Investigating the impact of inter-fractional variations to the delivered dose to esophagus during VMAT for lung cancer using CBCT-based deformable image registration

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Purpose

This study aims at estimating the accumulated dose delivered to esophagus throughout the course of radiation therapy examining the dosimetric impact of its inter-fractional variations in location and shape. Also, to examine the dosimetric impact in treatment delivery when contrast is used during CT simulation.

Materials and methods

This analysis involves ten lung cancer patients treated with VMAT to 60Gy in 30 fractions using daily Cone Beam CT (CBCT). A total of 120 fractions of four patients were analysed. Manually contours drawn on each CBCT were used to drive the contour/intensity-based deformable image registration (DIR). MIM (MIM Software, Inc) was used to calculate the cumulative dose in esophagus. The clinical dosimetric metrics (mean dose, D_{1cc}) and the normal tissue complication probability (NTCP) were calculated for the comparisons with the treatment plans.

Table 1 shows the results of the comparisons between the planned and delivered doses for a number of different dosimetric and radiobiological metrics. Fig. 1 illustrates 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 differentiating the patients, who were simulated with and without contrast.

Table 1. Summary of the delivered doses to esophagus based on the CBCTs and the doses from the treatment plans for four of the patients. The clinical goals were: D_{mean} < 34 Gy, $D_{0.1cc}$ < 60 Gy.

Patient	Dose Distribution	D_{mean} (Gy)	D_{max} (Gy)	$D_{0.1cc}$ (Gy)	NTCP (%)	BEUD (Gy)
With Contrast						
1	Plan	18.3±22.7	63.5	62.6	13.0	58.9
	Delivered	18.4±22.2	62.3	61.9	10.5	58.0
2	Plan	20.0±24.2	63.4	62.4	12.7	58.7
	Delivered	19.7±23.1	61.7	61.5	10.4	57.9
Without Contrast						
3	Plan	26.6±24.4	62.3	61.9	14.0	59.1
	Delivered	27.2±25.0	61.7	61.6	15.0	59.4
4	Plan	14.4±14.8	53.3	49.5	0.03	47.1
	Delivered	14.7±14.9	55.4	51.7	0.17	49.1

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 dosimetric deviations ended up to be small.

More specifically, the expected clinical impact on the outcome was 0.1-1.0% for the patients without contrast and around 2.5% for the patients with contrast during simulation.

Results

The results were grouped based on whether the patient was CT simulated with or without contrast. The dose differences between the delivered doses and those in the treatment plan were less than 1.0 Gy in mean dose for all the patients. Regarding the clinical metric D1cc, the differences ranged between 0.3-2.2Gy and in most cases the doses were lower for the delivered doses. The NTCP values were 2.5% lower for the delivered doses for the patients with contrast compared to 0.1-1.0% for the patients without contrast (where the values were lower for the plans). The values of the biologically effective uniform dose followed the same pattern.

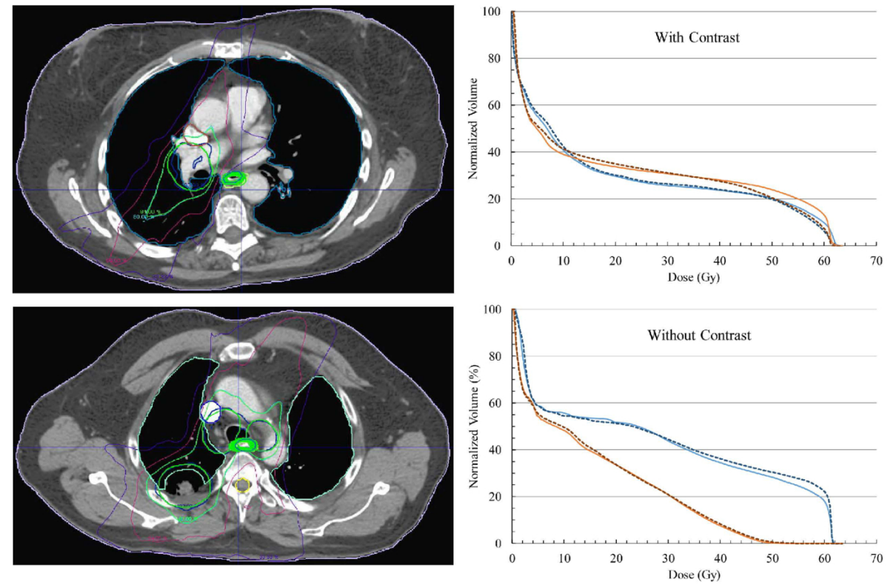

Fig. 1. Left panel: Central axial CT slice of two patients where the inter-fractional variation in the position and shape of esophagus is shown against the isodose lines. Right panel: The planned and delivered DVHs of the four analyzed patients are presented. The upper plot shows the results of two patients, who received contrast during CT simulation, whereas the lower plot refers to patients, who were simulated without contrast.

Conclusions

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 dosimetric deviations were small. It seems that the use of contrast during simulation have some impact in the dose delivered to esophagus compared to treatment plan.

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