapy. Interstitial catheters and fiducials were placed under fluoroscopy and intraoperative 3T MRI to confirm the desired catheter placement for adequate target volume coverage. Single plan was generated from first-fraction CT fused with the MRI and used for all fractions of treatment. CT image was acquired before each treatment and registered to the first-fraction CT. Displacement of fiducials and catheters was calculated for each fraction and its effects on dosimetric parameters such as dose covering 90% for high-risk clinical target volume and intermediate-risk clinical target volume and dose to the 2 cm^3 of the volume for bladder, rectum, sigmoid, and bowel were studied.

RESULTS: Average movements of fiducials and catheters were 1.6 mm (range: 0.1−7.1 mm) and 1.7 mm (range: 0.1−4.5 mm), respectively. Overall, deviation of the delivered dose to the target in each fraction was insignificant for all patients (p-value: 0.66 for high-risk clinical target volume and 0.87 for intermediate-risk clinical target volume). The mean dose to organs at risk showed maximum difference up to 0.9, 2.7, 1.6, and 2.1 Gy for bladder, rectum, sigmoid, and bowel, respectively (p-value: 0.88, 0.34, 0.68, and 0.85 for bladder, rectum, sigmoid, and bowel, respectively).

CONCLUSIONS: The interfractional dosimetric variation for both target and organs at risk was within clinically acceptable limit throughout the entire course of interstitial HDR-Syed brachytherapy. Only 6% of cases performed replanning, which could be readily identified using CT imaging.

Keywords: Syed; Interstitial; High-dose-rate; Interfractional variation; Gynecologic brachytherapy

Introduction

In gynecologic brachytherapy, interstitial implant is a superior alternative to intracavitary technique for gynecologic malignancies presenting as bulky cervix/vaginal disease with extensive parametrial involvement (>0.5-cm thick), vaginal involvement, invasion to the bladder or rectum, recurrent endometrial carcinoma after hysterectomy, or previous pelvic external beam radiation therapy (EBRT), or for patients with distorted vaginal anatomy (1, 2). In comparison with an intracavitary technique, the interstitial technique provides better target coverage by escalating dose to the tumor while sparing adjacent normal tissues and critical structures. However, it is important to place adequate number of catheters at appropriate locations for optimal dose distribution and desired clinical outcome (1, 3, 4).

Interstitial high-dose-rate (HDR) brachytherapy requires placement of multiple catheters interstitially directly into

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the cancerous target volume. These catheters allow dwelling a radioactive source for optimal dose delivery using afterloading technique with radioactive sources such as Iridium-192 (5–9). The use of image guidance during the procedure allows the interstitial catheters to be positioned in the desired location. CT, fluoroscopy, ultrasound, positron emission tomography, or MRI have been used to delineate the extent of the target volume and determine the proper depth of the catheter insertion in relation to patient's anatomy and tumor volume before, during, or after catheter implementation (10–17). Recently, real-time MRI guidance has been introduced to identify the needles and anatomic volumes with superior tumor contrast during insertion (5, 18, 19), whereas CT imaging has been typically used to generate the dosimetric plan for the HDR brachytherapy treatment. In our department, intraoperative MRI (iMRI) is available during catheter implant in the operating room (OR), which basically allows for the MRI-based treatment planning. However, there is still a probability of catheter displacement and geometric changes of the organ and patient's pelvic configuration. Hence, the dose delivery to the patient may be erroneous because the catheter position in relation to target may not be secured throughout the course of interstitial brachytherapy. In this study, we have investigated the displacement of relative distance of fiducials and catheters by comparing the positions between activated dwell positions of each catheters and reference dwell position of center catheter. We have also investigated the necessity of dosimetric replanning by quantifying dose of target volume and organs at risk (OARs).

Methods and materials

In our institution, a total of 15 patients diagnosed with cervical or vaginal cancer were treated with interstitial HDR brachytherapy between May 2014 and November 2016. This study was approved by the institutional review board. There were eight patients (53%) with cervical cancer (one Stage IIA, one Stage III, one Stage IB, two Stage IIB, and three Stage IIIB) and seven patients (47%) with vaginal squamous cell carcinoma (three Stage IA, one Stage IVA, one Stage IB, one Stage II, and one Stage III), according to International Federation of Gynecology and Obstetrics system. Six patients (40%) indicate recurrent vaginal cancer after hysterectomy. Characteristics of the patient population treated are shown in Table 1. All patients were previously treated with a complete course of EBRT ranged from 42.5 to 61.2 Gy, and three patients had received further treatment with boost irradiation ranged from 5.31 to 8.85 Gy due to lymphatic invasion, resulting in the total EBRT doses of 50.4–61.2 Gy. One patient previously received vaginal cylinder brachytherapy (21 Gy in three fractions). One patient received concurrent chemotherapy with EBRT. For interstitial brachytherapy, the patients were prescribed with 5.5–6.0 Gy for a total dose of 22.5–30.0 Gy in five fractions using two fractions per day scheme, prescribed to a volumetric clinical target volume per American Brachytherapy Society guidelines. HDR radiation was administered using Iridium-192 with a remote afterloading system (microSelectron-V2, Elekta, Stockholm, Sweden).

Table 1
Characteristics of patients and treatment

Characteristics	Value
Age (y), median (range)	60.0 (40–81)
Site of treatment	
Squamous cell carcinoma of vulva	4
Squamous cell carcinoma of cervix	6
Adenosquamous cell carcinoma of vulva	1
Recurrent adenosquamous cell carcinoma of endometrium	4
Tumor FIGO stage	IA–IVA
Target volume (cm^3), median (range)	32.3 (6.1–114.1)
Number of fiducials, median (range)	3 (0–5)
Number of catheters, median (range)	11 (7–18)
Prescribe dose per fraction (Gy), median (range)	5.5 (5–6)
Total number of fractions	5
Prior EBRT dose (Gy), median (range)	45 (45–66)
Total HR-CTV EQD2 (Gy), median (range)	84.4 (75.1–109.8)

FIGO = International Federation of Gynecology and Obstetrics; EBRT = external beam radiation therapy; HR-CTV = high-risk clinical target volume; EQD2 = equivalent dose in 2 Gy fractions.

The interstitial implant procedure was performed in the OR equipped with a 3T MRI (Verio, Siemens Healthcare, Erlangen, Germany) under general anesthesia. A Foley catheter was placed in the bladder, and a balloon was filled with 7-cc radiopaque contrast. Gold markers (CIVCO, Kalona, IA) were placed in or near the gross tumor to aid in determining the depth of insertion of catheters in different positions: superior, inferior, left and right borders of the tumor. A vaginal obturator through Syed–Neblett template (Best Medical International Inc., Springfield, VA) was inserted into the patient's vagina in dorsal lithotomy position on the operating table. Under the fluoroscopic guidance, magnetic resonance (MR) compatible interstitial catheters were then placed and adjusted to the depth and parallelism. In most cases, a single rigid catheter (titanium needle) was inserted through the center of the vaginal obturator, and other peripheral catheters were placed in the desired locations. After the catheter placement, the patient was moved to the MRI located adjacent to the OR, minimizing patient's movement. An iMRI scan was performed to obtain T2 sequence while the patient was still under anesthesia. Using an iMRI scan, the depth of catheter and its placements compared to the implanted fiducials were confirmed to have adequate target volume coverage with an aid of diagnostic radiologist. After the adjustment of catheter position, if necessary, an iMRI scan was repeated to confirm the corrected position. After completion of the catheter placement, the patient recovered from anesthesia was transferred to radiation oncology department for CT simulation. After the first insertion, all patients received analgesia under conscious sedation with combined Versed and fentanyl to provide pain control. An anteroposterior and a lateral scout