ELSEVIER

Brachytherapy ■ (2017) ■

BRACHYTHERAPY

The value of systematic contouring of the bowel for treatment plan optimization in image-guided cervical cancer high-dose-rate brachytherapy

Antonio L. Damato[1,*], Ivan Buzurovic[2], Mandar S. Bhagwat[2], Robert A. Cormack[2], Phillip M. Devlin[2], Scott Friesen[2], Jorgen Hansen[2], Larissa J. Lee[2], Matthias M. Manuel[2], Linda P. Cho[2], Desmond O'Farrell[2], Akila N. Viswanathan[3]

[1]*Department of Medical Physics, Memorial Sloan Kettering Cancer Center, New York, NY*
[2]*Department of Radiation Oncology, Dana-Farber Cancer Institute/Brigham and Women's Hospital, Boston, MA*
[3]*Department of Radiation Oncology and Molecular Radiation Sciences, Johns Hopkins Medicine, Baltimore, MD*

ABSTRACT

PURPOSE: To investigate the dose−volume histogram metrics and optimization results of the contoured bowel in cervical cancer brachytherapy.

METHODS AND MATERIALS: Treatment plans of cervical cancer patients treated with image-guided high dose rate were retrospectively analyzed with institutional review board approval. In addition to the clinical target volume, rectum, bladder, and sigmoid, the bowel was contoured at the time of planning (Group 1) or at the time of this analysis (Group 2).

RESULTS: Thirty-two patients treated with 145 insertions were included. Before optimization, mean ± 1 standard deviation overall bowel minimum dose to the most irradiated 2 cm^3 volume of an organ (D_{2cc}) was 67.8 $Gy_{\alpha/\beta 3}$ ± 13.7 $Gy_{\alpha/\beta 3}$ (Group 1: 72.6 ± 13.2 $Gy_{\alpha/\beta 3}$; Group 2: 57.3 ± 8.0 $Gy_{\alpha/\beta 3}$). Before optimization, one patient in Group 1 presented a bowel D_{2cc} metric exceeding 100 $Gy_{\alpha/\beta 3}$. After optimization, bowel D_{2cc} mean ± 1 standard deviation was 59.4 ± 6.7 $Gy_{\alpha/\beta 3}$ (Group 1: 61.4 ± 6.0 $Gy_{\alpha/\beta 3}$, $p < 0.001$; Group 2: 55.2 ± 6.5 $Gy_{\alpha/\beta 3}$, $p = 0.026$).

CONCLUSIONS: Given the potentially high doses and the benefit of optimization in reducing dose to the organs at risk, we recommend consideration of systematic contouring of the bowel when bowel is present in the pelvis.

Keywords: Cervical cancer; Contouring; Bowel

Introduction

Intracavitary brachytherapy is the standard of care for locally advanced cervical cancer throughout the world. Intracavitary brachytherapy was historically performed with low-dose-rate sources loaded manually in an applicator to deliver a pear-shaped dose distribution normalized to Point A (1−3). With practice patterns shifting to pulsed-dose-rate and high-dose-rate sources with robotic delivery, the increased flexibility in optimization of dose contributed to the development of the concept of the sculpted pear (4). Patient-specific optimization allows departures from the standard pear shape and increases sparing of the organs at risk while maintaining acceptable doses to the clinical target volume (CTV) (5−9). Guidelines from Groupe Europeen de Curietherapie - European Society for Radiotherapy & Oncology (GEC-ESTRO) (10) and American Brachytherapy Society (ABS) (11) suggest the necessity to systematically contour the rectum, sigmoid, and bladder, and to base optimization choices on dose−volume histogram (DVH) analysis, in particular on minimum dose to the most irradiated 2 cm^3 volume of a given organ (D_{2cc}) values. Although dose constraints have been proposed for the bladder, rectum,

Received 23 September 2016; received in revised form 17 January 2017; accepted 18 January 2017.

Funding: Data management and cases (MR and CT) were supported by the National Institutes of Health R21 CA167800 (principal investigator: Viswanathan).

* Corresponding author. Department of Medical Physics, Memorial Sloan Kettering Cancer Center, R122, 1275 York Avenue, New York, NY 10065. Tel.: +1-212-639-8256.

E-mail address: damatoa@mskcc.org (A.L. Damato).

1538-4721/$ - see front matter
http://dx.doi.org/10.1016/j.brachy.2017.01.008

and sigmoid, few studies have assessed the value of bowel contouring and subsequent dose metrics to the bowel. Guidance on bowel optimization is less available, and reports suggest an uneven attitude toward the necessity of contouring the bowel and basing optimization on bowel metrics (12). A bowel planning goal of $D_{2cc} < 70-75$ $Gy_{\alpha/\beta 3}$ was reported by some institutions (13), whereas others report not using a planning goal (14). Moreover, many institutions adopt a CTV minimum dose to the most irradiated 90% of an organ (D_{90}) objective of 85 $Gy_{\alpha/\beta 10}$, whereas our institutional objective is 80 $Gy_{\alpha/\beta 10}$. This difference can partially explain the lower bowel constraint adopted in our clinic compared with other institutions.

Contouring is a time-consuming task with significant interobserver variability. The benefit of contouring of organs at risk that are not directly adjacent to the applicator is unknown. Our clinic policy is to systematically contour rectum, bladder, and sigmoid and to contour the bowel in general when the loops are close to the applicator. This qualitative approach to bowel contouring has been reported by other institutions (14). However, movement of the bowel between fractions and differences in visualization of the bowel based on the interpretation by different physicians may result in uncertainties in the implementation of this qualitative approach. The goal of this study is to evaluate the bowel dose metrics, the impact of optimization of the bowel as an organ at risk, and the necessity to systematically contour the bowel in cervical cancer brachytherapy (BT) cases. All our analyses are based on our institutional dose constraints to the bowel D_{2cc} dose of 65 $Gy_{\alpha/\beta 3}$.

Methods

Records of all cervical cancer patients treated between January 2013 and August 2014 with radical intent using an intracavitary applicator with or without the additional use of interstitial needles were analyzed with institutional review board approval. All patients were implanted under general anesthesia with CT or MR guidance. CT-guided insertions were performed in a dedicated BT suite equipped with CT, and the patient remained on the CT table until treatment was administered. MR-guided insertions were performed in an operating room equipped with a 3T MR and moved under general anesthesia to the BT suite for treatment.

Following a previously described workflow (15), contouring was performed by a physician, whereas a physicist reconstructed the BT applicator and generated a standard plan, aiming in general at providing a pear-shaped dose distribution normalized to Point A (8), with the tandem dwell locations activated up to the tip. The CTV, rectum, bladder, and sigmoid were systematically contoured for all patients and fractions. Because the patients were under general anesthesia, oral contrast could not be given, and therefore, bowel contours include both small and large bowels, as there was no way on CT to accurately distinguish between small and large bowels. The bowel was contoured at the time of planning when considered proximal to the uterus and cervix region (Group 1) and was contoured for purposes of this study otherwise (Group 2). Group 2 patients did not have their bowel contoured at the time of BT because the bowel did not appear immediately adjacent to the applicator. In cases where the bowel was contoured for some fractions but not others, the patient was assigned to Group 1 if the bowel was contoured in half of the fractions or more; otherwise it was assigned to Group 2. An example of bowel contour for the two groups is show in Fig. 1. When contoured, bowel D_{2cc} metrics were used to guide optimization choices. Optimization was performed by a physician starting from the standard pear-shaped plan and manually modifying dwell times to adjust the dose distribution. DVH objectives were CTV $D_{90} > 80$ $Gy_{\alpha/\beta 10}$, rectum and sigmoid $D_{2cc} < 75$ $Gy_{\alpha/\beta 3}$, and bladder $D_{2cc} < 90$ $Gy_{\alpha/\beta 3}$. Bowel $D_{2cc} < 65$ $Gy_{\alpha/\beta 3}$ was also an optimization objective. Metrics were calculated summing BT and external beam dose with the equieffective dose 2 Gy per fraction (EQD2) formalism. A slice-by-slice review of the isodose lines was performed before finalizing the plan for treatment. Typically, the 200%, 150%, 100%, 70%, and 50% isodose lines were displayed during the review. This step was always performed and allowed for a secondary visual verification that the isodose lines cover the visible CTV and satisfactorily avoid visible organs at risk. Theoretically, this extra step may allow optimization of bowel dose but without a formal analysis of the D_{2cc} metric.

In this study, we report the total bowel D_{2cc} (BT + external beam) and the bowel-sparing factor (BT D_{2cc}/BT D_{90}). The sparing factor allows calculating how effective optimization was at achieving a low dose to the bowel while maintaining a high dose to the CTV. A plan with a lower sparing factor was more effectively optimized than a plan with a higher sparing factor. A first analysis of the data was performed to evaluate our clinic policy on bowel contouring. Bowel D_{2cc} values in Group 1 (contoured) were compared with values in Group 2 (not contoured) for standard plans. An unpaired t test was used to assess the significance of the difference in metrics between the groups, and a Fisher exact test was used to assess the significance of the difference in number of patients meeting optimization objectives in the two groups. A comparison of D_{2cc} before and after optimization in both groups was also performed. Within each group, a paired comparison between the bowel-sparing factors in standard and optimized plans was performed. A paired Student's t test was used to assess the significance of the difference in sparing factors. Threshold for significance for all tests was $p < 0.05$.

Results

Thirty-two patients met the inclusion criteria of this study, 22 in Group 1 and 10 in Group 2. Staging is summarized in Table 1. The patients received a total of 145