Radiotherapy and Oncology 87 (2008) 350—356
www.thegreenjournal.com

Rectal cancer

Evaluation of three different CT simulation and planning procedures for the preoperative irradiation of operable rectal cancer

Jacques H. Borger*, Jørgen van den Bogaard, Daniëlle F.M. de Haas, Anna P.B.M. Braeken, Lars H.P. Murrer, Ruud M.A. Houben, Guido Lammering

MAASTRO clinic, Maastricht, The Netherlands

Abstract

***Purpose*: To find the best procedure regarding quality and work load for treatment planning in operable non-locally advanced rectal cancer using 3D CT-based information.**

***Methods*: The study population consisted of 62 patients with non-locally advanced tumours, as defined by MRI in the lower ($N = 16$), middle ($N = 25$) and upper ($N = 21$) rectum referred for preoperative short-course radiotherapy. In procedure 1 (Pr1), planning in one central plane was performed (field borders/shielding based on bony anatomy). In procedure 2 (Pr2), field borders were determined by 2 markers for the extension of the CTV in the cranial and ventral direction. Dose optimization was performed in one central and two border planes. In procedure 3(Pr3) the PTV volume (CTV was contoured on CT) received conformal treatment (3D dose optimization).**

***Results*: Conformity index reached 1.6 for Pr3 vs. 2.2 for Pr2 ($p < 0.001$). PTV coverage was 87%, 94%, 99% in Pr1, Pr2, Pr3, respectively ($p = 0.001$). In Pr2 target coverage was below 95% for low/middle tumours. PTV coverage was reduced by narrow field borders (18—23%) and shielding (28%). A total of 43.5% (1—100) of the bladder volume was treated in Pr2 in contrast to 16% (0—68) in Pr3 ($p < 0.001$). The maximum dose was exceeded in 10 patients (26—298 cc) and 2 patients (21—36 cc) in procedures 1 and 2, respectively. The overall time spent by technologists was 86 min for Pr3 vs 17 min in Pr2 and Pr1 ($p < 0.001$), for radiation oncologists this difference was 24 vs 4 min ($p < 0.001$).**

***Conclusions*: Pr1 does not fulfill todays quality requirements. Pr3 provides the best quality at the cost of working time. Pr2 is less time consuming, however, the PTV coverage was insufficient, with also much larger treatment volumes. An optimization of the PTV coverage in Pr2 even further enlarged the treatment volume.**
 Radiotherapy and Oncology 87 (2008) 350—356.

Keywords: Rectal cancer; Preoperative radiotherapy; CT planning; CT simulation

Preoperative short-course hypofractionated radiotherapy is nowadays a commonly used treatment for rectal cancer. Usually in our country this short hypofractionated course (5×5 Gy) is given immediately before total mesorectal excision (TME) surgery to those patients, who have been staged as operable rectal cancer patients [9,19,21]. Interestingly, this short-course hypofractionated radiotherapy might also prove to be effective in down-sizing non-resectable rectal cancer, if the surgical excision is delayed, as has been recently published [3,17].

In more and more centers, the patient selection nowadays for short-course preoperative radiotherapy is based on Magnetic Resonance (MR) Imaging with a special attention to the circumferential resection margins (CRM). The clinical target volume (CTV) consists of the primary tumour and involved lymph nodes (GTV), the mesorectal fat area including the fascia and the regional lymph nodes [18]. The introduction of Computed Tomography scans in the treatment planning of radiotherapy has had an enormous impact on planning procedures and daily clinical practice. The patient contouring and attenuation correction can nowadays be performed in 3D using today's computer technology. In addition, dose calculation and adaptation per voxel have become the basis of modern radiotherapy techniques. Importantly, the use of the CT scanner as a simulator has also had a big impact on the delineation of the target volumes [18]. The modern radiation field design to cover primary tumour extension and regional lymph nodes is often no longer based on the classical bony landmarks. The GTV and CTV can be delineated as soft tissue anatomy on CT images, often accompanied by other imaging modalities (Positron Emission Tomography (PET), MRI). On the

0167-8140/$ - see front matter doi:10.1016/j.radonc.2008.03.024

other hand, the delineation of all the target structures is time consuming and may not always be necessary if new anatomic landmarks could be defined. Nevertheless, many centers still perform the classical planning procedure by using bony landmarks, although no studies have ever been done to verify the equality of the classical method with the 3D-conformal technique. Therefore, we felt it is important to perform a study, in which the classical 2D bony landmark method will be evaluated for its Planning Target Volume (PTV) coverage quality and dose homogeneity by comparing it with the 3D-conformal technique as reference. In addition, we developed a CT-3D based technique without target delineation but with the help of 2 defined landmarks in order to reduce working time and also evaluate its quality in comparison to the reference 3D-conformal technique.

Patients and methods

Patients

The CT scans of 62 patients with rectal carcinoma were used to perform the study. In the period between January 2004 and December 2005 almost all the resectable rectal cancer cases referred for preoperative hypofractionated radiotherapy were selected with a special focus on a comparable distribution of the tumour localization overall 3 levels of the rectum (Level I 3–7 cm (21 patients), Level II 7–10 cm (25 patients), Level III >10 cm (16 patients) from the anocutaneous border). The median age was 68 years (range: 34–82 years). All the patients received an MRI of the abdomen as a standard work-up before treatment decision making. The resectability criteria were judged in multidisciplinary teams. All the patients with non-locally advanced tumours received short-course preoperative radiotherapy. This treatment was given in supine position and with a full bladder instruction. The PTV was treated to a total dose of 25 Gy in 5 fractions of 5 Gy. CT scans were made with 3 mm slice intervals. To identify the anal verge, we localized it at the most caudal CT-slice of the anus. Anal markers were not used for that purpose, because they were found to be unuseful in most cases due to misplacement. The isocenter was located at the midline, upper border of the symphysis os pubis and 8 cm above the treatment couch (promontorium).

Planning procedures

In procedure 1 (Fig. 1c) CT scans were used to design the fields based on bone anatomy: promontorium (superior), promontorium +2 cm (anterior), pelvic rim +1.5 cm (lateral). The promontorium in this study is defined as the most prominent part of S1. The inferior field border was determined depending on the position of the primary tumour. In tumours closer than 4 cm from the anorectal verge the anal verge was included with a caudal margin of 2 cm (caudal field border). In all other cases the inferior field border was set 3 cm above the anal verge, as defined on CT slices The sacrum was included in the posterior field border for the Left Lateral and Right Lateral fields (LL, RL). Standard shielding of hip joints and sacrum (posterior one third) was applied according to the guidelines from the Dutch TME trial. Using 3 fields (LL, RL, postero–anterior (PA)) the treatment plan was evaluated in one central plane according to the ICRU 50 criteria [15,16].

In procedure 2 (Fig. 1c) upper, lower and anterior field (LL/RL) borders were determined on basis of the extent of the tumour (GTV), the submucosal axial margin of 3 cm proximal and distal from the primary tumour (Surgical Target Volume (STV)), the mesorectum and the bifurcation of the common iliac vessels. The posterior (LL/RL fields) and lateral (Antero–posterior (AP) field borders were defined identical to those described in procedure 1. The most cranial and anterior extension of the CTV was manually marked with a cross symbol (Fig. 1a) by a radiation oncologist on the CT-slices in 3D view with transversal, coronal and sagital orientation. For the placement of this cross symbol, the primary extension of the GTV and STV was taken into account according to MRI using dual projection of both the MRI and CT images as well as the origin of the internal iliac vessels. Whatever led the most cranial and anterior extension defined the placement of the cross symbol. The second cross symbol defined the most caudal extension of the mesorectum or the GTV and STV. All the cross symbol positions were independently approved by one more radiation oncologist out of a team of three well trained radiation oncologists specialized in the treatment of rectal cancer.

The field as indicated by these two cross symbols was then extended by 2 cm in the cranial, caudal and anterior direction in order to determine the definitive field border. Dose distribution was optimized in one central and two border planes (2 cm inside cranial/caudal field border). Four fields were choosen in the case of >80% dose in the central plane on the hips or under the cutis or in case of an overdosage in the 3 planes with more than 107% dose. Dose optimization in procedures 1 and 2 was done blinded without knowledge of the PTV as delineated in procedure 3.

In procedure 3, a CTV(Fig. 1b) volume was constructed from GTV (primary tumour based on MR), STV, mesorectal subsite, posterior pelvic subsite, and the regional lymph nodes at risk, which were defined by contouring the internal iliac vessels, the middle and superior rectal vessels and the obturator artery (not for tumours located in level III). The CTV of the lymph nodes was defined by the contour of the arteries and veins expanded by 0.5 cm in all the directions except for the cranial direction. The CTV of the primary tumour was obtained by circumferential expansion of the GTV with 0.5 cm. For mesorectal and posterior pelvic subsite as well as STV no margins were added for the CTV. The CTV–PTV expansion from the total CTV was 1 cm in all the directions. All the delineations for one particular patient were independently approved by another colleague out of a team of three well trained radiation oncologists specialized in the treatment of rectal cancer. MLCs were used to shield the bladder and small bowel. Dose prescription and 3D dose optimization were performed according to ICRU 50 criteria [15,16].

The PTV of procedure 3 (Fig. 1c) served as the gold standard to determine target coverage, conformity index, homogeneity index and the volume of normal tissue (blad-