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Technical notes

Determination of optimal planning target volume margins in patients with gynecological cancer

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ABSTRACT

Purpose: To define optimal planning target volume (PTV) margins for intensity modulated radiotherapy (IMRT) ± knee-heel support (KHS) in patients treated with adjuvant radiotherapy.
Methods: Computed tomography (CT) scans ± KHS of 10 patients were taken before and at 3rd and 5th week of treatment, fused and compared with initial IMRT plans.
Results: A PTV margin of 15 mm in anteroposterior (AP) and superoinferior (SI) directions and 5 mm in lateral directions were found to be adequate without any difference between ± KHS except for the SI shifts in CTV-primary at the 3rd week. Five mm margin for iliac CTV was found to be inadequate in 10–20% of patients in SI directions however when 7 mm margin was given for iliac PTV, it was found to be adequate. For presacral CTV, it was found that the most striking shift of the target volume was in the direction of AP. KHS caused significantly less volume of rectum and bladder in the treated volume.
Conclusions: PTV margin of 15 mm in SI and AP, and 5 mm in lateral directions for CTV-primary were found to be adequate. A minimum of 7 mm PTV margin should be given to iliac CTV. The remarkable shifting in presacral CTV was believed to be due to the unforeseen hip malposition of obese patients. The KHS seems not to provide additional beneficial effect in decreasing the shifts both in CTV-primary and lymphatic, however it may have a beneficial effect of decreasing the OAR volume in PTV margins.

Introduction

Adjuvant radiotherapy (RT) and/or chemotherapy is the standard treatment approach for early stage cervix and endometrial cancer patients with risk factors for developing local or regional relapse after curative surgical resection [1,2]. The main purpose of RT is to provide higher doses to areas having high risk for recurrence while minimizing the dose to surrounding normal critical structures. Bladder, rectum and small intestine are the most relevant dose limiting organs in gynecological cancer patients.

With the implementation of computed tomography (CT)-based planning, it has become possible to make use of new software developments to create fully three-dimensional conformal RT (3DCRT) treatment planning. In the last years intensity modulated RT (IMRT) has been designed and used frequently as a more sophisticated treatment system of 3DCRT. IMRT gives us the ability to produce high-dose distribution in the target volumes while minimizing the dose to critical normal tissues in gynecologic cancers [3–5]. However, due to the steep dose fall off between tumor and surrounding normal tissues every step should be carefully considered throughout IMRT planning and delivery process. Therefore the quality of the delivered dose distribution is more affected by motion, respiration, setup error in IMRT compared with other RT techniques and planning target volume (PTV) should be defined considering these inaccuracies. Due to the high conformality of the treatment, marginal relapses may occur in cases that were treated with inadequate PTV margins. On the other hand, the hot spots near surrounding normal tissue may cause radiation damage in organs at risk (OARs).

In traditional RT planning systems, the patient is simulated with CT simulator once at the beginning of the treatment and treated with the same plan till the end of the treatment. Dose distributions of target volume, OARs, and surrounding normal tissues may change due to loss of weight and organ motions throughout the treatment in addition to the changes of tumor size and location during RT which can lead to decrease in tumor control probability

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and increase the risk of normal tissue toxicity [6–8]. On the other hand, Zhang et al. emphasized that the rotational set up errors were usually neglected in most Radiation Oncology centers which might lead to significant dosimetric changes especially in large target volumes [9].

In recent years, a new concept called adaptive RT has become a new standard of care in various tumor types [10,11]. The definition of adaptive RT is that to adapt the initial treatment plan to patient and tumor specific changes that are unaccounted for in initial plan in order to optimize dose delivery throughout the whole treatment [12]. In this technique, portal images are taken daily during the first week and weekly thereafter, and essential corrections are made inter-fractional and/or intra-fractional.

In this dosimetric study, we aimed to evaluate the changes in dose distributions related to organ motions and weight loss in patients with endometrial or cervical cancer patients who were treated with adjuvant RT after definitive surgery and tried to determine the optimal PTV margin in Turkish patients with gynecological cancer with or without knee-heel support (KHS).

Materials and methods

In this study 10 patients with gynecological cancer treated with adjuvant RT after definitive surgery were included after approval of institutional ethics committee. Three (30%) out of 10 patients were with cervical and seven (70%) patients were with endometrial cancer. All patients with cervical cancer were within normal weight limits with body mass index (BMI) values as below 25. However, 5 out of 7 patients with endometrial carcinoma were considered as overweight with BMI values between 25 and 29.9. One out of 7 patients in this group was considered as obese with BMI value as 35 and the other one as morbid obese with BMI value of 40. The body height of this morbid obese patient was 1.6 m and the weight was 102 kg.

Computed tomography simulation

All patients underwent CT simulation in treatment position with full bladder and empty rectum protocol. All the scans were taken after intravenous contrast injection in supine position both with KHS and without KHS system. Therefore all the patients had at least two CT scans in every CT simulation process. CT simulation was held at the beginning of the RT (pre-RT), at the end of the 3rd week and at the beginning of the 5th week in every patient that led to 6 CT scans for each patient for this study.

Target volume delineation

CT simulation images were transferred to Eclipse treatment planning system (TPS) via DICOM. Primary tumor bed, parametrial tissues, proximal vagina, iliac, obturator, and presacral lymphatics, and OARs were delineated by the same radiation oncologist (M.G.) based on Radiation Therapy Oncology Group (RTOG) consensus guidelines for the delineation of the CTV in the postoperative pelvic RT of endometrial and cervical cancer [13]. In order to create PTV, anteroposterior (AP) and superoinferior (SI) 15 mm, and laterally 5 mm margin was added to CTV-primary including primary tumor bed, parametrial tissues, and proximal vagina. Common iliac, external and internal iliac vessels including obturator and hypogastric branches were delineated starting from aortic bifurcation. In order to create iliac lympatic CTV, 7 mm margin were given to iliac vessels and 5 mm PTV margin was added to iliac PTV formation. Additionally presacral region was delineated as presacral lymphatic CTV till the level S3 vertebra as recommended in RTOG contouring atlas. Presacral PTV was created by giving 5 mm margin to CTV. Rectum, sigmoid colon, bladder, femoral heads, sacral plexus, bone marrow and small intestines were contoured as OARs without any planning risk volume (PRV) margin [13,14].

Treatment planning

First, the reference CT scans taken at the beginning of the treatment was registered in 2 different positions (KHS+, KHS-). The following 3rd and 5th week's CT scans were fused on the reference CT scans using the bony structures which is a common method used in clinical RT, and AP, SI, lateral-medial shifts in CTVs (CTV-primary, iliac CTV, presacral CTV) and OARs (rectum, bladder, bowels, femoral heads, sacral plexus and bone marrow) were calculated by center of mass method. The minimum required PTV margin in all CTVs with or without KHS was tried to be determined.

IMRT plan was made using inverse planning algorithm with 6 MV photon beams. Seven fields with 26°, 77°, 129°, 180°, 231°, 283°, and 334° non-reciprocal gantry angles were chosen for this purpose and a total dose of 50.4 Gy in conventional daily fractionation was prescribed. It was mandatory to give 95% of the dose to the 95% of the PTV volumes.

Dose volume histograms (DVHs) of each patient were evaluated in terms of minimum, maximum and mean dose changes in the 3rd and 5th week of CT planning compared to reference plan both with KHS and without KHS. Additionally, V30, V40, V45, and V50 for OARs were compared with the reference plan.

Statistical analysis

Statistical analysis was performed using the SPSS version 18.0 for Windows (SPSS Inc., Chicago, IL). Descriptive statistics of scalar variables were presented as mean and standard deviations. A paired non-parametric Wilcoxon test and a student t-test were used to test for statistical differences in volumes and margins during the course of treatment. Statistical significance was defined as $p < 0.05$.

Results

All patients were evaluated for the body weight changes at the end of the 3rd week and the beginning of the 5th week. In addition AP and lateral dimensions were calculated on CT scans. There was no significant body weight change at 3rd week, however at the beginning of the 5th week patients showed decline in the body weight with a mean value of 1.5 ± 1 kg. The mean BMI decline at this week was 0.61 with a range of 0.3–1. There was no remarkable difference on lateral dimensions at both the 3rd and the 5th week CT comparing to the pre-RT scans. The mean value of decline in both weeks was 2 ± 1 mm. On the other hand the mean AP dimension change at 3rd week was 3 ± 2 mm and around 5 ± 3 mm at 5th week.

The fusion images of the 3rd and 5th week with the pre-RT planning CT scans with or without KHS showed that there were no significant differences in terms of the shifts both for CTV-primary and lymphatic CTVs except for SI shifts in CTV-primary at the 3rd week (Tables 1 and 2). The mean shift in SI dimension in CTV-primary was 2 ± 1 mm with KHS. This value was 4 ± 2 mm without KHS ($p = 0.04$). There was no significant difference at 5th week of evaluation.

When considering the shifts from the pre-RT CT scans with KHS, the mean shift in AP direction in CTV-primary was 5 ± 2 mm at the 3rd week and 6 ± 4 mm at the 5th week without any significant difference (Table 1). All other mean values of shifts were less than 5 mm. PTV margins when given as 15 mm in AP and SI directions and 5 mm in lateral directions during planning

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