Real-time prostate motion evaluation during intensity-modulated radiotherapy; an assessment of time dependency of intrafraction motion

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Purpose

❖ The prostate location can change systematically during the treatment course while fluctuating randomly around its mean daily position.
❖ Systematic and random variations in prostate location can also occur during daily treatment fractions.
❖ The purpose of this study was to quantify and describe prostate intrafraction motion using real-time electromagnetic transponder detection in a cohort of patients treated with classic intensity-modulated radiotherapy (IMRT).
❖ Furthermore, this study also sought to identify intrafraction time trends, if any, in the prostate motion.

Methods

❖ Sixty-eight supine prostate patients each implanted with three electromagnetic transponders and underwent a course of 39 fractions of definitive IMRT formed the basis of this study.
❖ Daily localization was based on transponder detection, with weekly independent validation using volumetric imaging.
❖ Intra-treatment target motion was monitored continuously by the Calypso System with a 4-mm action level for post localization intra-treatment positional corrections.
❖ Population statistics were calculated and the effect of treatment duration on random and systematic errors was evaluated.
❖ The fraction of time the prostate was displaced by > 1, > 2, > 3 and > 4 mm was calculated for each session and patient.
❖ The frequencies of displacements after initial patient positioning were analyzed over time.

Results

Time (min)	LR			SI			AP		
	M (mm)	RE (mm)	SE (mm)	M (mm)	SE (mm)	RE (mm)	M (mm)	SE (mm)	RE (mm)
1-4	0.01	0.19	0.77	0.00	0.34	1.13	-0.21	0.34	1.27
4-8	0.02	0.41	0.94	0.02	0.55	1.42	-0.43	0.59	1.59
8-12	-0.11	0.63	1.14	0.01	0.91	1.73	-1.07	0.91	1.85
12-16	-0.16	0.69	1.21	-0.10	1.02	1.91	-1.33	0.96	1.86

Table 1: LR, SI, and AP systematic error (SE) and random error (RE), computed at discrete intra-treatment time periods.

Results

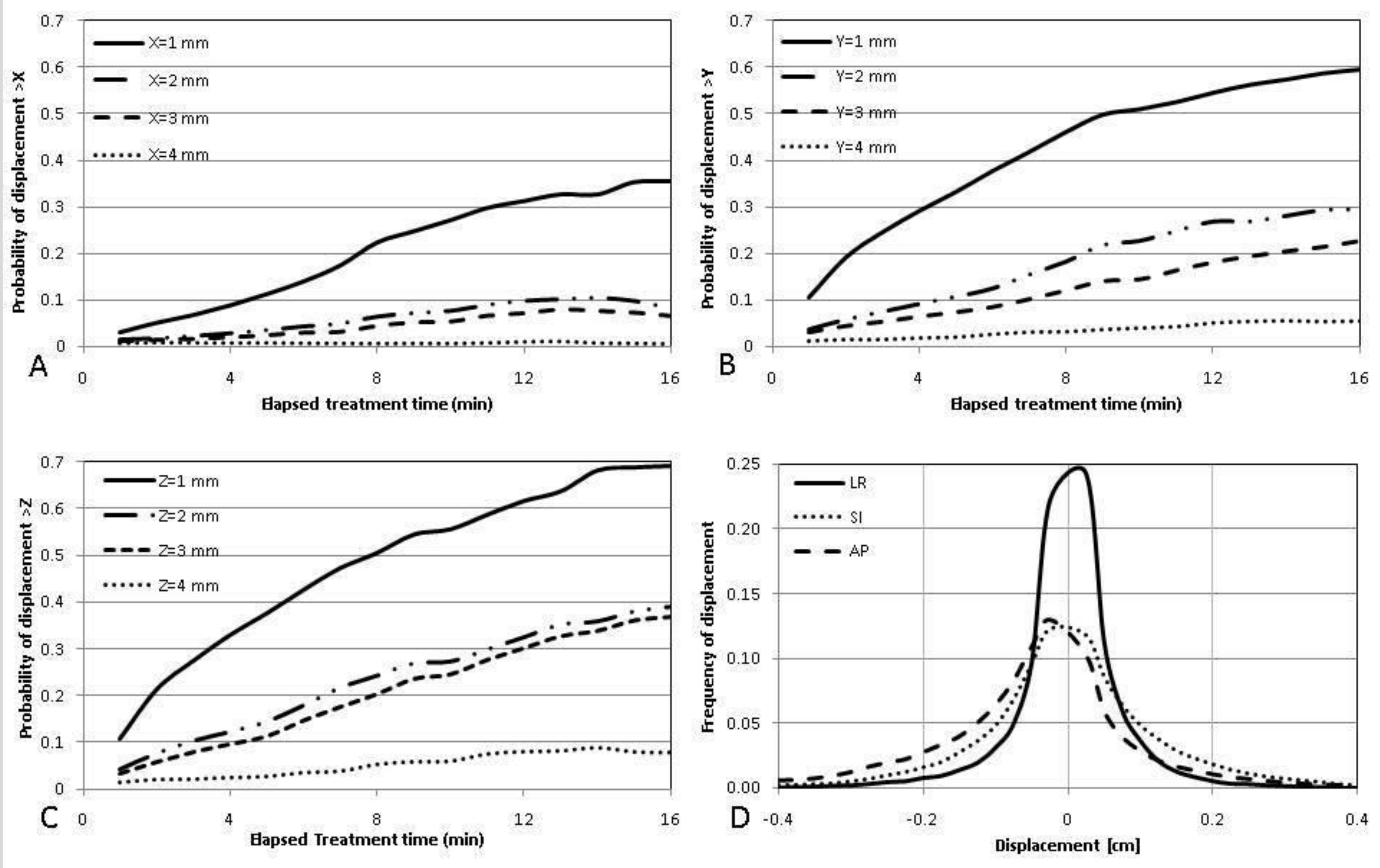

Figure 1: Probability of displacement in the (A) LR or X, (B) AP or Y and (C) SI or Z directions vs. elapsed treatment time. (D) Overall frequency of displacement throughout the course of treatment.

Results

❖ The probability of motion increased with treatment duration and was most significant in the anterior-posterior direction (AP) and least in the left-right (LR) direction (Table 1 and Figure 1A-C).
❖ Overall, prostate displacement > 4 mm in the LR, superior-inferior (SI), AP directions were non-negligible; 0.8%, 2.6%, and 3.8% of the total treatment time, respectively (Figure 1D).
❖ Considerable variability in prostate motion was observed among the cohort; the probability of a > 4-mm, > 3-mm, > 2-mm and > 1-mm displacement ranging from 0.0 – 9.8%, 0.4 – 15.4%, 1.3 – 32.9% and 12.4 – 58.6%, respectively.

Conclusions

❖ Intrafraction motion was found to be patient-specific suggesting individualized management approaches.

❖The likelihood of prostate displacement increased with elapsed treatment time:

❖ Indicating the relevance of prompt initiation of dose administration post patient positioning/repositioning.

❖ Suggesting temporal dependency of intrafraction uncertainties be taken into consideration in order to avoid bias in margin assessment.

❖ The temporal dependence of intrafraction motion was found to be much more significant in the SI and AP directions than in the LR direction.

Presented at: the 93rd Annual Meeting of the American Radium Society, Palm Beach, Florida, April 30 – May 4, 2011
Support for this project was provided, in part, by Calypso Medical Technologies, Inc.