Quantification of Intrafraction Prostate Motion Using Detected Features in Sagittal 2D Cine-MR

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INTRODUCTION

Intrafraction motion can degrade target coverage or increase dose to healthy surrounding tissues during extreme hypofractionated radiotherapy of prostate cancer. PTV margins were traditionally largely determined by rigid setup uncertainty, however prostate motion is non-rigid. Cine MR is a useful modality to continually monitor the non-rigid motion of internal pelvic organs with high soft-tissue contrast. From the knowledge of dynamic anatomy changes proper IGRT protocol can be established.

AIM

To describe intrafraction motion of different regions of prostate and seminal vesicles (P+SV) using cine-MR.

METHOD

For nine consecutive prostate cancer patients, 2D sagittal cine-MR was acquired for a median of 8 minutes (range 5-11 min) with a frame rate of 1.8 frames/sec . The characteristic features (KFs) were recognized on the first image of cine-MR series by the Harris corner detector [1]. The region of interest included prostate and seminal vesicles (P+SV). The extracted set of points were tracked through consecutive images of cine-MR frames using the Kanade-Lucas-Tomasi (KLT), feature-tracking algorithm. From tracking 2D position changes of KFs, the time-series were generated. To robustness of tracking were ensured by setting the bidirectional error to 0.5 mm[3].

In order to find patterns and/or similarities among different KFs tracks, hence different prostate anatomy regions, we applied spectral clustering of the generated time series [4]. The centroids of different clusters is used for evaluation and description of motion of the prostate+SV.

The analysis was done in Matlab R2018a.

RESULTS

The patterns in time-series showed distinctive sets of movement for different parts of P+SV. The posterior part of the prostate and SV were more sensitive to rectum movement. Anterior part, adjacent to the pubic bone, base, and apex of the prostate were less affected by the rectum movement and hence less prone to deviate from the initial position. The full bladder had non-significant interference on the position of P+SV. The probability that displacement of P+SV is within 5 mm on the last frame was 100% for all patients. The probabilities of maximum displacements to be in 5mm during the whole cine MR time for different regions of P+SV over patients

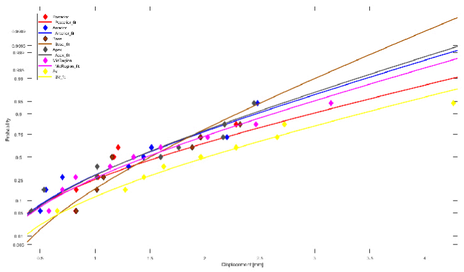

Figure 1. The probability distribution of features displacements on the last frame of the cine MR series over patients population(data points)

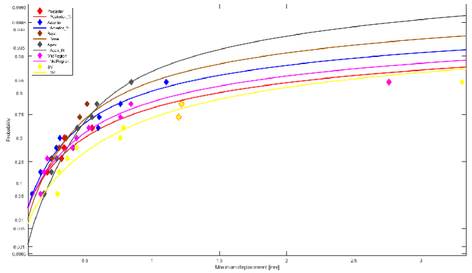

Figure 2. The probability distribution of maximum features displacements for the full cine MR scan over patients population(data points)

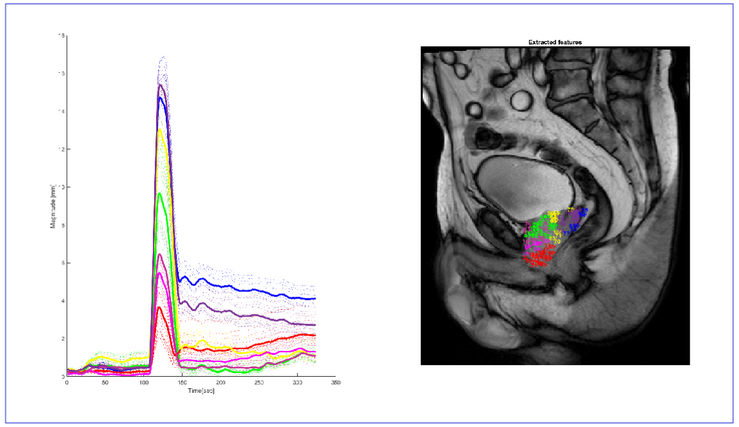

Figure 3. The example of tracking output for one patient. KP were recognized by Harris corner detector on the right image. On the left are extracted time series for different KPs. The colours indicate different clusters of time series based on spectral clustering.

Table 1. Probabilities that displacement on the last frames and maximum displacements during full cine MR is less than or equal to a specified value over patient population. Average acquisition time was 8 (5-11) min..

	<5 mm		<3.5mm		<3mm		<2.5mm		<2mm	
	Displacement on the last frame	Max Displacement during full CINE	Displacement on the last frame	Max Displacement during full CINE	Displacement on the last frame	Max Displacement during full CINE	Displacement on the last frame	Max Displacement during full CINE	Displacement on the last frame	Max Displacement during full CINE
Posterior region	100%	87%	95%	76%	90%	70%	81%	61%	68%	50%
Anterior region	100%	96%	99%	88%	97%	82%	91%	73%	78%	58%
Base	100%	93%	99%	84%	99%	79%	95%	70%	79%	58%
Apex	100%	98%	99%	94%	98%	90%	92%	80%	78%	65%
Mid region	100%	93%	98%	84%	95%	77%	87%	68%	73%	56%
SV	100%	82%	91%	65%	81%	56%	68%	44%	49%	31%

CONCLUSIONS

We were able to describe prostate motion as time-series of independent features in cine-MR. The posterior part and SV are more correlated to the rectum movement. Anterior part, adjacent to the pubic bone, base, and apex are less affected by the rectum movement and hence less prone to deviate from the initial position. We didn't find significant interference of full bladder to localization of prostate base or SV. Time-series showed the slow drifting motion of the organ and excursion of P+SV. The rectum filling is a major cause of organ deformation and excursion. The deformation of P+SV can be significant and should be taken into account to optimize planning margin, especially for SBRT and proton treatments.

REFERENCES

[1] Chris Harris and Mike Stephens (1988). A Combined Corner and Edge Detector. 1988, Alvey Vision Conference;15.

[2] Carlo Tomasi and Takeo Kanade. Detection and Tracking of Point features. Carnegie Mellon University Technical Report CMU-CS-91-132, 1991.

[3] Kalal, Zdenek, Krystian Mikolajczyk, and Jiri Matas. Forward-Backward Error: Automatic Detection of Tracking Failures., Proceedings of the 20th International Conference on Pattern Recognition, 2010, 2756–2759.

[4] Wang F., Zhang C. Spectral Clustering for Time Series. In: Singh S., Singh M., Apte C., Perner P. (eds) Pattern Recognition and Data Mining. ICAPR 2005. Lecture Notes in Computer Science, vol 3686. Springer, Berlin, Heidelberg

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