ELSEVIER

BRACHYTHERAPY

Brachytherapy 17 (2018) 667–672

Gynecologic Oncology

Comparison of computed tomography with magnetic resonance imaging for imaging-based clinical target volume contours in cervical cancer brachytherapy

Agnieszka Zolciak-Siwinska[1,*], Adam Kowalczyk[2], Katarzyna Sikorska[2], Michal Bijok[2], Wojciech Michalski[3], Ewelina Gruszczynska[2]

[1]*Department of Brachytherapy, The Maria Skłodowska-Curie Memorial Cancer Center and Institute of Oncology, Warsaw, Poland*
[2]*Department of Medical Physics, The Maria Skłodowska-Curie Memorial Cancer Center and Institute of Oncology, Warsaw, Poland*
[3]*Department of Clinical Trials and Biostatistics, The Maria Skłodowska-Curie Memorial Cancer Center and Institute of Oncology, Warsaw, Poland*

ABSTRACT

PURPOSE: To compare CT- and MRI-based brachytherapy (BT) target volumes for patients with advanced cervical cancer so as to identify those who benefit most from MRI-based planning. We also studied how the natural mobility of the organ at risks (OARs) affects the given doses.

METHODS AND MATERIALS: Subjects were 60 patients with International Federation of Gynecology and Obstetrics (FIGO) Stage IB–IVA cervical cancer. The CT high-risk clinical target volume (HR-CTV) was first delineated, then the MRI HR-CTV, with volume discrepancies calculated by subtraction. The DICE coefficient (DC) of similarity was calculated from a superimposition of the volumes. Maximum doses delivered to D_{2cc} of OARs in CT and MRI plans were compared; the effect of time on the natural mobility was analyzed.

RESULTS: The mean HR-CTVs and the maximum doses given to OARs in CT- and MRI-based planes were similar. Multivariate analysis showed that deep infiltration affecting the uterine corpus and bowel loops adjacent to the cervix were the factors significantly impacting on the volume discrepancy between CT and MRI HR-CTV ($p = 0.001$, $p = 0.045$) and on the DC ($p = 0.005$, $p = 0.028$). Univariate analysis demonstrated that the FIGO stage had a significant impact on DC ($p = 0.022$). Patients with bowel loops adjacent to the cervix had lower body mass indices ($p = 0.003$). The median difference between the doses given in CT- and MRI-based plans, caused by mobility, were 0.5 Gy, 0.3 Gy, and 0.45 Gy per fraction for the rectum, bladder and sigmoid, respectively. No correlation of observed uncertainties and time between image acquisitions was detected.

CONCLUSIONS: CT- or MRI-based scans at BT are adequate for OAR dose–volume histograms analysis. Cervical cancer patients with deep infiltration affecting the uterine corpus, a low body mass index with bowel loops adjacent to the cervix and an FIGO Stage III–IVA benefit most from MRI-based planning of BT.

Key words: HDR brachytherapy; CT-based planning; MRI-based planning; Cervical cancer

Introduction

Locally advanced cervical cancer patients require treatment with external beam radiation therapy (EBRT), concomitant cisplatin-based chemotherapy, and subsequent brachytherapy (BT). MRI with image-guided adaptive cervical cancer BT is a gold standard. Whenever access proves difficult, CT BT planning provides useful information, such as applicator position or delineating the organ at risk (OAR), which is comparable with MRI (1). MRI is superior to CT for soft tissue visualization. After an MRI facility became accessible to our Brachytherapy Department in Warsaw, we conducted a prospective study aimed at adopting recommendations on MRI-based planning for high-dose-rate (HDR) BT into our routine treatment (2, 3). We compared the CT- and MRI-based BT target volumes to

Received 30 January 2018; received in revised form 4 April 2018; accepted 4 April 2018.

Conflict of interest: The authors report no proprietary or commercial interest in any product mentioned or concept discussed in this article.

* Corresponding author. Roentgen Street 5, 02-781 Warsaw, Poland. Tel.: +48506063633; fax: +48225463151.

E-mail address: agnieszka.zolciak@wp.pl (A. Zolciak-Siwinska).

1538-4721/$ - see front matter
https://doi.org/10.1016/j.brachy.2018.04.004

identify those patients who might benefit most from MRI-based planning. During BT HDR treatment planning, differences in the position of OAR in relation to the target in both CT and MRI images were observed. As a further aim, it was decided to study how the natural mobility of OAR that occurs while waiting for treatment affects the changes in the doses given to these organs.

Methods and materials

During 2014–2017, 60 patients with locally advanced cervical cancer International Federation of Gynecology and Obstetrics (FIGO) Stage IB–IVA were enrolled in a prospective study. This started in 2012 gaining experience in proper contouring, matching of these two imaging modalities, accurate visualization of the applicator (especially when needles are used), and achieving good quality MRI images. After treating first group of 13 patients, another group of 60 consecutive patients was enrolled into our study. Patients were treated with curative intent. The protocol, consent procedure and study were approved by the local medical authority. Because only one weekly MRI study per BT patient was possible, we tried to accrue more advanced patients or those with poor response for irradiation after definitive radiochemotherapy. Initial locoregional staging involved a clinical examination, abdominal and pelvic CT, chest X-ray, and biopsy-proven cervical cancer. Pretreatment MRI was not performed in 83% of patients. All MRI analysis was thereby performed only during the first fraction of BT HDR. Patients were staged according to FIGO criteria: 2 (3.3%) IB2, 25 (41.7%) II, 31 (51.7%) III, and 2 (3.3%) IVA. Fifty-three (88.3%) patients had squamous cell cancer, whereas seven (11.7%) had other types of cancer. Nine (15%) patients had hydronephrosis.

Fifty-eight patients underwent concomitant chemotherapy with 40 mg/m^2 weekly cisplatin. Patients were planned by the Oncentra External and Varian Eclipse Treatment Planning System according to International Commission on Radiation Units and Measurements 50 and 62 protocols using the 3D conformal technique or intensity-modulated radiation therapy (IMRT) and were treated with high megavoltage photons from a linear accelerator (×6 and ×15 MV). EBRT was administered in daily fractions of 1.8–2 Gy (Gray) to total doses of up to 45–50.4 Gy in the elective area and approximately 60 Gy to enlarged lymph nodes. The standard dose for most of the patients was 46 Gy delivered in 23 fractions. BT began immediately after EBRT. Oncentra Brachy System (Nucletron) was used for BT treatment planning system (TPS). HDR BT was delivered using an Ir-192 source (10 Ci nominal activity) from Nucletron devices (Microselectron). The planning aim was to deliver four fractions of 7.5 Gy to the high-risk clinical target volume (HR-CTV) according to Group European de Curietherapie-European Society for Therapeutic Radiology and Oncology recommendations ($D_{90} \geq 85$ Gy equivalent dose, $\alpha/\beta = 10$). All plans for treatment and for the purposes of this study were MRI based. CT scans were performed for the purpose of the trial. The CT images (SOMATOM Emotion Duo Siemens) at BT were generated in 2-mm slice intervals from the iliac crest to the ischial tuberosities. The first BT fraction consisted of inserting the applicator under general anesthesia and performing CT in the operating room, after which 16–162 min (median 57 min) later MRI was performed. BT-MRI scans were acquired on a 1.5 T scanner GE Signa HD. MRI was performed with a pelvic surface coil. The uterus with an applicator in place, vaginal packing, and bladder balloon were displayed as sagittal, axial, and coronal T2-weighted images. The section thickness was 4–5 mm with no intersection gap. Axial images were obtained from the level above the uterine fundus to the inferior border of the symphysis pubis below the tumor, whereas sagittal images were obtained between the internal obturator muscles and coronal images included the tumor, cervix, corpus uteri, parametria, and vagina.

All patients were examined and treated by the same radiation oncologist. After familiarization with the patient's history, a gynecological examination was conducted after EBRT before the first fraction of BT. The physician delineated the HR-CTV and the OARs (i.e., rectum, bladder, and sigmoid) using firstly CT imaging and then independently, the MRI. The contouring investigator was blinded to the MRI while contouring the CT HR-CTV. The MRI HR-CTV was determined by a radiation oncologist to be a tumor in the first BT fraction as represented by a high-signal-intensity mass on MRI with the entire cervix. The CT HR-CTV was defined in a cervix with an average height of approximately 3 cm. HR-CTV and the whole of the OAR structures were delineated on a TPS according to recommendations (1–3). Contours of the rectum began from the anus to the sigmoid flexure. The sigmoid was considered to begin at the level of the rectosigmoid flexure, located on the length of 2–3 cm along the uterus. The bladder ended at the beginning of the urethra. No contrast was used in this study. The CT and MRI volumes were fused using the anatomy-modeling tool of TPS. Manual fusion using landmarks was applied including the tip of the tandem, center of the ring, Utrecht ovoids, or the tip of the interstitial needles.

The patient treatment plans were applied using CT and MRI images to assess the dose delivered to D_{2cc} of the bladder, sigmoid, and rectum calculated from the cumulative dose volume histograms (DVHs) and were independently analyzed for both plans. The CT HR-CTV and MRI HR-CTV were then compared. Volumes in cubic centimeters were obtained for each HR-CTV contour, and their volume discrepancies were calculated by subtracting the MRI HR-CTV from the CT HR-CTV. The CT HR-CTV and MRI HR-CTV were then superimposed on each another, and the DICE coefficient (DC) of similarity was calculated using the formula DC (A, B) = 2 (A$\cap$B):(A + B); where A represents the CT HR-CTV contour, B represents the MRI HR-