Medical Dosimetry ■■ (2017) ■■–■■

Medical Dosimetry

journal homepage: www.meddos.org

Dosimetry Contribution:

Comparison between DVH-based doses and ICRU point-based doses to the rectum and the bladder using CT-based high-dose rate brachytherapy to the cervix

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ARTICLE INFO

Article history:
Received 16 June 2017
Received in revised form 9 October 2017
Accepted 16 October 2017

Keywords:
ICRU point
Bladder
Rectum
Volumetric dose

ABSTRACT

Traditionally, doses to the bladder and the rectum were quantified using the bladder and rectal reference points defined by the International Commission on Radiation Units and Measurements (ICRU) in Report No. 38. In this study, we compared the 0.1-, 1.0-, 2.0-cc doses to the bladder and the rectum with the corresponding ICRU point doses using computed tomography (CT)-based planning in the intracavitary brachytherapy of carcinoma of the cervix. CT datasets of 136 consecutive intracavitary brachytherapy insertions between January and May 2015 were analyzed. The bladder and the rectum were contoured on consecutive CT slices as per Groupe Europeen de Curietherapie and the European Socie Ty for Radiotherapy and Oncology recommendations. Dose volume histograms were generated and doses of 0.1, 1.0, and 2.0 cc to the bladder and the rectum were recorded. ICRU bladder and rectal points were identified in the treatment plan. Mean doses of 0.1, 1.0, and 2.0 cc to the bladder was found to be 2.02, 1.57, and 1.35 times the ICRU point dose, respectively. The maximum dose received by the bladder was found to be 5.83 times the average ICRU point dose. Mean doses of 0.1, 1.0, and 2.0 cc to the rectum were found to be 1.12, 0.90, and 0.78 times the ICRU rectal point dose, respectively. The maximum dose received by the rectum was 4.79 times the average ICRU point dose. The Pearson correlation coefficient value (r) was found to be 0.639 for D2cc and ICRU bladder point values. The Pearson correlation coefficient value was found to be 0.752 for D2cc and ICRU rectal point values. Our results show that the ICRU bladder points underestimated the dose to the bladder, which is in agreement with other studies. ICRU rectal point doses were higher than the corresponding D2cc doses. However, there was a good correlation between D2cc and ICRU point doses for both the bladder and the rectum.

Introduction

Intracavitary brachytherapy is an integral part of the management of carcinoma of the cervix. It is possible to achieve a high therapeutic index with brachytherapy by delivering

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https://doi.org/10.1016/j.meddos.2017.10.005

a high dose to the tumor and by sparing adjacent organs like the bladder and the rectum.[1] Traditionally, the doses to the bladder and the rectum were quantified using the bladder and rectal reference points defined by the International Commission on Radiation Units and Measurements (ICRU) in Report No. 38.[2]

The ICRU bladder point is located on a radiograph by inserting a Foley catheter and the Foley balloon is filled with a 7-cm^3 radiopaque fluid. The catheter is pulled down to bring the balloon against the urethra. The bladder reference point is at the center of the balloon on an anteroposterior radiograph. On the lateral radiograph, the bladder reference point is located on an anteroposterior line drawn through the center of the balloon, at the posterior surface.

The ICRU rectal reference point is located at the lower end of intrauterine source or the middle of the intravaginal source on an anteroposterior radiograph. On a lateral radiograph, an anteroposterior line is drawn through from the lower end of intrauterine source and the rectal reference point is located 5 mm behind the posterior vaginal wall on this line.

With the advent of volumetric imaging and 3-dimensional planning in intracavitary brachytherapy, doses to the organs at risk (OARs), namely, the bladder, the rectum, and the sigmoid are quantified using dose-volume histograms. The recommendations for dose reporting for 3-dimensional image-based brachytherapy have been published by the GEC ESTRO (Groupe Europeen de Curietherapie and the European Socie Ty for Radiotherapy and Oncology) group.[3,4] The acceptable isoequivalent dose limits to the bladder and the rectum are 90 and 75 Gy, respectively, which include doses from teletherapy and brachytherapy.

Although there is widespread use of ICRU point-based dose reporting to the OARs in intracavitary brachytherapy, one cannot deny the inherent weakness of ICRU-based points in predicting the late toxicities.[5,6] Point-based dose reporting does not properly characterize the absorbed dose heterogeneity in the organ walls. Certain segments of the OARs, namely, the posterior recto sigmoid walls and the anterosuperior bladder walls, receive much lower doses. Hence, it is recommended to report the dose-volume values in the high-dose region. The minimum doses to 0.1-, 1.0-, and 2.0-cc volumes of OARs that receive the maximum dose are represented by D0.1cc, D1cc, and D2cc, respectively.

The differences between volumetric doses and point-based doses to the bladder and the rectum have been reported earlier in several studies.[7-9] The best correlation was found between the D2cc dose and ICRU point doses.[10-12] In the present study, we compared the 0.1-, 1.0-, 2.0-cc doses to the bladder and the rectum with the corresponding ICRU point doses using CT-based planning.

Methods and Materials

Patient selection

CT datasets of 136 consecutive intracavitary brachytherapy insertions between January and May 2015 were analyzed. The total external beam radiotherapy dose was 50 Gy to the whole pelvis. The patients also received weekly doses of cisplatin 40 mg/m^2.

Technique of intracavitary application

The procedure of intracavitary insertion was performed under general anesthesia in the operating room. The bladder was left to drain by catheterizing the bladder using a Foley catheter. The Foley bulb was filled with 3 mL of iodinated contrast and 4 mL of normal saline to localize the bladder neck. A soap and water enema was given before the procedure for all patients for adequate rectal preparation. We had 2 types of applicators in our department, namely, a CT magnetic resonance-compatible tandem ovoid applicator and a metallic tandem ring applicator. Applicator preference was based on the physician's choice. After securing the applicator in its position, anterior and posterior gauze vaginal packing was done. A rectal retractor was used for posterior vaginal packing for the tandem ring applicators.

Simulation. After the procedure, the patients were shifted to the CT simulator suite (Somatom, Siemens, Erlangen, Germany). CT scans of the pelvis were taken with the patient in the supine position. The slice thickness used was 3 mm. The acquired images were digitally exported to the Oncentra treatment planning system.

Contouring and planning. The bladder and the rectum were contoured by the radiation oncologist on the consecutive CT slices as per GEC ESTRO recommendations.[3,4] The outer wall of the bladder was contoured from the base to the dome. The outer wall of the rectum was contoured from the level of ischial tuberosities inferiorly to the rectosigmoid junction superiorly. Catheter reconstruction was done. A standard loading pattern of dwell points were activated and point A and point B doses were defined. The dose was normalized to point A. A dose of 8 Gy was prescribed to point A. ^{192}Ir source was used to deliver high-dose rate intracavitary brachytherapy. Manual dose optimization was done when necessary to minimize doses to OARs.

Dose volume histograms were generated and doses of 0.1, 1.0, and 2.0 cc to the bladder and the rectum were recorded. ICRU bladder and rectal points were inserted into the treatment plan. The rectal point was placed on the anterior rectal wall at the level of the lower uterine source on the tandem, on an anteroposterior line drawn through the tandem on the sagittal view. The ICRU bladder point was