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Original Article

Volumetric Modulated Arc Therapy with Simultaneous Integrated Boost for Locally Advanced Rectal Cancer

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Abstract

Aims: To report the feasibility of volumetric modulated arc therapy (VMAT) for neoadjuvant radiotherapy in locally advanced rectal cancer in a dose-escalation protocol and simultaneous integrated boost (SIB) approach. Moreover, the VMAT technique was compared with three-dimensional conformal radiotherapy (3D-CRT) and fixed-field intensity modulated radiotherapy (IMRT), in terms of target coverage and irradiation of organs at risk.
Materials and methods: Eight patients with locally advanced rectal cancer were treated with the SIB-VMAT technique. The VMAT plans were compared with 3D-CRT and IMRT techniques in terms of several clinically dosimetric parameters. The number of monitor units and the delivery time were analysed to score the treatment efficiency. All plans were verified in a dedicated solid water phantom using a two-dimensional array of ionisation chambers.
Results: All techniques meet the prescription goal for planning target volume coverage, with VMAT showing the highest level of conformality. VMAT is associated with 40, 53 and 58% reduction in the percentage of volume of small bowel irradiated to 30, 40 and 50 Gy, compared with 3D-CRT. No significant differences were found with respect to SIB-IMRT. VMAT plans showed a significant reduction of monitor units by nearly 20% with respect to IMRT and reduced treatment time from 14 to 5 min for a single fraction.
Conclusions: SIB-VMAT plans can be planned and carried out with high quality and efficiency for rectal cancer, providing similar sparing of organs at risk to SIB-IMRT and resulting in the most efficient treatment option. SIB-VMAT is currently our standard approach for radiotherapy of locally advanced rectal cancer.

Key words: Rectal cancer; SIB; VMAT

Introduction

Volumetric modulated arc therapy (VMAT) is a novel form of intensity modulated radiotherapy (IMRT) in which the gantry is rotating while the beam is on and the dose rate, the shape of the beam and the speed of rotation continuously change [1]. Various planning studies referred to several anatomic sites showed that VMAT has the potential to generate plans with similar quality to conventional IMRT but with a large reduction in treatment time and in the number of monitor units [2–6].

In rectal cancer, because of the horseshoe shape of the planning target volume (PTV), the irradiated volume of small bowel lying in the PTV concavity cannot be adequately reduced using conventional three-dimensional conformal radiotherapy (3D-CRT). So, the use of IMRT techniques for locally advanced rectal cancer (LARC) seems to be well suited and a significant reduction in the irradiation of small bowel volume was indeed observed [7–9]. Moreover, conventional IMRT techniques allow the simultaneous delivery of different doses to different target volumes within a single fraction, the so-called simultaneous integrated boost (SIB) technique. This strategy, introduced in several anatomic sites, is used to increase the fraction dose to the boost volume, keeping the dose to the elective volume at a lower level, and providing clinical and dosimetric advantages [10–14].

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Here we propose the use of a SIB-VMAT technique to replace the SIB-IMRT or conventional 3D-CRT two-phase treatment (whole-pelvis irradiation with concomitant boost to the tumour volume) for LARC. In particular, we propose to deliver simultaneously the same dose (e.g. 45 Gy, 25 × 1.8 Gy) as 3D-CRT to the pelvic nodes and higher doses (e.g. 57.5 Gy, 25 × 2.3 Gy) to the gross tumour volume in the same fraction number, in a dose-escalation protocol. The potential dosimetric advantages in using this approach in terms of target coverage and organ at risk (OAR) dose sparing for LARC has been evaluated with respect to 3D-CRT concomitant boost and fixed-field SIB-IMRT.

Materials and Methods

After the clinical implementation of the VMAT technique in our centre, eight patients with LARC (cT3-T4 and/or N1-2) were preoperatively treated with SIB-VMAT between October 2010 and February 2011. Patients signed an informed consent for inclusion in this study, approved by the local ethics committee. Exclusion criteria were: presence of active intestinal inflammation (ulcerous proctocolitis or diverticulitis) or uncontrolled pelvic inflammation (abscess, fistula). Concurrent chemotherapy consisted of oxaliplatin, 130 mg/m^2 (days 1, 17, 36) and capecitabine, 1300 mg/m^2 daily over all the treatment.

Simulation, Volume Definition and Dose Prescription

Patients underwent computed tomography-based simulation in the prone position and were instructed to achieve stable conditions of bladder and rectal filling. Immobilisation was achieved with an up–down table modified 'belly-board' device, with the aim to dislocate the small bowel out of the treatment field. The gross tumour volume was delineated on the basis of magnetic resonance imaging. Two clinical target volumes (CTVs) were defined: CTV1 was the gross tumour volume plus the corresponding rectum and mesorectum plus a margin of 1 cm in the cranio-caudal direction; CTV2 included the whole mesorectum and the perirectal and internal iliac nodes. In case of extension to the vagina, uterus, cervix, prostate or bladder, CTV2 was increased to include the external iliac nodes. Examples of CTVs are provided in Figure 1. PTV1 was obtained by adding non-uniform margins to CTV1 following the suggestions of Nijkamp *et al.* [15]. First, the rectum was divided in a superior and inferior half with the base of the bladder as the starting plane. In men, in the case of tumour situated in the lower half of the rectum, the anterior and posterior margin to PTV1 was 16 mm; the lateral margin was 14 mm. Otherwise, if tumour was located in the upper half of the rectum, the anterior, posterior and lateral margins were 19, 10 and 15 mm, respectively. Similarly, in women, for lesions located in the lower half of the rectum, the margin to PTV1 was 16 mm in all directions; in the case of tumour situated in the upper half of the rectum, the anterior margin was 24 mm, the posterior and lateral margins were 13 and 15 mm, respectively. For all cases, the margin in the cranio-caudal direction was 10 mm (5 mm inferiorly if the PTV included the anal canal).

PTV2 was obtained by adding an 8 mm uniform margin to CTV2. OAR included the small bowel, bladder and femoral heads.

The prescribed doses were 57.5 Gy to PTV1 and 45.0 Gy to PTV2, which were delivered simultaneously over 25 daily fractions.

Patient set-up was daily checked by comparing the megavoltage portal images (MPI) obtained by two square open beams at 0 and 90° gantry angles with the corresponding digitally reconstructed radiographs obtained by the planning system. Bony anatomy was used to verify the treatment isocentre position. Patients were treated only if the relative variations of the bone markers between the images were within 3 mm along the three spatial directions.

Treatment Planning

For each patient, the VMAT plan was compared with a 3D-CRT and a fixed-field IMRT plan, the last one being used as the benchmark. All plans were generated with Masterplan Oncentra TPS and delivered by an Elekta Precise linac.

For 3D-CRT we used a concomitant boost technique. Two plans, one for each PTV, were independently optimised. Dose calculations were separated in a dose prescription of

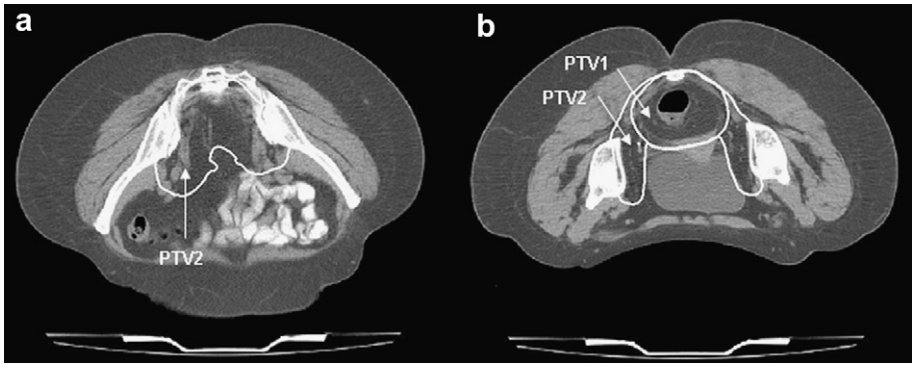

Fig 1. Planning target volume definition at two different axial levels: (a) sacro-iliac joints and (b) femoral heads. The action of the belly board table on small bowel displacement (a) and abdominal compression (b) is clearly visible.