
Proceedings Paper:
Arp, D.T., Appelt, A.L. orcid.org/0000-0003-2792-9218, Nielsen, M.S. et al. (2 more authors) (2023) Rectal tumour position variation: Systematic and random variations by point-based surface evaluation. In: Radiotherapy and Oncology. ESTRO 2023, 13-16 May 2023, Vienna, Austria. , S1685-S1686.

https://doi.org/10.1016/S0167-8140(23)66847-1

Title: Rectal tumour position variation: Systematic and random variations by point-based surface evaluation

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Purpose/Objective:

There is limited data on the interfraction motion of primary rectal tumours, hindering robust PTV margin calculations. We examined in-plane surface variation of the GTV on prospectively collected MRI data using a point-based surface displacement metric, with the aim of estimating systematic and random variations for PTV margin calculation.

Material/Methods:

We collected MRI scans before (x3) and during (x3) radiotherapy (RT) in a prospective clinical imaging study (NCT03619668). All patients were treated for locally advanced rectal cancer (T2-4 N0-2) with long course RT (50.4 Gy/28 frac.) and concomitant chemotherapy. The MRI scans (T2-weighted, Philips Ingenia 3T MRI) were co-registered using a rigid bony match, and GTVs delineated by an experienced oncologist. Each GTV was represented by 5000-23.000 surface points, depending on the size. The within-patient surface variation was calculated using a point-based bidirectional local distance (BLD). For each point position, the distance between the point on the baseline scan and subsequent MRI scans was calculated as a 3D displacement vector. To collate information across patients, a reference rectum structure was created, consisting of 120 equidistant surface points on each slice. Baseline GTV volumes (and their set of displacement vectors) were transferred to the reference geometry using the relative distance from the anal verge and correlated to a point using the BLD metric. Systematic ($\sum$) and random (σ) variation, were calculated for each surface point on the reference rectum (see Figure 1). To evaluate anterior, posterior, and left/right directions, each reference slice was divided into four 90º angle spans (30 points each). To evaluate different regions along the height of the rectum, three sections were defined and analysed separately. Based on $\sum$ and σ from each section, local anisotropic PTV margins were calculated.

Results:

Sixteen patients (7 male, 9 female) were included, with tumors in the lower (13/16) and mid (3/16) rectum. The four top and bottom baseline GTV slices were removed from each patient dataset, to ensure that only in-plane variation was considered. Slices on the reference rectum containing data from less than six patients were excluded. Variation analysis was consequently performed from 3.7 cm to 10.1 cm in the rectum relative to the anal verge, and the sections defined as: low (3.7-5.8cm), mid (5.9-8.0cm), high (8.1-10.1cm). Figure 1 shows $\sum$ and σ variations on the surface of the reference rectum. Table 1 shows mean variations divided into the sections of the reference rectum, including SD, range and 95th percentile. Local PTV margins based on the 95th percentile variations are provided.

Conclusion:

Using prospectively collected MRI scans and innovative point-based surface evaluations, we robustly calculated systematic and random variation for rectal tumours in different sections of the rectum. We calculated corresponding PTV margins to account for position variation when using rigid bony match for positioning.

(table on next page)

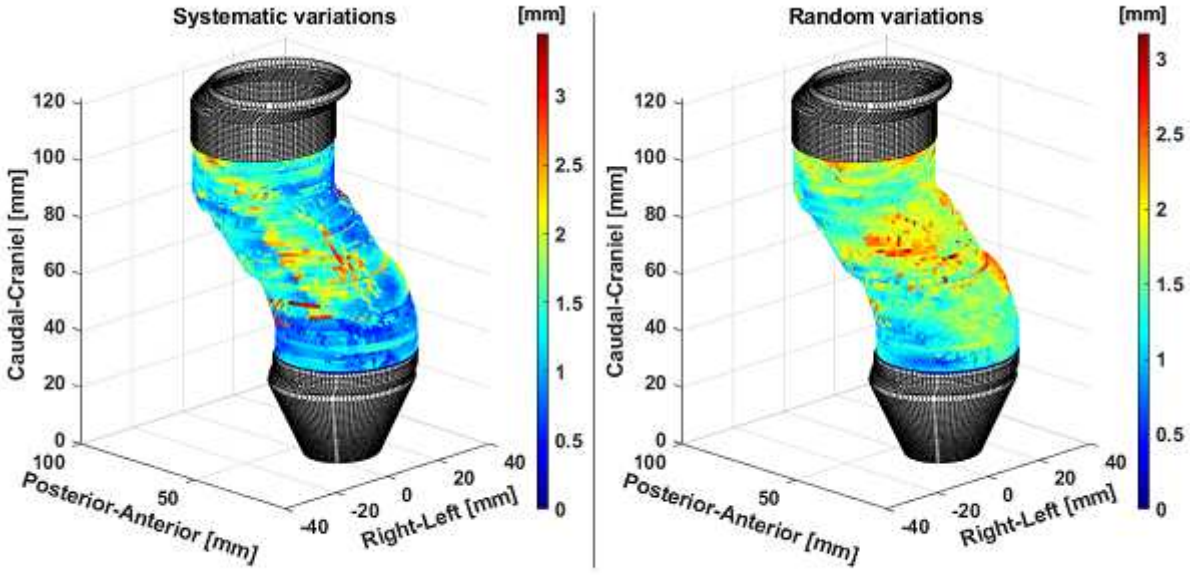

Figure 1: Systematic (left) and random (right) point-based surface variation. To calculate the systematic ($\sum$) and random (σ) variation, the root-mean-square of the SD and the SD of the means were calculated for each surface point on the reference rectum.

Direction/section	Anterior			Posterior		
	low (3.7-5.8cm)	mid (5.9-8.0cm)	high (8.1-10.1cm)	low (3.7-5.8cm)	mid (5.9-8.0cm)	high (8.1-10.1cm)
mean ∑ [mm] (SD, range) 95th percentile	1.0 (0.3, 0.4-2.4) 1.5	1.5 (0.5, 0.5-3.3) 2.5	1.2 (0.4, 0.4-2.6) 1.9	1.2 (0.4, 0.3-3.1) 2.1	1.4 (0.5, 0.5-3.0) 2.4	1.2 (0.4, 0.5-2.5) 2.0
mean σ [mm] (SD, range) 95th percentile	1.5 (0.3, 0.5-2.7) 1.9	1.9 (0.3, 1.1-3.2) 2.4	1.7 (0.3, 1.1-2.9) 2.3	1.3 (0.3, 0.6-2.5) 1.8	1.6 (0.3, 0.9-2.5) 2.1	1.6 (0.2, 0.9-2.7) 2.0
PTV margin [mm] based on 95th percentile	5.2	7.8	6.4	6.4	7.6	6.4

Direction/section	Right			Left		
	low (3.7-5.8cm)	mid (5.9-8.0cm)	high (8.1-10.1cm)	low (3.7-5.8cm)	mid (5.9-8.0cm)	high (8.1-10.1cm)
mean ∑ [mm] (SD, range) 95th percentile	1.2 (0.6, 0.3-3.5) 2.8	1.4 (0.4, 0.7-2.9) 2.3	1.5 (0.4, 0.6-2.8) 2.3	1.3 (0.6, 0.3-3.0) 2.6	1.7 (0.5, 0.4-3.3) 2.6	1.2 (0.5, 0.3-2.9) 2.1
mean σ [mm] (SD, range) 95th percentile	1.2 (0.3, 0.5-2.7) 1.9	1.5 (0.4, 0.7-2.9) 2.2	1.5 (0.3, 0.7-2.6) 2.1	1.3 (0.6, 0.6-3.0) 2.6	2.0 (0.4, 1.3-3.0) 2.6	1.8 (0.2, 1.0-2.8) 2.1
PTV margin [mm] based on 95th percentile	8.4	7.2	7.2	8.4	8.3	6.7

Tabel 1: Systematic (∑) and random (σ) variations divided into anterior, posterior, left and right direction for different sections of the evaluated reference rectum structure. Local anisotropic PTV margin calculation for position variation of tumour relative to bony match, without accounting for other uncertainties, using the margin equation PTV=2.5Σ + 0.7σ (van Herk et al., 2000, IJROBP).