Estimation of the delivered dose to small bowel during VMAT for gynecological cancer based on daily CBCT. Is the impact of inter-fractional variations large?

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Purpose

This study aims to estimate the accumulated dose delivered to small bowel throughout the course of radiation therapy for locally advanced cervical cancer by examining the dosimetric and radiobiological impact of the organ's inter-fractional variations in location and shape against treatment plan.

Presently, radiotherapy treatment planning for gynecological cancer does not explicitly consider the dosimetric consequences of internal organ deformation. This study aims at examining the effects of anatomical deformations on daily VMAT doses utilizing deformable registration and daily Cone Beam Computed Tomography (CBCT) images. The cumulative delivered dose distribution to small bowel was derived from all the fractions per patient.

Table 1 shows the results of the comparisons between the planned and delivered doses for a number of different dosimetric and radiobiological metrics. Figs. 1 and 2 illustrate the spatial relation of those daily anatomical variations with the applied dose distribution for two patients as well as the comparison of the dose volume histograms between plan and delivery.

Methods

This analysis involves ten gynecological cancer patients treated with VMAT to 45Gy in 25 fractions using daily Cone Beam CT (CBCT) localization. A total of 125 fractions of five patients were analysed here. Small bowel was manually delineated on each CBCT and an in-house extension was used to multiply the HU values inside those contours to drive the deformable registrations. A MIM-UNC designed workflow (MIM Software, Inc) was used to calculate the cumulative dose in small bowel. The clinical dosimetric metrics (mean dose, D1cc) and the normal tissue complication probability (NTCP) were calculated for the comparisons with the treatment plans.

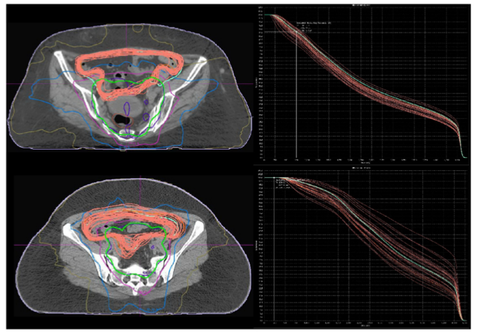

Figure 1. Central axial CT slice of two patients where the inter-fractional variation in the position and shape of small bowel is shown against the isodose lines. The corresponding DVHs are also shown (green is the planned DVH, orange are the fractional DVHs).

Results

Table 1. Summary of the delivered doses to small bowel based on the CBCTs and the doses from the treatment plans for five of the patients. The clinical goal was: $D_{0.1cc} < 45$ Gy.

Patient	Dose Distribution	D_{mean} (Gy)	D_{max} (Gy)	$D_{0.1cc}$ (Gy)	NTCP (%)	BEUD (Gy)
1	Plan	23.7±13.8	47.1	46.9	2.6	40.5
	Delivered	26.2±13.7	46.2	46.2	3.1	40.9
2	Plan	35.8±11.6	51.2	49.9	7.3	43.2
	Delivered	35.3±10.0	47.7	47.5	4.4	41.7
3	Plan	26.4±15.1	47.2	47.1	1.5	39.2
	Delivered	25.6±14.7	46.4	46.3	1.2	38.8
4	Plan	31.1±12.1	47.8	47.6	1.7	39.6
	Delivered	28.9±13.1	46.7	46.6	1.5	39.3
5	Plan	33.8±10.3	46.5	46.4	1.5	39.2
	Delivered	34.5±9.4	46.2	46.1	1.3	39.1

Dmean: mean dose, Dmax: maximum dose, D0.1cc: minimum dose to the hottest 0.1cc of small bowel, NTCP: normal tissue complication probability, BEUD: biologically effective uniform dose

The deviations between the estimated daily delivered and planned doses were considerable and had different patterns per patient. However, after accumulating the dose distributions from all the fractions, the final dosimetric deviations were small. The dose differences between the planned and delivered doses ranged between 0.5 Gy to 2.5 Gy in mean dose. Regarding clinical metric D_{1cc}, the differences ranged between 0.3-2.4Gy and in all the cases delivered dose was lower than the predicted dose from the treatment plan on simulation CT. The respective differences in NTCP values ranged between 0.2% to 2.9%, which is translated to a biological equivalent doses of 0.1 Gy to 1.5 Gy.

Conclusion

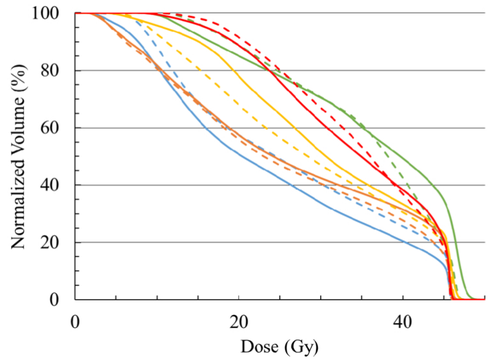

Figure 2. The planned and total delivered DVHs of the five analyzed patients (solid lines: plan, dashed lines: delivered).

Internal organ displacements and deformations resulted in considerable deviations between the estimated delivered and planned doses between fractions. However, after accumulating the fractional dose distributions from all the fractions, the final cumulative dosimetric deviations were small. The differences had an observable expected clinical impact in only on one patient, where small bowel dose was 3% less than the treatment plan.