Supplementary material for Joye I. et al. Implementation of volumetric modulated arc therapy for rectal cancer: Pitfalls and challenges. Acta Oncol 2015; doi:10.3109/0284186X.2015.1064159

Supplementary Appendix

Supplementary material: methodological details

Data acquisition

CT scans were acquired with a conventional helical CT scanner (Siemens Somatom Sensation®, Siemens Medical Solutions) with 3 mm slice thickness from L3-4 to 5 cm below the ischial tuberosities. Intravenous contrast (Visipaque®) was administered if serum creatinine was below 2 mg/dl in non-contrast allergic patients. For prone positioning, a bellyboard was used (MacroMedics® Pelvic Prone Board™) with a rotated knee support as ankle support to increase stability (Cablon®, Kneefix™). The forehead was positioned on a pillow with an aperture for the head and support for the shoulders (Macromedics® Pron Pillo). For the scans in supine position, only the knee support was used.

Delineation of organs at risk

The small and large bowels were delineated as individual loops [20]. The bowel bag was defined as the entire volume of peritoneal space in which the bowel loops could be located, with exclusion of the bladder, prostate, seminal vesicles and uterus. Bowel structures were delineated up to 2 cm above the CTV [20]. The bladder was delineated as the outer bladder contour, from the base to its dome.

Treatment plans and dosimetrical analysis

VMAT plans were considered acceptable if ≥95% of the PTV received ≥95% of the prescribed dose and if Dmax was ≤107% of the prescribed dose. During a 2-step VMAT optimization process, the highest priority was given to the maximal dose (D_{max}) to the organs at risk and to the PTV coverage. When these initial goals were reached, the doses to the organs at risk were further optimized.

CTV motion prone on a bellyboard vs. supine

Aim: to investigate the interfractional CTV motion in prone on a bellyboard and supine position

Material and Methods

Data acquisition

This analysis was performed in an independent patient group of fourteen patients.

Seven rectal cancer patients who were scheduled for preoperative RCT underwent a planning CT in prone on a bellyboard. Because rectal cancer patients are not treated in supine position in our institution, seven patients with prostate cancer were selected. CT simulation protocols for both patient groups are similar in our department. CBCTs were performed daily during the first week of irradiation and thereafter weekly during 4 other weeks. This yielded a total of 9 CBCTs per patient.

Delineation

On the planning CT CTVs were delineated according to the guidelines of Roels et al. [12]. On the supine scans, the CTV was delineated assuming that the patient had a cT3N1 rectal tumor at 8 cm from the anal verge.

The CBCTs were automatically matched with the planning CT (Eclipse®, Varian). The CTV as delineated on the planning CT was copied to the CBCT and the CTVs were adapted to the anatomy as visible on the CBCTs. This led to a total of ten delineated CTVs (1 based on the planning CT, 9 based on CBCT).

CTV motion

With in-house developed software, the CTV surfaces of each patient were sampled with around 1000 equally distributed dots and a 3D surface mesh was calculated, with the CTV of the planning CT as a reference. The obtained CTV volume was divided into six subregions. The maximal distances between the CTVs were calculated for each subregion.

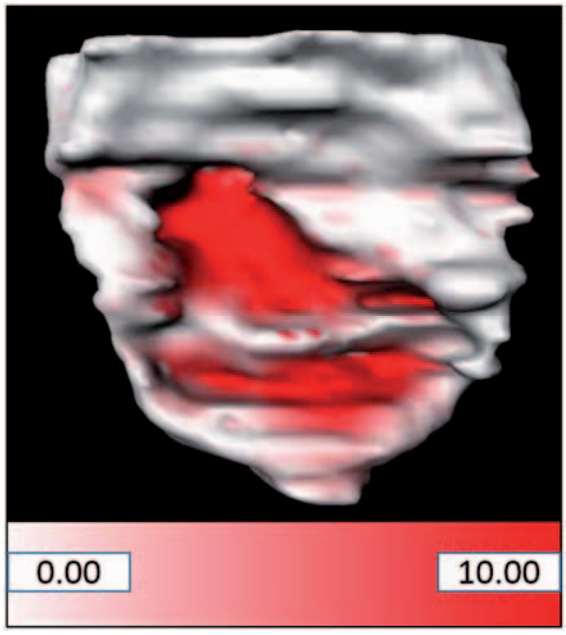
Results

An example of a 3D volume of one patient is depicted in Supplementary Figure 1. For all subregions, the maximal CTV motion was larger in the supine position compared to the prone on a bellyboard position (Supplementary Table 1). In both positions, CTV motion was largest at the anterior border of the CTV (mean maximal distance 15.7 ± 6.5 mm and 20.8 ± 9.5 for prone and supine position, respectively).

Conclusion

The CTV motion was at least not larger in prone on a bellyboard compared to supine position. The largest motion was observed at the anterior CTV border. An anisotropic anterior margin of 1.5 cm is required when highly conformal radiotherapy techniques are used.

Supplementary Figure 1. Example of a 3D volume of one patient



Legend: Example of a 3D volume of one patient. The red color bar indicates the maximal distance between the CBCT CTVs and the CTV on the planning CT. This figure clearly indicates that the largest CTV motion in situated at the anterior part of the CTV.

Supplementary Table I. Maximal CTV motion per subregion for prone on bellyboard vs. supine scans

Subregion	**Prone (mean ± SD)**	**Supine (mean ± SD)**
Anterior	15.7 ± 6.5	20.8 ± 9.5
Posterior	6.0 ± 1.1	6.3 ± 3.1
Cranial	3.9 ± 1.4	5.4 ± 1.5
Caudal	3.6 ± 2.3	3.9 ± 2.3
Lateral left	5.4 ± 2.0	5.7 ± 2.0
Lateral right	5.2 ± 2.5	6.1 ± 1.8

Supplementary material: Feasibility of moderate dose-escalation VMAT prone (50 Gy) vs. 3D-CRT prone (45 Gy).

Aim: to investigate the feasibility of moderate dose escalation with VMAT

Material and Methods

To investigate the feasibility of moderate dose escalation, only the prone scans were used and 3D-conformal radiotherapy (3D-CRT) plans (45 Gy in fractions of 1.8 Gy) were compared with VMAT plans (50 Gy in fractions of 2 Gy). Target and organ at risk delineation were similar as previously described. In concordance with the standard clinical practice in our department, the CTVs of the 3D-CRT plans were expanded an isotropic PTV margin of 1 cm.

3D-CRT plans were constructed using two lateral and one posterior field. Dynamic wedges were applied for adequate dose distribution. 3D-CRT plans were considered acceptable if 100% of the PTV

received ≥95% of the prescribed dose but with a Dmax ≤107% of the prescribed dose. The investigated dosimetrical parameters and the statistical analysis were similar as previously described.

Results

Moderate VMAT dose escalation up to 50 Gy did not increase the dose to the organs at risk for doses below 45 Gy compared to 3D-CRT up to 45 Gy (Supplementary Table 2, Supplementary Figure 2). The V15 of the large bowel and the bowel bag was significantly lower with VMAT 50 Gy compared to 3D-CRT 45 Gy (median 38.9 cc vs. 41.4 cc, p = 0.006; median 445.2 cc vs. 562.6 cc, p = 0.003 respectively). The D_{mean} of the small bowel, large bowel and bowel bag was significantly lower in the VMAT 50 Gy plans compared to 3D-CRT 45 Gy plans (median D_{mean} small bowel 18.2 Gy vs. 22.5 Gy, p = 0.005; median D_{mean} large bowel 21.3 Gy vs. 26.0 Gy, p = 0.003; median D_{mean} bowel bag 18.0 Gy vs. 21.5 Gy, p = 0.003). Although the D_{mean} of the bladder was not significantly different, the V40 of the bladder was significantly lower in the 50 Gy VMAT plans compared to the 45 Gy 3D-CRT plans (median 32.8 cc vs. 47.1 cc; p = 0.003).

3D-CRT plans had a higher CI compared to VMAT (median 1.00 vs. 0.96; p = 0.003). The HI of the PTV was better in the 3D-CRT plans compared to the VMAT plans (median 8.13 vs. 9.48; p = 0.006).

Supplementary Table II. Dosimetrical comparison 3D-CRT prone (45 Gy) vs. VMAT prone (50 Gy) (median, IQR)

Volume	Dose parameter	3D-CRT prone (45 Gy)	VMAT prone (50 Gy)	p-value
PTV	D_2	47.4 (47.2 – 47.5)	51.8 (51.5 – 51.9)	**0.003**
	D_{98}	43.6 (43.5 – 43.9)	46.7 (46.6 – 47.3)	**0.003**
	D_{mean}	45.3 (45.0 – 45.7)	50.0 (50.0 - 50.3)	**0.003**
	CI	1.00 (1.00 - 1.00)	0.96 (0.95 - 0.97)	**0.003**
	HI	8.13 (7.44 – 8.76)	9.48 (8.44 – 10.5)	**0.006**
Small bowel	D_{mean}	22.5 (2.7 – 32.0)	18.2 (2.3 – 23.4)	**0.005**
	V15	95.7 (0.0 – 201.8)	66.4 (0.0 – 304.6)	0.208
	V45	28.9 (0.0 – 83.1)	10.1 (0.0 – 102.7)	0.484
Large bowel	D_{mean}	26.0 (22.8 – 35.9)	21.3 (18.0 – 29.8)	**0.003**
	V15	41.4 (30.1 – 102.3)	38.9 (17.2 – 91.2)	**0.006**
	V45	15.1 (4.8 – 25.1)	11.9 (3.6 – 28.3)	0.534
Bowel bag	D_{mean}	21.5 (18.2 – 26.0)	18.0 (16.2 – 21.2)	**0.003**
	V15	562.6 (474.7 – 673.3)	445.2 (352.1 – 575.7)	**0.003**
	V45	160.0 (141.0 – 192.6)	134.9 (96.9 – 172.0)	0.062
Bladder	D_2	46.3 (45.4 – 47.2)	49.3 (47.3 – 50.9)	0.062
	D_{mean}	35.5 (32.2 – 37.4)	33.9 (31.3 – 36.6)	0.322
	V40	47.1 (29.4 – 75.8)	32.8 (12.2 – 48.1)	**0.003**

Doses are in Gy, volumes in cc. Bold values depict statistical significance.

Supplementary Figure 2. Average Dose Volume Histograms of small bowel, large bowel and bowel bag: 3D-CRT prone (45 Gy) vs. VMAT prone (50 Gy). Doses are in Gy, volumes in cc.