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Dosimetric comparison of optimization methods for multichannel intracavitary brachytherapy for superficial vaginal tumors

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ABSTRACT

PURPOSE: Multichannel vaginal applicators allow treatment of a more conformal volume compared with a single, central vaginal channel. There are several optimization methods available for use with multichannel applicators, but no previous comparison of these has been performed in the treatment of superficial vaginal tumors. Accordingly, a feasibility study was completed to compare inverse planning by simulated annealing (IPSA), dose point optimization (DPO), and graphical optimization for high-dose-rate brachytherapy using a multichannel, intracavitary vaginal cylinder.

METHODS AND MATERIALS: This comparative study used CT data sets from five patients with superficial vaginal recurrences of endometrial cancer treated with multichannel intracavitary high-dose-rate brachytherapy. Treatment plans were generated using DPO, graphical optimization, surface optimization with IPSA (surf IPSA), and two plans using volume optimization with IPSA. The plans were evaluated for target coverage, conformal index, dose homogeneity index, and dose to organs at risk.

RESULTS: Best target coverage was achieved by volume optimization with IPSA 2 and surf IPSA with mean V100 values of 93.89% and 91.87%, respectively. Doses for the most exposed 2-cm^3 of the bladder (bladder D2cc) was within tolerance for all optimization methods. Rectal D2cc was above tolerance for one DPO plan. All volume optimization with IPSA plans resulted in higher vaginal mucosa doses for all patients. Greatest homogeneity within the target volume was seen with surf IPSA and DPO. Highest conformal indices were seen with surf IPSA and graphical optimization.

CONCLUSIONS: Optimization with surf IPSA was user friendly for the generation of treatment plans and achieved good target coverage, conformity, and homogeneity with acceptable doses to organs at risk.

Keywords: Brachytherapy; Optimization; IPSA; Intracavitary; Vagina

Radiotherapy is a widely used treatment option for primary or recurrent vaginal cancers. Treatment approaches vary and involve vaginal brachytherapy, external beam radiotherapy (EBRT), or a combination of both (1−12). Better local control rates are reported with high doses of radiation through a combination of EBRT and brachytherapy (9); however, brachytherapy alone is employed for patients with a greater risk of radiation-related morbidity from whole pelvic irradiation or for small superficial tumors (3). Low-dose-rate or high-dose-rate (HDR) brachytherapy may be used. Brachytherapy is commonly delivered using intracavitary vaginal cylinders for superficial vaginal lesions (<5 mm deep), whereas interstitial needles are required for thicker lesions to achieve sufficient coverage (13, 14).

Variations of multichannel vaginal cylinders have been used in intracavitary brachytherapy for primary and recurrent vaginal cancers (15−17). These cylinders feature 6−14 peripheral channels and generally have a central channel. Multichannel vaginal applicators offer several

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advantages over single-channel cylinders. Asymmetrical loading of the peripheral channels allows localized vaginal irradiation and reduced dose to organs at risk (OARs), such as the bladder and rectum (15, 16). Peripheral channels can also compensate for single-line source anisotropy at the vaginal apex (13, 18).

Technological advances have allowed incorporation of three-dimensional imaging into brachytherapy treatment planning with the use of CT and MRI. This allows target volumes and OARs to be delineated accurately and dose distributions can be optimized to improve target volume dose coverage with adequate sparing of OARs (14, 19).

Optimization involves modification of HDR dwell positions and dwell times to produce dose distributions that best conform to the target volume (18). Various optimization algorithms have been developed for brachytherapy planning. These include dose point optimization (DPO), graphical optimization (GrO), and inverse planning by simulated annealing (IPSA) (20). The DPO algorithm optimizes dose at user-defined dose points. For GrO, the user manually adjusts isodose lines on the screen to produce a desired dose distribution. The IPSA method produces optimized dose distributions based on prescribed dose constraints on identified anatomic volumes (21). The optimization algorithm and dose optimization points selected have a large effect on the dose distribution produced. Optimization algorithms have been compared in HDR interstitial brachytherapy for prostate (22, 23) and gynecologic cancers (24, 25), but no previous study has compared optimization methods for multichannel vaginal cylinders.

The aim of this study was to dosimetrically compare plans generated by DPO, GrO, and IPSA for multichannel intracavitary vaginal brachytherapy for superficial vaginal recurrences of endometrial cancer to determine the most appropriate optimization method.

Materials and methods

The Miami vaginal applicator [Nucletron, an Elekta company, Elekta AB, Stockholm, Sweden; Fig. 1 (26)]

Fig. 1. Miami vaginal applicator (Nucletron, an Elekta company; Elekta AB, Stockholm, Sweden) (26).

was commissioned at the Calvary Mater Newcastle in 2009. Between January 2010 and November 2011, five patients with superficial vaginal vault recurrences of endometrial cancer were treated with HDR intracavitary brachytherapy using the Miami vaginal applicator (Nucletron, an Elekta company). Four patients received EBRT to a dose of 45−48.6 Gy in 1.8 Gy per fraction. One patient did not receive EBRT owing to previous radiotherapy. The median brachytherapy total dose was 18 Gy (range, 10−36) and dose per fraction varied from 4.5 to 6 Gy. Before this period, patients with superficial vaginal tumors (recurrent endometrial cancer and superficial primary vaginal cancers) were treated with a single-channel vaginal cylinder with the dose most commonly prescribed to a depth of 5 mm from the surface of the applicator. This brachytherapy component of treatment was used as a boost after EBRT. However, for the purposes of this comparative study, patients were assumed to have received EBRT of 45 Gy in 25 fractions, 1.8 Gy per fraction followed by 18 Gy in 3 fractions, 6 Gy per fraction with HDR intracavitary vaginal brachytherapy.

The Miami vaginal applicator (Nucletron, an Elekta company) is a cylindrical applicator with a minimum diameter of 30 mm and consists of a central channel with six equally spaced channels around the periphery. The central channel can accommodate an intrauterine tube, but this was not used in the five study patients. For each patient, the largest possible diameter was used that allowed comfortable vaginal applicator insertion and maximal contact of the applicator with the vaginal mucosa as determined by CT guidance. The applicator was inserted with the patient supine on the CT couch and secured using a base plate. Local anesthetic gel was used routinely as a lubricant. Patients were given oral analgesia if there was discomfort with the procedure (the smallest diameter of the Miami applicator is 30 mm), especially where there was persistent mucositis in the vagina after EBRT.

A CT dataset was acquired for each of the five patients incorporating the clinical target volume (CTV) and bladder and rectal contours. The CTV was defined as the presumed residual tumor based on clinical examination immediately before brachytherapy, pretreatment imaging, fiducial markers (gold seeds were used in 2 patients), and taking into account tumor extent at diagnosis including findings at examination under anesthesia (27). The CTV usually included the vaginal mucosa and submucosa to a depth of 5 mm. Using IPSA requires active dwell positions to lie inside the target volume. Therefore, the CTV also included the applicator in the vicinity of the vaginal CTV. In addition, a vaginal mucosa volume was contoured with a depth of 1 mm from the cylinder surface to report vaginal surface dose.

Using Oncentra Brachy planning software (version 4.2; Nucletron, an Elekta company), treatment plans were generated with the following optimization methods for each patient: DPO, GrO, surface optimization with IPSA (surf IPSA), and volume optimization with IPSA (vol IPSA).