BRACHYTHERAPY

Brachytherapy 13 (2014) 94−99

Evaluating adjacent organ radiation doses from postoperative intracavitary vaginal vault brachytherapy for endometrial cancer

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ABSTRACT

PURPOSE: To document doses received by critical organs during adjuvant high-dose-rate (HDR) vaginal vault brachytherapy.

METHODS AND MATERIALS: Patients treated with HDR vaginal vault radiation between January 1, 2009, and January 31, 2012, who had a CT simulation with the treatment cylinder in situ were included. The CT scans were retrospectively reviewed and the rectum, sigmoid, small bowel, and bladder were contoured. Standardized plans treating the upper 4 cm of the vaginal vault were used to deliver a total of 21 Gy (Gy) at 0.5 cm from the apex of the vaginal vault in three fractions.

RESULTS: There were 41 patients. Median age was 62 years. The median vaginal cylinder diameter was 3 cm. The mean 2cc dose to the rectum, sigmoid, small bowel, and bladder were 5.7, 4.7, 4.0, and 5.6 Gy, respectively. Bladder volume ranged from 67−797 cc. Assuming minimal interfraction organ variation, the equivalent dose in 2 Gy/fraction was extrapolated from data and may be near or beyond organ tolerance for rectum, sigmoid, and small bowel in some cases. Spearman correlation found that increased bladder volume was not associated with adjacent organs at risk dose but may be associated with a trend ($p = 0.06$) toward increased bladder dose (R = 0.30).

CONCLUSIONS: This study describes the dose received by adjacent critical structures during vaginal vault HDR brachytherapy. This is important information for documentation in the rare setting of treatment-related toxicity or recurrence. Bladder volume was not associated with dose to adjacent organs.

Keywords: Brachytherapy; Dosimetry; Vaginal vault; Endometrial cancer

Introduction

Endometrial cancer arises from the lining of the uterus and is the most common gynecologic malignancy in developed countries (1). The mainstay of staging and treatment is surgery (2). Adjuvant radiotherapy, which may be in the form of brachytherapy, is indicated to reduce the risk of recurrence when certain risk factors are present, including advanced age, high grade, and greater depth of myometrial invasion (3).

Adjacent organs receive radiation during brachytherapy. Although low, vaginal vault brachytherapy is not without potential side effects from adjacent organ dose. Literature evaluating the efficacy of brachytherapy found a 12.6% rate of European Organization for Research and Treatment of Cancer−Radiation Therapy Oncology Group Grade 1 and 2 gastrointestinal side effects and a <1% rate of late Grade 3 complications (3). The American Brachytherapy Consensus guidelines recommend that dose to adjacent organs be documented but the clinical implications of recording dose and compliance with appropriate dose constraints are unclear in the setting of vaginal vault brachytherapy (4). Dose documentation may be useful in situations when a patient develops toxicity from treatment or if pelvic irradiation is required in the future for relapse or other malignancy.

Received 25 May 2013; received in revised form 15 September 2013; accepted 23 September 2013.

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1538-4721/$ - see front matter
http://dx.doi.org/10.1016/j.brachy.2013.09.007

The objective of this study was to evaluate dose to organs at risk (OARs) during cylinder-based, vaginal vault high-dose-rate (HDR) brachytherapy following hysterectomy for cancer of the endometrium. The effect of bladder volume on adjacent organ dose was also investigated.

Methods and materials

Patients who received vaginal vault cylinder HDR brachytherapy at the British Columbia Cancer Agency Vancouver Centre between January 1st, 2009, and January 31st, 2012, were identified. The time frame was chosen based on the timing of the introduction of CT simulation for treatment verification and planning at the center. Eligible subjects were those who had a CT simulation scan of the pelvis following initial cylinder insertion but before treatment.

The largest cylinder diameter tolerable by the patient was used to spare adjacent tissue by exploiting the inverse-square law. In addition, using the largest tolerable cylinder size reduced air gaps between the cylinder and vaginal mucosa. Although there is no protocol regarding cylinder angle, it is clinical practice that the cranial end of the cylinder be halfway between the sacrum and anterior abdominal wall. The cylinder was held in position with a table clamp. A CT scan was obtained with the cylinder in situ before the first treatment. The cylinder used was compatible with the CT simulator to minimize any image distortion. Patients were asked to empty their bowel and then maintain a full bladder for the CT scan and subsequent brachytherapy treatment. Although bladder filling is not standardized with catheterization, patients are instructed to drink 750 mL 30–45 minutes before each brachytherapy procedure. Radiation treatment consisted of a single Iridium-192 source in a vaginal cylinder using an afterloading technique. A total dose of 21 Gy in three fractions over 1 week was prescribed at 0.5 cm from the external surface of the cylinder.

CT scans were reviewed. A single physician, using a standard contouring template, contoured the bladder, rectum, sigmoid, and small bowel (OARs). The bladder was defined as the whole organ, as contoured along the external wall; the most inferior contour was the last slice where urine was seen. The rectum was contoured from the ischial tuberosities (or lowest slice inferiorly on the CT scan) to the sigmoid flexure. The sigmoid contours extended from the sigmoid flexure to 2 cm superior to the vaginal vault (or most superior slice on the CT scan). The small bowel loops were contoured from most inferior seen to 2 cm superior to the vaginal vault (or most superior slice on the CT scan).

Standardized treatment plans were designed to treat the upper vagina. A 4 cm treatment length was measured from 0.5 cm from the tip of the cylinder (superiorly) to where the 100% isodose line intersected the cylinder (inferiorly). Brachytherapy consisted of a single Iridium-192 source with variable dwell times and positions. Plans were not computer optimized. Dwell times were entered manually by physicists and, with input from the radiation oncologist, dwell times were adjusted to obtain the desired isodose distribution. The dose prescription was 21 Gy in three fractions to a 0.5 cm depth over 1 week duration. The Eclipse treatment planning system (Varian Medical Systems Inc, Palo Alto, CA) was used to calculate dose to contoured structures and generate dose–volume histograms (DVHs). Doses to 2cc (D_{2cc}), 1cc (D_{1cc}), and 0.1cc ($D_{0.1cc}$) of various OARs were abstracted from DVHs. The mean, median, and range of doses were calculated for D_{2cc} of various organs. Assuming that the dosimetry obtained from the initial planning CT scan and treatment stayed the same for the subsequent two treatments, a total dose each OAR received could be generated. Using an alpha/beta (a/b) of 3, equivalent dose in 2 Gy fractions ($EQD2 = D [d + (a/b)]/[2 + (a/b)]$) was derived for the upper OAR dose range and compared with EQD2 published for radical cervical brachytherapy.

Data were analyzed using SPSS, version 17.0 (SPSS, Chicago, IL). Descriptive statistics were applied. The Research Ethics Board of the University of British Columbia approved the study.

Table 1
Organs at risk volumes

Organ at risk	Mean volume (cc)	Volume range (cc)
Rectum	79	27–208
Sigmoid[a]	73	5–217
Small bowel[b]	136	3–314
Bladder	234	67–797

[a] One patient had no sigmoid for contouring on CT scan.
[b] Five patients had no small bowel for contouring on CT scan.

Results

Among the 173 women with endometrial cancer treated with vaginal vault HDR brachytherapy during the study era, 41 had a CT scan with the cylinder in place and were the study subjects. These 41 patients were treated by one radiation oncologist who, in the study era, was performing routine CT simulation scans as part of their clinical practice, whereas other treating physicians were not. The median age was 62 years (range, 38–80 years). The median cylinder diameter was 3.0 cm (range, 2.0–3.5 cm).

Contoured OARs' volumes varied substantially (Table 1). In particular, there was a large range of bladder volumes (67–797 cc) with a mean volume of 234 cc.

D_{2cc}, D_{1cc}, and $D_{0.1cc}$ of various OARs were abstracted from DVHs. The mean, median, and range of these doses are shown in Table 2. The distribution of OAR doses is illustrated in Fig. 1.

Based on data suggesting that OAR dosimetry does not vary significantly between fractions (5), the total dose each OAR received was calculated. Using this, equivalent dose in 2 Gy fractions was derived for the upper and average