Feasibility of gold fiducial markers as a surrogate for GTV position in image-guided radiotherapy of rectal cancer

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PURPOSE:

To evaluate the feasibility of fiducial markers as a surrogate for GTV position in image-guided radiotherapy of rectal cancer.

METHODS:

We analyzed 35 fiducials in 19 rectal cancer patients who received short course radiotherapy or long-course chemoradiotherapy (LC-CRT). Two MRI exams and daily pre- and post-irradiation CBCT scans were acquired in the first week of radiotherapy. Weekly CBCT scans were acquired thereafter for patients that received LC-CRT. Between the two MRI exams, the fiducial displacement relative to the center of gravity of the GTV (COG_{GTV}) and the COG_{GTV} displacement relative to bony anatomy was determined. Using the CBCT scans, inter- and intrafraction fiducial displacement relative to bony anatomy was determined.

RESULTS:

The systematic error of the fiducial displacement relative to the COG_{GTV} was 2.8, 2.4 and 4.2 mm in the left-right (LR), anterior-posterior (AP) and craniocaudal (CC) direction. Large interfraction systematic errors of up to 8.0 and random errors up to 4.7 mm were found for COG_{GTV} and fiducial displacements relative to bony anatomy, mostly in the AP and CC directions. For tumors located in the mid- and upper rectum these errors were 9.4 (systematic) and 5.6 mm (random) compared to 4.9 and 2.9 mm for tumors in the lower rectum. Systematic and random errors of the intrafraction fiducial displacement relative to bony anatomy were <2.1 mm in all directions.

CONCLUSION:

Large interfraction errors of the COG_{GTV} and the fiducials relative to bony anatomy were found. Therefore, despite the observed fiducial displacement relative to the COG_{GTV}, the use of fiducials as a surrogate for GTV position reduces the required margins in the AP and CC direction for a GTV boost using image-guided radiotherapy of rectal cancer. This reduction may be larger in patients with tumors located in the mid- and upper rectum compared to the lower rectum.

SUPPORTING DOCUMENT

Innovation/Impact:

In rectal cancer, there is an increased interest for organ preservation for patients who achieved a complete response after chemoradiotherapy. Boosting the primary tumor is suggested to increase the pathological complete response rate in rectal cancer patients. We consider this study innovative, as it is the first study to investigate the feasibility of fiducials as a surrogate for the gross tumor volume (GTV) position in a GTV boost setting for rectal cancer patients. The results of this study show that using fiducials, the tumor can be irradiated more precisely while sparing the surrounding tissue.

Key results:

The calculated displacements and resulting systematic and random errors were combined to calculate the errors of different setup correction scenarios (Table 1). Corresponding margins were calculated using the Van Herk margin recipe [1]. Setup correction based on fiducials reduces required margins in the anterior-posterior and craniocaudal direction compared to setup correction based on bony anatomy. However, a fiducial-GTV uncertainty remains. Setup correction based on a direct visualization of the GTV, for instance using a MR-guided radiotherapy system, would therefore further reduce required margins.

Table 1. Systematic error, random error and corresponding margin for different setup correction scenarios

		LR (mm)	AP (mm)	CC (mm)	Combined errors
Setup correction based on bony anatomy (COG_{GTV} MRI data)	Σ	2.9	7.3	8.2	Interfraction COG_{GTV} displacement w.r.t bony anatomy
	σ	1.4	1.7	2.1	Intrafraction fiducial displacement w.r.t. bony anatomy
	Margin	8.3	19.5	21.9	
Setup correction based on bony anatomy (fiducial CBCT data)	Σ	3.7	5.0	4.9	Interfraction fiducial displacement w.r.t bony anatomy
	σ	3.0	4.5	5.1	Intrafraction fiducial displacement w.r.t. bony anatomy
	Margin	11.3	15.7	15.8	
Setup correction based on fiducials	Σ	2.9	2.8	4.5	Interfraction fiducial displacement w.r.t. COG_{GTV}
	σ	1.5	1.9	2.3	Intrafraction fiducial displacement w.r.t bony anatomy
	Margin	8.3	8.3	12.8	
Setup correction based on GTV	Σ	0.8	1.4	1.6	Intrafraction fiducial displacement w.r.t. bony anatomy
	σ	1.4	1.7	2.1	
	Margin	3.0	4.7	5.5	

Σ = systematic error, σ = random error

[1] Van Herk M, Remeijer P, Rasch C, Lebesque J V. The probability of correct target dosage: Dose-population histograms for deriving treatment margins in radiotherapy. Int J Radiat Oncol Biol Phys 2000;47:1121–35.