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Brachytherapy 12 (2013) 156–161

BRACHYTHERAPY

Evaluation of quality indices during multifractionated pelvic interstitial brachytherapy for cervical cancer

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ABSTRACT

PURPOSE: To evaluate the impact of needle displacements on quality indices during multifractionated pelvic interstitial brachytherapy (IBT).

METHODS AND MATERIALS: Patients undergoing boost IBT were included. Postprocedure planning and verification CT scans were obtained. Three-dimensional needle displacements were measured. Clinical target volume and organ at risk were delineated. Coverage index (CI), dose homogeneity index (DHI), dose nonuniformity ratio (DNR), V_{170}, V_{200}, V_{250}, and dose received by 2 cc of organs at risk were obtained at baseline. The displacements were simulated by shifting dwell positions, and dose point optimized and graphically optimized plans were generated. Wilcoxon test determined statistical significance of differences in quality indices.

RESULTS: Fifteen patients were included and received five fractions of IBT over 3 days. Maximum displacements were observed in caudal direction (average, 19.1 mm). At baseline, CI of 0.94 (range, 0.91–0.99), DHI of 0.90 (range, 0.80–0.94), and DNR of 0.10 (range, 0.05–0.10) were attained. The CI, DHI, and DNR in Day 3 dose point optimized plans were 0.76 (range, 0.4–0.99), 0.76 (range, 0.40–0.94), and 0.23 (range, 0.06–0.64), respectively. The difference in CI, DHI, and DNR between baseline and Day 3 dose point optimized plans was statistically significant ($p = 0.002$, 0.007, and 0.001, respectively). Day 3 graphically optimized plans were superior to Day 3 dose point optimized plans (CI, 0.82 vs. 0.76; $p = 0.01$). Graphically optimized could however improve CI without compromise in DHI, DNR, V_{170}, V_{200}, and V_{250} only in patients wherein caudal displacements ≤15 mm.

CONCLUSIONS: Caudal needle displacements during multifractionated IBT cause significant deterioration of quality indices. Replanning with graphically optimized and/or needle repositioning maybe required for maintaining the quality of IBT.

Keywords: Cervix; Interstitial; Brachytherapy; Quality indices; MR-guided

Introduction

The American Brachytherapy Society recommends pelvic interstitial brachytherapy (IBT) in patients, wherein intracavitary brachytherapy is expected to result in a suboptimal dose distribution (1). The integration of template-based IBT with external beam radiotherapy allows dose escalation to residual gross target volume and improves local control (2, 3). Quality of IBT implants has been previously reported to be an important predictive factor for local control and late toxicity (4) and can be defined for each interstitial implant using coverage index (CI), dose homogeneity index (DHI), and dose nonuniformity ratio (DNR). Quality assurance study undertaken at our institute in patients undergoing pelvic IBT for vault cancers demonstrated that clinically significant caudal needle displacements may occur during the course of multifractionated IBT (5). The adverse impact of interfraction catheter migration on brachytherapy quality indices has been previously

Received 2 May 2012; received in revised form 31 May 2012; accepted 22 June 2012.

Grant or other financial support: None.

Conflicts of interest notification: Actual or potential conflicts of interest do not exist.

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1538-4721/$ - see front matter
http://dx.doi.org/10.1016/j.brachy.2012.06.003

reported for prostate and breast brachytherapy (6, 7). However, the correlation of needle displacements and brachytherapy quality indices has not been systematically evaluated for patients undergoing multifractionated pelvic IBT for gynecological cancers. The present study was undertaken to evaluate the impact of craniocaudal (CC) needle displacements on quality indices of pelvic IBT.

Methods and materials

Patients with postoperative vault recurrences and scheduled to undergo boost IBT after concomitant chemoradiation were included. All patients underwent baseline MRI for tumor mapping. Subsequently, all patients underwent CT/MRI-based radiotherapy planning. All patients received 50 Gy per 25 fractions over 5 weeks to the planned target volume along with concomitant cisplatin 40 mg/m^2. Within a week of completing chemoradiation, all patients underwent response assessment. This included clinical examination and pelvic MRI. Subsequently, all were scheduled for pelvic IBT.

IBT procedure

All implants were performed under spinal anesthesia by radiation oncologists with 6 or more years of experience using Martinez Universal Perineal Interstitial Template. Baseline clinical examination and MRI findings were used to decide the clinical target volume (CTV). Implantation procedure followed methods previously published (5). In brief, all the needles were implanted transperineally such that the needle tips are positioned 2–2.5 cm cranial to the CTV. All the needles were secured with the help of screw and plate assembly. The whole assembly was sutured to the perineal skin to prevent caudal displacement.

Brachytherapy planning

Brachytherapy planning CT scans were obtained immediately after recovery from anesthesia (i.e., 1.5–3 h after the procedure). CT scan was performed with patients in supine position and arms on the chest. Imaged volume encompassed the entire pelvis and upper third of femur at an interslice interval of 3 mm on Somatom version 4 (Siemens AG, Hamburg, Germany). These image sets were transferred to Oncentra Brachytherapy version 4.1 (Nucletron BV, Veenendaal, The Netherlands) for planning. CTV was delineated on CT images using information from baseline and after chemoradiation MRI and clinical findings. Organ at risk (OAR) contouring included delineation of rectum, bladder, small bowel, urethra, and sigmoid colon. Dose point optimized plans were generated for all patients. As an earlier study from our group demonstrated superiority of graphical optimization over dose point optimization (8); hence, graphically optimized plans were generated for each patient. CI (volume of target encompassed by 100% of isodose), DHI (volume of target receiving 100% of dose – volume of target receiving 150% of dose/volume receiving 100% of dose), and DNR (volume of target receiving 150% of isodose/volume of target receiving 100% of dose) (9) were calculated. In addition, dose received by 2 cc of OARs was also calculated. In addition, volume receiving 170%, 200%, and 250% of isodose was also calculated.

Needle displacements

All patients underwent daily quality assurance CT scans, and needle displacements were calculated with a methodology described in a previous publication (5). Average displacement was recorded for all the needles for each day on per patient basis. For each patient, the CC needle displacement was calculated between Days 1 and 3.

Brachytherapy quality indices

As our previous study (5) demonstrated clinically significant displacements in only CC direction, we evaluated the impact of CC displacements on brachytherapy indices. Day 1 CTV and OAR contours served as reference contours. To evaluate the dosimetric impact of CC displacements, dwell positions were readjusted, and all sources were shifted cranially or caudally equivalent to the calculated needle displacement such that the superior most source position simulated the extent of needle displacement on Day 3. New dose points were defined along the revised source positions, and dose point optimized plans were generated. CI, DHI, DNR, and OAR doses (2 cc) were then calculated for Day 3.

Impact of optimization on quality indices

As CC needle displacements could lead to deterioration in CI, we investigated if the use of optimization could improve the brachytherapy quality indices. Our previous work has demonstrated that graphical optimization could improve brachytherapy quality indices (especially CI) over dose point optimization (8); hence, we performed graphical optimization on Day 3 dose point optimized plans. In this, the dose distribution was altered by manually dragging the isodose lines on each individual CT slice on the screen using the mouse. Although graphical optimization allowed for changes in dwell times, no change was allowed for dwell position. CI, DHI, DNR, and 2 cc OAR doses were obtained for Days 2 and 3 graphically optimized plans. As graphical optimization could lead to hot spots, we also calculated volume receiving 170%, 200%, and 250% of prescription isodose and compared it with baseline plans.

Statistical analysis

All statistical analysis was done using the SPSS version 16 (Chicago, IL). The CC needle displacements were summarized as the average of all needles. Wilcoxon test