

Theme: Physics Abstract No.: 0078

A Shuttle-based MR-guided Workflow and Margin Calculation in Prostate Proton Therapy

Chin Chak HO¹, Darren Ming Chun POON², Yeung Sum WONG¹, Hui GENG¹, Wai Wang LAM¹, Ka Keung TANG¹, Ting Chuan LI¹, Wing Ki Claudia CHAN¹, Shu Ting HUNG¹, Kin Yin CHEUNG¹, Siu Ki YU¹, Bin YANG¹

¹ Medical Physics Department, HKSH Eastern Medical Center, Shau Kei Wan, Hong Kong;
² Comprehensive Oncology Centre, Hong Kong Sanatorium & Hospital, 2 Village Road, Happy Valley, Hong Kong

Background / Aims:

Positional verification of the prostate gland and nearby organs-at-risk is essential in prostate proton therapy (PT). A shuttle-based MR-guided workflow was proposed to account for the inter-fractional prostate position changes relative to bony structure. A dose probability-based margins for the proposed workflow was established.

Subjects and Methods:

Thirty prostate cancer patients that underwent 5-fraction stereotactic body proton therapy were included. All patients were implanted with fiducial markers for prostate localization. T1-weighted Dixon MRI was acquired before each fraction at treatment position for positional verification. A two-step rigid-body registration was performed simulating on-line orthogonal X-ray image matching during PT treatment: 1) A translational and rotational image registration based on bony structure; 2a) A translational only image registration based on fiducial markers; 2b) A translational only image registration based on the prostate gland. The differences in bone to fiducial correction (b2fΔ) obtained from orthogonal X-ray images and pre-treatment MRI was used to calculate the standard deviation of the systematic errors (Σ) and the random errors (σ) as described by van Herk¹. The dose probability-based margin formulation was used to ensure that 90% of patients receive the 95% of prescribed dose to CTV.

Result:



Margin = $2.5 \sqrt{\Sigma_{b2f\Delta}^2 + \Sigma_{motion}^2} + 1.64 \sqrt{\sigma_{b2f\Delta}^2 + \sigma_{motion}^2 + \sigma_{PT\ penumbra}^2 + \sigma_{reg}^2} - 1.64 \sigma_{PT\ penumbra}$

	LR		AP		SI	
	Σ (mm)	σ (mm)	Σ (mm)	σ (mm)	Σ (mm)	σ (mm)
Bone to fiducial correction (b2fΔ)	0.70	0.92	1.20	1.48	1.14	1.69
Intra-fractional motion	0.68	1.26	0.50	0.99	0.42	0.58
PT penumbra width	-	4.05	-	1.72	-	1.00
Interobserver registration uncertainty	-	0.40	-	0.80	-	1.00
Margin (mm)	2.95		4.69		5.12	

The intra-fractional motion uncertainty (Σ_{motion} , σ_{motion}) was estimated by the fiducial tracking data from 9 localized prostate cancer patient treated with Cyberknife.

$\sigma_{PT\ penumbra}$ denotes the SD of the penumbra width between the 50% to the 95% isodose line, in which the PT treatment plan was optimized to accommodate a 5mm patient position uncertainty and 3% range uncertainty.

The interobserver registration uncertainty (σ_{reg}) was calculated as the SD of the grouped registration results.

The proposed shuttle-based MR-guided workflow with the margin formulation offering a potential alternative to traditional fiducial marker-based prostate localization in proton therapy.

¹ Van Herk M, Remeijer P, Rasch C, Lebesque JV. The probability of correct target dosage: dose-population histograms for deriving treatment margins in radiotherapy. *Int. J. Radiat. Oncol.* 2000; 47(4): 1121–1135.