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Dosimetric comparison of multichannel with one single-channel vaginal cylinder for vaginal cancer treatments with high-dose-rate brachytherapy

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ABSTRACT

PURPOSE: To compare the three-dimensional (3D) image (CT/MR)-based planning with a multichannel vaginal cylinder (MVC) to a single-channel vaginal cylinder (SVC) for the treatment of vaginal cancer.

METHODS AND MATERIALS: A total of 20 consecutive patients were treated with 3D CT/MR image-based high-dose-rate (HDR) brachytherapy using an MVC. All patients received external beam radiation therapy before HDR brachytherapy. A brachytherapy dose of 20–25 Gy of more than five fractions was delivered to clinical target volume (CTV). Retrospectively, treatment plans for all patients were generated using the central channel only to mimic an SVC applicator. The SVC plans were optimized to match CTV coverage with MVC plans. Dose homogeneity index as well as bladder, rectum, sigmoid, and urethral doses were compared.

RESULTS: The mean D_{90} for CTV was 74.2 Gy (range: 48.8–84.1 Gy). The mean (±standard deviation) of dose homogeneity index for MVC vs. SVC was 0.49 (±0.19) and 0.52 (±0.23), respectively ($p = 0.09$). Mean bladder 0.1, 1, and 2 cc doses for MVC vs. SVC were 69 vs. 71.2 Gy ($p = 0.35$), 61.4 vs. 63.8 Gy ($p = 0.1$), and 59.5 vs. 60.9 Gy ($p = 0.31$), respectively. Similarly, mean rectum 0.1, 1, and 2 cc doses for MVC vs. SVC were 67.2 vs. 75.4 Gy ($p = 0.005$), 60.0 vs. 65.6 Gy ($p = 0.008$), and 57.3 vs. 62.0 Gy ($p = 0.015$), respectively, and mean sigmoid doses were 56.3 vs. 60.5 Gy ($p = 0.10$), 50.9 vs. 53.1 Gy ($p = 0.09$), and 49.1 vs. 50.7 Gy ($p = 0.10$), respectively.

CONCLUSION: The 3D CT-/MR-based plan with MVC may provide better dose distribution in the management of certain clinical situations of vaginal cancer requiring intracavitary brachytherapy, especially in minimizing potential late rectal complications.

Keywords: Vaginal cancer; Multichannel cylinder; Single-channel cylinder

Introduction

Primary or recurrent cancer in the vagina is a rare entity (1, 2). Because organ-sparing surgical resection is often not feasible, it is commonly treated with definitive radiation therapy with the combination of external beam radiation therapy (EBRT) and brachytherapy (3, 4). Brachytherapy is delivered using either an intracavitary or interstitial technique depending on the location and extent of residual disease after EBRT (5, 6).

Single-channel vaginal cylinder (SVC) is a commonly used applicator for intracavitary brachytherapy for superficial lesions (2). The dose distribution with the SVC is uniform around the applicator; however, this may not be optimal for all patients as the size, location, thickness, and morphology of disease varies considerably among patients (7). Thus, dosimetric limitations may preclude the utilization of the SVC in some clinical scenarios.

A multichannel vaginal cylinder (MVC) applicator may offer better flexibility to individualize dose distribution for each patient (8–10). Advances in high-dose-rate (HDR) brachytherapy planning have led to the increased utilization of three-dimensional (3D) image-based brachytherapy. The ability of 3D image-based HDR brachytherapy planning to more precisely cover the target and limit critical organ dose has been reported in many studies (11–13). With the help of 3D planning, MVC applicator treatments may also stand

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to benefit from the ability to more precisely customize the plan to the individual patient.

Our institution implemented the MVC applicator for vaginal cancers in 2011 and has adopted an image-based technique with CT- and/or MR-based planning with each fraction of HDR brachytherapy. The purpose of this study is to assess and compare dosimetry of MVC plans to SVC plans with 3D image-based planning.

Methods and materials

A total of 20 consecutive patients with primary or recurrent vaginal cancer were treated with 3D CT/MR image-based HDR brachytherapy plans using MVC from November 2011 to April 2013 and were analyzed for this study. The first 15 patients were treated with a custom-designed MVC applicator (one central channel and four peripheral channels, Fig. 1a) and the last 5 patients with commercially available MVC applicator with one central channel and eight peripheral channels (Fig. 1b, Nucletron; Elekta company, Elekta AB, Stockholm, Sweden).

Around 16 patients presented with recurrent disease in vagina, whereas the remaining 4 had primary vaginal cancer. The location of tumor in vagina was in the anterior ($n = 1$), posterior ($n = 2$), lateral walls ($n = 6$), and cuff area ($n = 11$). The length of vagina involved was the upper one-third for 13, upper to midvagina for 4, and distal for 3 patients (Table 1). Before brachytherapy, 19 patients received EBRT dose of 45–50.4 Gy, whereas 1 patient with previous adjuvant treatment received a dose of 23.4 Gy. A total of 18 patients were treated with intensity-modulated radiation therapy technique and the other 2 patients with 3D conformal radiation therapy.

All patients had residual thickness of 7 mm or less at the time of brachytherapy as assessed by imaging and clinical examination. All patients received a dose of 20–25 Gy for more than five fractions of HDR brachytherapy (delivered once or twice a week) with the dose prescribed to clinical target volume (CTV). For all patients, X-ray orthogonal films were taken to confirm the position for each fraction. Thereafter, a CT scan of pelvis was acquired with 2.5-mm slice thickness. A total of 4 patients had the MRI scan with MVC applicator *in situ* for the treatment planning. The T2 axial images with 2.0-mm slice thickness were used for the MRI-based planning. For the remaining patients, pretreatment and post-EBRT MRI scans were used to define the target volume. The CTV and critical organs (bladder, rectum, sigmoid, and urethra, when applicable) were contoured by an experienced radiation oncologist.

The CTV was defined based on a combination of clinical examination and pre- and post-EBRT MRI findings. Palpable disease at the time of brachytherapy was marked with gold seeds. The length and circumference for CTV was based on pretreatment extent of disease, whereas thickness was based on post-EBRT MRI and clinical examination. For patients who had complete clinical and imaging response at the time of brachytherapy, the length and circumference of vagina was based on the pretreatment scan.

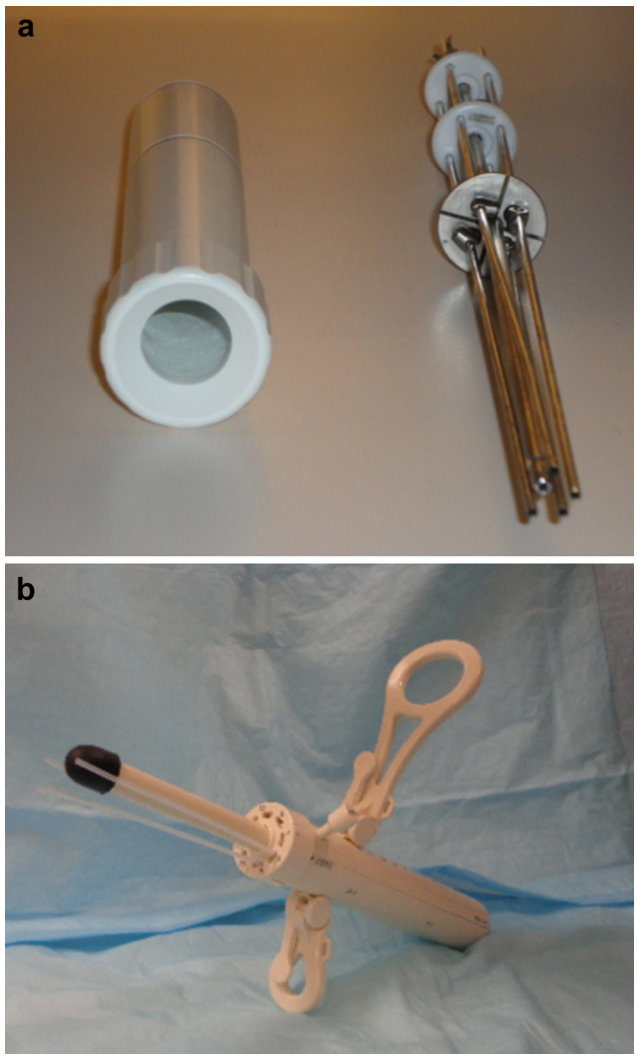

Fig. 1. Home-made multichannel cylinder (a) and commercial multichannel cylinder (b) by Nucletron, an Elekta company (Elekta AB, Stockholm, Sweden).

The CT scans were used for treatment planning, which was performed with Nucletron Plato Brachytherapy Planning System Version 14.3 (Nucletron; an Elekta company, Elekta AB, Stockholm, Sweden). Each plan was optimized to cover at least 90% of CTV (D_{90}) with prescription dose and to minimize dose to the critical organs including bladder, rectum, sigmoid, and urethra where applicable.

Table 1
Tumor location and length of vagina

Location	Length of vagina involved	*n*
Anterior	Distal and mid	1
Posterior	Upper	2
Lateral	Upper	4
	Distal and mid	2
Vaginal cuff	Upper	7
	Upper and mid	4