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Characterizing the impact of adaptive planning on image-guided perineal interstitial brachytherapy for gynecologic malignancies

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ABSTRACT

PURPOSE: To determine the dosimetric impact of organ and implant motion/deformation in the context of adaptive planning in image-guided gynecologic brachytherapy using a 3-fraction transperineal approach.

METHODS AND MATERIALS: Twenty-six patients were analyzed. Each patient was treated with three fractions given over a 24-h period using a single insertion. A planning CT scan (±MRI) was acquired before the first fraction. A verification scan was taken within 1 h following the second fraction. A single plan was delivered for Fractions 1 and 2 with an adaptive plan delivered for Fraction 3. Two evaluation frameworks were established. Framework 1 investigated the effects of motion/deformation from both implant and organs. Framework 2 investigated the impact of implant motion/deformation alone. Differences in high-risk clinical target volume (HRCTV) $D_{90\%}$, $V_{100\%}$, and bladder/rectum D_{2cc} were assessed.

RESULTS: From implant to verification, the HRCTV $D_{90\%}$ and $V_{100\%}$ decreased significantly (5.0%, $p < 0.01$; 3.1%, $p < 0.01$) and rectal D_{2cc} was significantly higher (12.2%, $p = 0.02$). Adaptive planning recouped these changes. Implant changes resulted in a reduction in HRCTV dose and coverage, but no significant effect was seen in the bladder or rectum.

CONCLUSIONS: Adaptive planning represents an important aspect of perineal-based interstitial image-guided brachytherapy given in three fractions; its absence would result in plan degradation.

Keywords: Brachytherapy; Interstitial; Adaptive; Gynecologic cancer; Radiation

Introduction

The treatment of locally advanced and/or recurrent gynecologic malignancies remains a common and challenging scenario for clinicians. Brachytherapy remains an essential aspect of curative treatment approaches. With the advent of three-dimensional image-based planning, a perineal interstitial brachytherapy (pISBT) technique is becoming increasingly used for bulky lesions, particularly in the setting of postoperative local recurrence (1). There is growing consensus that volumetric image-guided brachytherapy (IGBT) is a central component for maximizing the therapeutic ratio in these cases (2, 3).

Akin to external beam radiotherapy (EBRT), characterizing treatment uncertainty in IGBT is a key element to delivering safe and optimal treatment. Primary sources of uncertainty specific to pISBT include motion and deformation of the implant and soft tissues, occurring both on an intrafraction and interfraction basis (4). Much like online imaging serves as an image-guided tool for EBRT, reimaging and adaptive planning provide the primary strategy to reduce uncertainty in IGBT. The optimal frequency for this process is unknown and is often limited in practice due to both resource availability and patient comfort. Several groups have investigated and characterized interfraction implant motion and the resulting dosimetric impact (4–7); however, these groups used a higher number of fractions with a longer inpatient stay.

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Our center frequently uses a previously published technique of delivering three fractions within a 24-h period in cases of recurrent endometrial cancer, primary vaginal cancer, or occasionally bulky cervical cancer in otherwise frail patients (8). This technique is attractive in that it offers a single operative procedure, acceptable toxicity, and a limited inpatient stay. In addition, we have instituted a ''verification'' scan taken within 1 h of delivering the second fraction that also serves as planning scan for Fraction 3 (Fx3). A schematic representation of this workflow is seen in Fig. 1. This workflow offers an opportunity to simulate several implementations of pISBT delivery and to separate and characterize the dosimetric influence of both organ and implant motion deformation, an interplay which to our knowledge has not been investigated previously. The aim of this work is to quantify the uncertainties associated with this 3-fraction technique and the benefits of adaptive planning with this particular workflow.

Methods and materials

Patient characteristics

Between October 2014 and September 2016, 26 patients with gynecologic malignancies were treated with high-dose-rate (HDR) pISBT using the Syed–Neblett template at the Odette Cancer Centre (9, 10). All patients were enrolled in a hospital research ethics board approved prospective registry study. The eligibility criteria for undergoing interstitial brachytherapy were based on treating physician preference and no contraindications to pISBT. Most patients were treated in conjunction with EBRT before brachytherapy; however, 4 patients were treated with pISBT alone for reirradiation due to prior high-dose pelvic radiotherapy. External radiotherapy was carried out using a standard four-field box based on classic field gynecologic field borders, with the exceptions of 2 patients who received extended field coverage for treatment of the paraaortic lymph nodes. Five patients received external beam nodal boost based on pelvic node enlargement on baseline diagnostic imaging. One patient received concurrent cisplatin chemotherapy for primary cervix cancer.

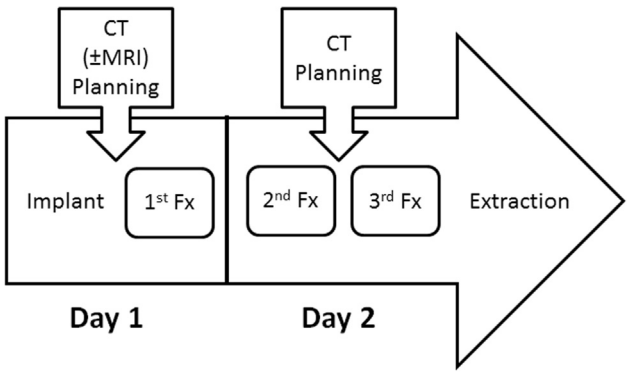

Fig. 1. HDR perineal brachytherapy schedule. Note MRI planning was done only on Day 1. HDR = high-dose-rate.

Applicator implantation and imaging

All patients underwent a single implantation procedure, with the exception of 1 patient who received two implantations separated by 1 week for a total of six fractions. This patient was being treated for recurrent colorectal cancer localized to the vagina. She had previously been treated with high-dose pelvic radiotherapy neoadjuvantly for her rectal cancer and was being treated radically with interstitial brachytherapy for this local recurrence. On the day of insertion, patients were placed under general anesthesia and positioned into dorsal lithotomy. An examination under anesthesia was performed. The patients were then prepped and draped in the usual fashion and a Foley catheter was placed in the urethra. Gold fiducial markers were placed at the proximal and distal extent of the palpable and/or visible disease. In the three cases of cervical cancer, an MRI-compatible uterine tandem was placed and positioning confirmed with transabdominal ultrasound, after which a 2.5-cm vaginal cylinder was secured to the tandem. In noncervical cancer patients, the vaginal cylinder was placed into the vagina directly. A disposable Syed–Neblett template was positioned over the vaginal cylinder. Flexible 24-cm 6F plastic catheters were then inserted through the template. The position and depth of the catheters were based on previous imaging and the examination under anesthesia. The template was then secured to the perineum with four sutures and secured to the vaginal cylinder with a rubber ring. Following patient recovery, a planning CT was performed without oral contrast. MRI planning scans became standard in mid-2015, before which CT scans alone were done with IV contrast (Visipaque, 100–120 cc at 5 cc/s). No IV contrast was used for MRI and patients who received MRI planning did not receive IV contrast for CT. CT scans were acquired with a 1.5-mm slice thickness (Philips Brilliance CT Big Bore, Best, Netherlands). CT markers were inserted into each catheter before scan acquisition. Sagittal, coronal, and axial T2-weighted magnetic resonance images were acquired on a 3T scanner (Philips Achieva) with a pelvic imaging coil. All catheters remained empty during magnetic resonance scan acquisition. Before CT, a rectal tube was inserted to a depth of 15 cm unless resistance was met earlier, left *in situ* during imaging and removed following scan completion. Following treatment planning and quality assurance testing, patients returned to the HDR suite to undergo Fraction 1 (Fx1). The following morning they returned to the HDR suite and received Fraction 2 (Fx2) using the original plan. Immediately following treatment, they underwent a verification scan which also served as a planning CT for Fx3. A rectal flatus tube was inserted and left *in situ* for each treatment fraction and removed afterward analogous to imaging. MRI was not repeated. Fx3 was delivered a minimum of