Medical Dosimetry ■■ (2017) ■■–■■

Medical Dosimetry

journal homepage: www.meddos.org

Dosimetry Contribution:

Dynamics of the vaginal wall dose in HDR interstitial brachytherapy for gynecological cancer: Systematic analysis of phantom *vs* patient case

Robert Y. Kim, M.D., Andrew M. McDonald, M.D., Omer Lee Burnett, III, M.D., and Sui Shen, Ph.D.

Department of Radiation Oncology, University of Alabama Medical Center, Birmingham, AL

ARTICLE INFO

Article history:
Received 30 August 2017
Accepted 14 September 2017

Keywords:
HDR
Interstitial brachytherapy
Vaginal wall dose
Dose optimization
Gynecological cancer

ABSTRACT

This study aimed to investigate the dynamics of the vaginal wall dose for interstitial brachytherapy (ISBT). A patient undergoing ISBT was selected as the patient case. The phantom case was generated to simulate the patient case in all regards with the exception of parallel needle positions. The vaginal wall was contoured as a 0.5-cm expansion around the vaginal surface of the obturator. The prescribed ISBT dose was 20 Gy in 4 fractions. Six treatment plans were generated by modifying relative dwell times and needle positions (DTNP). The volume of the vaginal wall receiving > 150% of prescription dose ($V_{>150\%}$) and D_{2cc} of the vaginal wall were compared among plans. The $V_{>150\%}$ was much larger in the patient case (49.3%) due to unparallel needles compared with the phantom case (14.3%) without modification (plan 1). Among the 6 plans, reduced dwell time (plan 3) and no dwell time (plans 5 and 6) on the vaginal surface needles had the lowest vaginal wall doses with the use of a central obturator needle in both cases. In comparison of patient case plans 1, 3, 5, and 6, $V_{150\%}$ was 49.2%, 19.0%, 21.3%, and 28.7%, respectively, and D_{2cc} was 41.15 Gy, 33.10 Gy, 36.51 Gy, and 34.37 Gy, respectively, which was limited around each loaded needle. Modification of DTNP is able to reduce the vaginal wall volume exceeding 150% of the prescription dose in the patient case. Understanding these dynamics of the vaginal wall dose will improve dose optimization of ISBT and may reduce vaginal morbidities.

Introduction

Interstitial brachytherapy (ISBT) has been used for vaginal cancer, vaginal recurrences of endometrial cancer, and cervical cancer not amenable to standard intracavitary brachytherapy (ICBT) such as extensive parametrial involvement or extending into the distal vagina. ISBT has a potential higher risk of vaginal wall dose and vaginal morbidities compared with ICBT due to heterogeneity of high vaginal wall dose which depend on the degree of diverging needle positions. External beam radiation therapy is generally delivered first to reduce tumor volume before ISBT.

Recently, high-dose rate (HDR) ISBT has gained increasing acceptance as an alternative to low-dose rate (LDR) ISBT

Reprint requests to Robert Y. Kim, M.D., Hazelrig Salter Radiation Oncology Center, University of Alabama at Birmingham, Birmingham, AL 35249-6832.

E-mail: rkim@uabmc.edu

https://doi.org/10.1016/j.meddos.2017.09.002

due to radiation safety issues and the benefit of dose computer optimization. With advances in imaging technology and 3-dimensional treatment planning systems, investigators can calculate dose-volume histograms (DVHs) of the organs at risk (OARs) such as the rectum, bladder, and sigmoid colon using D_{2cc} volumes according to Groupe European de Curietherapie, European Society (GEC-ESTRO) guidelines[1,2] in an attempt to quantify risks of toxicities. However, the vaginal wall is rarely contoured and evaluated.

Our previous study[3] evaluated the dynamics of pear-shaped isodoses in ICBT. To the best of our knowledge, there is no systematic evaluation of vaginal wall dose for ISBT. It is well known that higher vaginal wall doses cause higher vaginal morbidities. The purpose of the current study is to evaluate the dynamics of the vaginal wall dose by adjusting the source dwell time and needle position (DTNP) between the vaginal surface and the central obturator needles with ISBT.

Materials and Methods

Patient and phantom cases

For the purpose of this analysis, we selected the case of a woman with recurrent cervical cancer at the anterior upper vagina after radical hysterectomy who was treated with HDR ISBT using a transperineal template (Template Syed/Neblett/Hedger, Alpha-Omega Service, Inc, Bellflower, CA). For this case, we had inserted an obturator needle (tandem) and 30 needles within the semicircular template (Fig. 1B). Twenty-one needles (including the obturator needle) were loaded to cover the target volume, including the anterior vaginal wall. Because the position of needle tracks can be quite variable among individual patients (even when using an identical template layout), evaluating the dynamic dosimetric changes on the vaginal wall by modification of DTNP is extremely difficult in a patient-specific manner. Therefore, to aid with plan comparison, an ideal phantom case was also generated using identical needle numbers and positions within the template, but with the needles parallel to one another along their entire length (Fig. 1A). Because the tumor coverage is dependent on adequacy of needle placement, we assume adequate needle placement was accomplished in this study. The dynamics of vaginal wall dose was evaluated in this study.

The planning computed tomography (CT) of the patient case was acquired with 1.0-mm slices to have fine spatial resolution for digitizing needle position in superior-inferior direction. The planning CT of the Phantom case was acquired similarly but with the implant in air. The source dwell positions inside the needles were digitized into the treatment planning system (BrachyVision, Varian Medical Systems Inc., Palo Alto, CA), with a step size of 5 mm between each

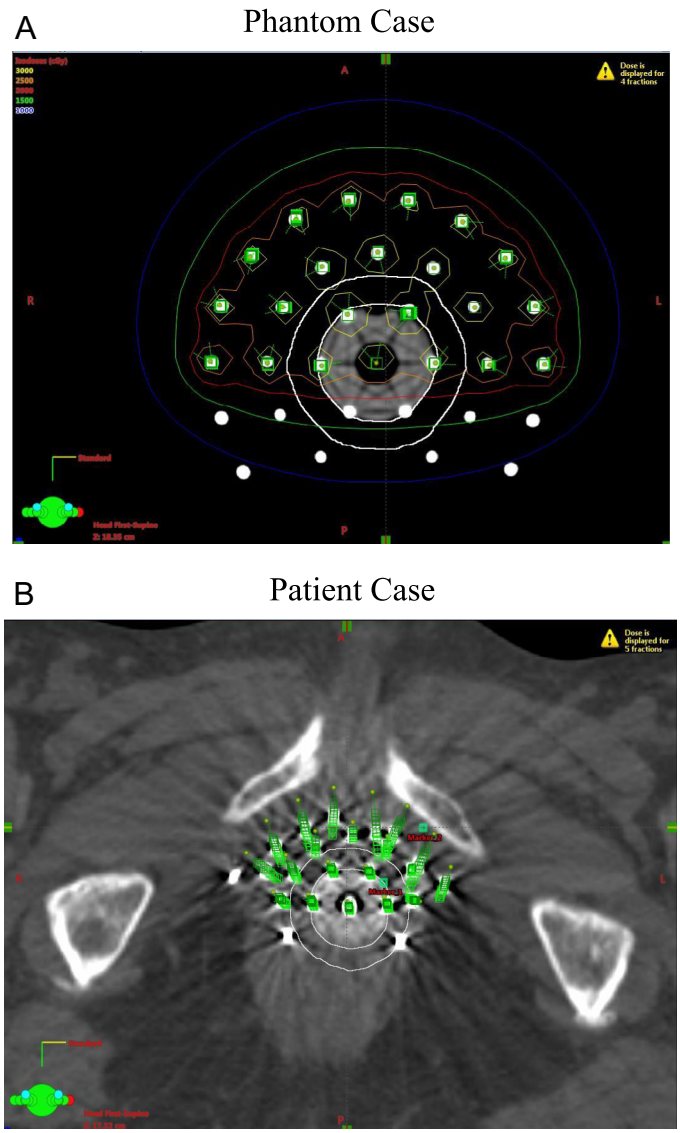

Fig. 1. Phantom and patient cases: (A) Phantom case. (B) Patient case showing vaginal wall drawing and loaded needle position. Needles outside of the target volume were not loaded. (Color version of figure is available online.)

dwell positions. Treatment was delivered with an Ir-192 remote after-loading unit (Varisource, Varian Medical System, Inc., Palo Alto, CA).

Treatment planning and plan comparison

The vaginal wall was defined as a 0.5-cm thickness around the outer surface of the 2-cm diameter vaginal obturator. The reference dose point was 5 mm away from one of the perimeter needles in third upper semicircular. The prescribed radiation dose to the reference point was 20 Gy in 4 fractions as a boost dose after external beam radiation therapy. Geometric optimization (GO) was done to get the homogeneous dose between needles as much as possible in the target volume. Six different plans were generated with DTNP modi-