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Impact of delineation uncertainties on dose to organs at risk in CT-guided intracavitary brachytherapy

Frances K. Duane[1,*], Brian Langan[2], Charles Gillham[1], Lorraine Walsh[1], Guhan Rangaswamy[1], Ciara Lyons[1], Mary Dunne[3], Christopher Walker[2], Orla McArdle[1]

[1]*Department of Radiation Oncology, St. Luke's Radiation Oncology Network, Rathgar, Dublin, Republic of Ireland*
[2]*Department of Medical Physics, St. Luke's Radiation Oncology Network, Rathgar, Dublin, Republic of Ireland*
[3]*The Clinical Trials Unit, St. Luke's Radiation Oncology Network, Rathgar, Dublin, Republic of Ireland*

ABSTRACT

PURPOSE: This study quantifies the inter- and intraobserver variations in contouring the organs at risk (OARs) in CT-guided brachytherapy (BT) for the treatment of cervical carcinoma. The dosimetric consequences are reported in accordance with the current Gynecological Groupe Européen de Curiethérapie/European Society for Therapeutic Radiology and Oncology guidelines.

METHODS AND MATERIALS: A CT planning study of 8 consecutive patients undergoing image-guided BT was conducted. The bladder, rectum, and sigmoid were contoured by five blinded observers on two identical anonymized scans of each patient. This provided 80 data sets for analysis. Dosimetric parameters analyzed were $D_{0.1\ cc}$, $D_{1\ cc}$, and $D_{2\ cc}$. The mean volume of each OAR was calculated. These endpoints were compared between and within the observers. The CT image sets from all patients were evaluated qualitatively.

RESULTS: The interobserver coefficient of variation for reported $D_{2\ cc}$ was 13.2% for the bladder, 9% for the rectum, and 19.9% for the sigmoid colon. Unlike the variation seen in bladder and rectal contours, which differed largely in localization of the organ walls on individual slices, sigmoid colon contours demonstrated large differences in anatomic interpretation.

CONCLUSIONS: Variation in recorded $D_{2\ cc}$ to the bladder and rectum is comparable with the previous published results. Inter- and intraphysician variations in reported $D_{2\ cc}$ is high for the sigmoid colon, reflecting varying interpretation of sigmoid colon anatomy. Variation in delineation of the OARs may influence treatment optimization and is a potential source of uncertainty in the image-guided BT planning and delivery process.

Keywords: Cervical cancer; Organs at risk; Image-guided brachytherapy; Delineation variation

Introduction

Combined chemoradiation is the standard of care for the radical treatment of locally advanced cervix carcinoma. The additional radiation dose delivered by intracavitary brachytherapy (BT) after external beam radiotherapy (EBRT) to the whole pelvis is critical in curing patients (1, 2). Image-guided BT (IGBT) is fast becoming a standard practice with more centers now routinely performing MRI- or CT-guided BT (3, 4). Normal tissue toxicity remains a limiting factor in the radical treatment of these patients. Advancing technology allows treatment plan optimization and provides the potential to improve the therapeutic window by adapting the BT dose on an individual basis.

Contouring the organs at risk (OARs) is an essential step in the IGBT process. Given the steep dose gradient of the BT dose distribution, it is important to accurately outline OAR boundaries close to the BT source to accurately record the dose received by each OAR and allow optimal treatment planning. Most physicians reporting dose to OARs using CT-based postinsertion imaging delineate the bladder and rectum, whereas less than half also contour the sigmoid colon and small bowel (4).

Much of the data available regarding dose to OARs are based on two-dimensional (2D) BT planning, using the

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* Corresponding author. Department of Radiation Oncology, St. Luke's Radiation Oncology Network, Highfield Road, Rathgar, Dublin 6, Ireland. Tel.: +353-1-406-5000; fax: +353-1-406-5222.

E-mail address: fran.duane@ctsu.ox.ac.uk (F.K. Duane).

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bladder and rectal dose reference points as described by the International Commission on Radiation Units (ICRU) Report 38 (5). With the advent of 3D planning for intracavitary BT, the working group for gynecologic BT of the Groupe Européen de Curiethérapie/European Society for Therapeutic Radiology and Oncology (GYN GEC-ESTRO) has provided guidelines with a view to establishing a common language for reporting of dose to both the OARs and the high-risk clinical target volume (HRCTV) and intermediate-risk CTV. For the OARs, GEC-ESTRO II recommends the reporting of the minimum dose absorbed in the most irradiated tissue volume (0.1, 1, and 2 cm^3) adjacent to the sources, denoted $D_{0.1\ cc}$, $D_{1\ cc}$, and $D_{2\ cc}$, respectively. However, reliable OAR dose constraints remain to be established (6). As reported by Georg *et al.* (7, 8), total $D_{1\ cc}$ and $D_{2\ cc}$ are predictive of late rectal and bladder toxicity. For the HRCTV, D_{90} (the isodose that includes 90% of the target) is associated with local control (9). Individual treatment plan optimization aims to achieve adequate coverage of HRCTV and intermediate-risk CTV with acceptable doses to OARs.

It is well known that the interphysician variation in delineation of CTVs is a significant source of systematic error in the radiotherapy treatment process. In the setting of gynecologic BT, acceptable interobserver variability in contouring the HRCTV has been demonstrated (10–14). However, there are little data available on the impact of delineation error on the doses to OARs. One study has shown that the absorbed dose in the bladder and rectum can be determined with an accuracy of approximately 10% as a result of the interobserver delineation variability (15). Recently, Hellebust *et al.* (16) reported that the mean relative standard deviation (SD) for $D_{2\ cc}$ for the bladder and rectum was 5–8%, whereas that for the sigmoid colon was 11%.

Motivated by the above factors, our study set out to examine the inter- and intraobserver variabilities in the delineation of bladder, rectum, and sigmoid volumes for IGBT for cervical cancer. The impact of delineation uncertainty on the recorded dose to the OARs is evaluated. The dose to each OAR is recorded based on a single fraction of IGBT and the total dose to each OAR is then estimated assuming that each patient received full-dose EBRT and completed three identical BT fractions.

Methods and materials

This is a monoinstitutional prospective CT planning study whereby OARs were contoured on 16 image sets by five observers. The 16 image sets included two identical, anonymized CT scans from 8 patients referred for BT. This yielded a total of 80 scans for analysis.

Patient selection

The CT scans included those of 8 consecutive patients referred for BT as part of radical treatment for locally advanced cervical cancer. All patients had biopsy-proven squamous cell carcinoma of the cervix and were undergoing radical treatment with chemoradiation. Patients with a prosthetic hip, prior abdominal surgery, or other abdominal malignancy were excluded.

Patient preparation

All patients underwent spinal anesthesia in theater. A Foley catheter was inserted. A ring and tandem applicator was placed with a rectal paddle. An external fixator was used to secure the applicator in place. The urinary catheter was allowed to drain freely in an attempt to achieve a consistently empty bladder.

Treatment planning

The CT scans were acquired with a slice thickness of 2.5 mm from L4/L5 superiorly to below the perineum. Bladder contrast (25 mL) was instilled at the time of CT to facilitate identification of the bladder wall. Images were transferred to the treatment planning system (Oncentra Masterplan v3.3; Nucletron; Elekta AB, Stockholm, Sweden). Observers included five senior medical members of the gynecology radiation oncology team, all blinded to patient case details. The observers were not informed that the 16 cases for contouring were eight duplicated scans. The 16 scans were ordered randomly to avoid a pair of duplicated scans being contoured one after the other. The bladder, rectum, and sigmoid were outlined according to a standard delineation protocol. The contrast within the bladder was outlined using an automatic contouring tool such that the resulting volume was 25 mL. The entire bladder was then manually contoured from the urethrovesical junction to the apex of the bladder, using the contrast structure as a guideline in defining the posterior bladder wall. The entire rectum was contoured from the anorectum to the rectosigmoid junction. The sigmoid was contoured from the rectosigmoid junction to 1 cm above the tip of the central tandem. In all cases, the outer organ contours were drawn as opposed to the organ walls.

Our standard treatment schedule includes 50.4 Gy in 28 fractions of EBRT to the primary and regional lymph nodes followed by three BT treatments of 7 Gy each, using an ^{192}Ir source. At BT planning, sources are initially loaded in the tandem and laterally in the ring with the dose prescribed to Point A. An individual plan is then optimized using a graphical optimization tool to achieve sufficient HRCTV coverage while sparing OAR structures if possible as described below. The clinical plan thus achieved was then superimposed on both scans for that patient in the study. The HRCTV was neither recontoured on all CT scans in the study nor were the plans reoptimized based on the OAR contours drawn in the study.

The dose–volume histograms (DVHs) generated were used to evaluate the D_{90} for the target and the $D_{2\ cc}$ for the OARs. Total doses for each parameter were estimated