Impact of Temporal Resolution on Diagnostic Performance of Quantitative DCE-MRI of Prostate Cancer: Evaluation using a Novel Golden-Angle Radial Compressed-Sensing Sequence and Single Contrast Injection

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Purpose: The temporal resolution used for dynamic contrast-enhanced (DCE)-MRI of the prostate has varied greatly in the literature, with minimal data available to indicate the optimal temporal resolution. Determination of the temporal resolution achieving optimal diagnostic performance is methodologically challenging and would typically entail obtaining DCE data in a single patient during multiple sessions at different resolutions, each with its own intravenous contrast injection. A novel DCE-MRI technique named GRASP (Golden-angle Radial Sparse Parallel imaging) has recently been described that combines continuous golden-angle radial k-space acquisition, iterative image reconstruction, compressed-sensing, and parallel-imaging [1,2]. GRASP acquires continuous dynamic k-space data with no inherent temporal resolution and allows retrospective reconstruction at variable temporal resolutions based on the number of consecutive radial spokes grouped in a given time-point (i.e., fewer spokes combined to achieve faster resolution). Thus, GRASP allows direct comparison of multiple temporal resolutions in a single patient via a single contrast injection and continuous post-contrast acquisition. In this study, we employ the GRASP technique to compare the diagnostic performance of different rapid temporal resolutions for prostate DCE-MRI, based on a quantitative analysis.

Methods: 30 men with biopsy proven prostate cancer (63±8y) who underwent 3T pelvic phased-array coil MRI before prostatectomy were included in this retrospective IRB-approved study. All examinations included GRASP DCE-MRI performed using a fat-suppressed radial "stack-of-stars" 3D FLASH sequence with golden-angle ordering (TR/TE 4.10/1.89 ms, FA 12°, slice thickness 3 mm, 21 slices, FOV 240 x 240, matrix 224 x 224, resulting in a voxel size of 3.0 x 1.1 x 1.1 mm, 3,192 radial spokes, total acquisition time 5:55 min). Six dynamic data-sets were retrospectively reconstructed from this single acquisition using a radial variant of the multi-coil k-t SPARSE-SENSE method [3], with a variable number of spokes (8 to 89 spokes) grouped into each dynamic frame, thereby providing temporal resolutions varying from 0.9 to 9.7 sec (Table 1) [1]. Two radiologists evaluated images in consensus to localize on DCE-MRI the dominant tumor identified on pathologic assessment of prostatectomy specimens. 4 patients were excluded [dominant tumor not visualized on DCE-MRI, n=3 (all Gleason score=6); marked motion limited DCE assessment, n=1]. For the remaining 26 patients [15 low grade, Gleason ≤ 3+4; 11 high grade, Gleason ≥ 4+3], ROIs were placed on the dominant tumor and benign peripheral zone (PZ) using in-house software, and K_{trans} was separately derived from the ROIs for each of the six temporal resolutions using a two-compartment Tofts model and patient-specific arterial input function (AIF). Tumor-to-PZ contrast of K_{trans} values was computed as (Tumor-Benign)/(Tumor+Benign) [4]. Statistical tests comprised paired and unpaired t-tests, repeated measure analysis of variance, and ROC analysis.

Results: For all six temporal resolutions, K_{trans} was significantly higher in tumor than in benign PZ ($p<0.001$), as well as significantly higher in high-grade than in low-grade tumor ($p\leq0.042$). Tumor-to-PZ contrast of K_{trans} was nearly identical among temporal resolutions ($p=0.345$). AUC for benign vs. tumor was uniformly high and did not vary significantly among resolutions ($p\geq0.312$); AUC for low vs. high grade tumor was uniformly moderate and also did not vary among resolutions ($p\geq0.259$).

Table 1: Comparison of six DCE-MRI data-sets reconstructed from single continuous radial acquisition

Temporal Resolution	0.9 sec (8 spokes)	1.4 sec (13 spokes)	2.3 sec (21 spokes)	3.7 sec (34 spokes)	6.0 sec (55 spokes)	9.7 sec (89 spokes)
Tumor k_{trans}	1.52 ± 1.09	1.53 ± 1.11	1.55 ± 1.12	1.54 ± 0.70	1.51 ± 1.08	1.48 ± 1.05
Benign PZ k_{trans}	0.52 ± 0.36	0.51 ± 0.37	0.59 ± 0.59	0.50 ± 0.37	0.50 ± 0.36	0.49 ± 0.36
Tumor-to-PZ contrast	0.46 ± 0.20	0.47 ± 0.20	0.46 ± 0.22	0.48 ± 0.20	0.48 ± 0.20	0.47 ± 0.20
High grade tumor k_{trans}	2.04 ± 1.38	2.07 ± 1.40	2.09 ± 1.41	2.06 ± 1.39	2.01 ± 1.37	1.96 ± 1.34
Low grade tumor k_{trans}	1.14 ± 0.63	1.14 ± 0.63	1.15 ± 0.63	1.15 ± 0.63	1.14 ± 0.64	1.12 ± 0.61
AUC for tumor	0.87 ± 0.05	0.88 ± 0.05	0.85 ± 0.05	0.87 ± 0.05	0.88 ± 0.05	0.87 ± 0.05
AUC for high grade tumor	0.72 ± 0.11	0.70 ± 0.11	0.72 ± 0.11	0.72 ± 0.11	0.72 ± 0.11	0.70 ± 0.11

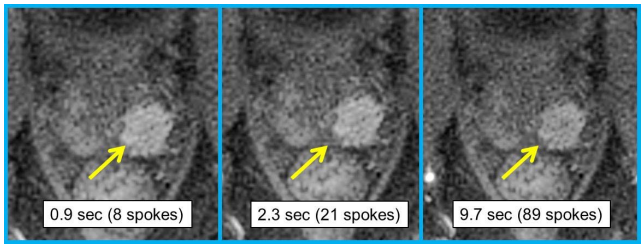

Figure 1: Similar appearance of left PZ Gleason 4+4 tumor from various retrospective reconstructions of single GRASP DCE-MRI data set at different temporal resolutions.

Discussion: Our findings suggest that when performing quantification of DCE-MRI of prostate cancer, a variation in temporal resolution from about 1 to 10 seconds minimally impacts K_{trans} values and subsequent diagnostic performance. Thus, when performing prostate perfusion quantification, rather than aiming to achieve the fastest temporal resolution possible, it may be more worthwhile to balance temporal resolution with spatial resolution and robust image SNR. This observation is clinically relevant given the widely variable temporal resolution of prostate DCE-MRI in the existing literature. Our assessment was possible using a single contrast injection and DCE acquisition given the application of the GRASP technique that provides retrospective reconstruction of flexible temporal resolutions, thereby demonstrating a novel framework for evaluation and optimization of DCE methodology in the prostate.

Conclusion: Increasing the temporal resolution from 10 sec to 1 sec did not improve diagnostic performance of quantitative prostate DCE-MRI. A novel continuous golden-angle radial acquisition sequence (GRASP) enabled this assessment using a single injection.

Ref: [1] Feng L, et al. MRM 2013; [Epub]. [2] Chandarana H, et al. Invest Radiol 2013 48:10-6. [3] Otazo R, et al. Magn Reson Med 2010; 64:767-76. [4] Cornfield DM et. al. J Magn Reson Imaging 2008 Jul; 28(1):121-7