Real-time intrafraction prostate motion during dose-escalated linac-based SBRT

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Purpose

Extreme hypofractionation requires tight CTV to PTV margins, high dose gradients, and strict adherence to planning criteria in terms of patient positioning and organ motion mitigation. An electromagnetic (EM) transmitter-based tracking device for prostate and urethra localization and monitoring during prostate cancer SBRT was implemented. The aim of this study was to evaluate the intra-fraction prostate motion in the very first clinical use worldwide.

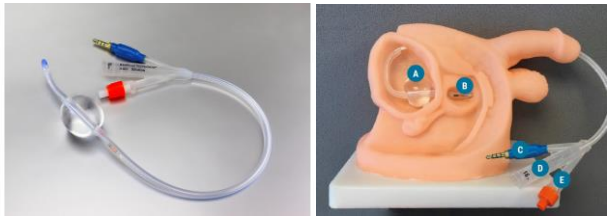


Figure 1. Raypilot Hypocath Component: A) Balloon in bladder; B) transmitter; C) Connector; D) Standard urine out lumen; E) Valve for balloon [1]

Materials and Method

Thirteen patients with organ-confined prostate cancer underwent dose-escalated SBRT in 4 or 5 fractions (BED1.5= 279 Gy and 253 Gy, respectively), using Volumetric Modulated Arc Therapy (VMAT) techniques with flattening filter free (FFF) beams on VersaHD linac. The EM tracking device consisted in an integrated Foley catheter with a transmitter in a dedicated lumen [1]. Signals sent by the transmitter were detected by antennas in a specific receiver placed on the linac couch. The system was calibrated to the treatment room isocenter and, based on the known relationship between the transmitter center and the isocenter in the planning CT, the system allowed treatment localization in addition to motion tracking.

Starting from the daily CBCT and during the delivery, the prostate motion was tracked with the EM system [2] and SBRT was interrupted when a 2-mm threshold was trespassed and corrected by a new CBCT, unless the offset was transient. Real-time measurement of prostate displacement was recorded for each treatment fraction. These measurements were used to determine the duration and magnitude of displacement along the three directional axes.

Result

Total treatment time lasted on average 10.2 minutes, 6.7 minutes for setup and 3.5 minutes for beam delivery [3]. In 45% of the monitored fractions, a new CBCT was mandated. The CBCT was repeated during the initial setup phase in 15 out of 56 fractions, while the beam delivery was interrupted only in 10. The mean value of the target average deviation was -0.18 mm, -0.01 mm, and -0.26 mm in vertical, lateral, and longitudinal direction, respectively. No main direction in the prostate displacement was observed. The prostate was found within 1 mm from its initial position in 83% of the treatment time, between 1 and 2 mm in 13.0%, and exceeds 2 mm only in 4% [4] .

Setup time (min)		
Mean	6.7	range [2.7-17.8]
SD	3.8	
Median	4.7	
Delivery time (min)		
Mean	3.5	range [2.5-7.3]
SD	0.9	
Median	3.3	
Total treatment time (min)		
Mean	10.2	range [5.5-22.7]
SD	4.2	
Median	8.0	

Figure 3. Phases duration analysis: mean, median, standard deviation and range of setup phase, treatment phase and global session [3]

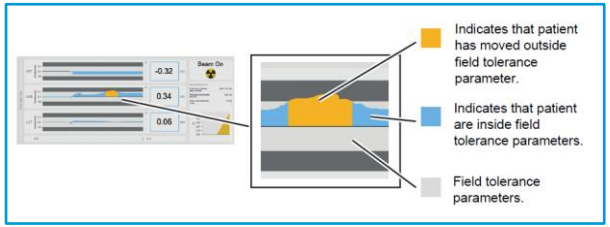
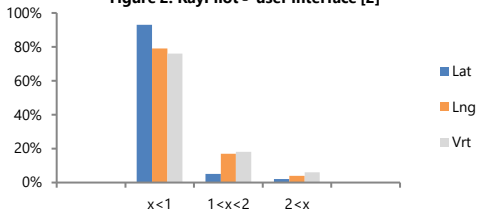


Figure 2. RayPilot® user interface [2]



Total treatment	Lat	Lng	Vrt	Mean
x<1	93%	79%	76%	83%
1<x<2	5%	17%	18%	13%
2<x	2%	4%	6%	4%

Figure 4. Histogram of prostate motion in the three directions from all the 56 treated fractions [4]

Conclusions

Our findings show that EM tracking is a reliable technique for real-time non-ionizing prostate monitoring during dose-escalated SBRT, allowing to keep the average target motion within 2 mm. It could be implemented rapidly and resulted well tolerated by the patient. Using FFF VMAT beams shortened the treatment time and significantly contributed to reduce intra-fractional motion.