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

James A. Tanyi, Tongming He, Sanja Ognjenovic, Tulsee S. Doshi, Lu Z. Meng, Arthur Y. Hung

Division of Medical Physics, Department of Radiation Medicine, Knight Cancer Institute, Oregon Health and Science University, Portland, Oregon, USA

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

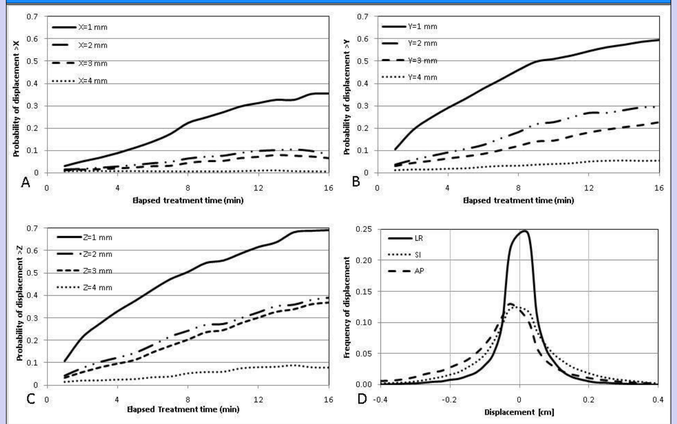

Figure 1: Probability of displacement in the (A) LR or X, (B) AP or Y and (C) SI or Z directions vs. elapsed treatment time. (D) Overall frequency of displacement throughout the course of treatment.

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.

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.