Combined Compressed Sensing, Parallel Imaging, and Golden-Angle Radial Sampling for High Spatiotemporal Dynamic Contrast-Enhanced MRI of the Prostate

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Purpose: DCE-MRI of the prostate has traditionally been challenged by the inherent trade-off between spatial and temporal resolution. Recently, a novel technique for DCE-MRI has been proposed with the name of GRASP (Golden-angle RAdial Sparse Parallel imaging) [1], which is based on continuous golden-angle radial k-space acquisition and iterative image reconstruction combining compressed-sensing [2] and parallel-imaging [3] principles. By exploiting redundancies in continuously acquired data, which lead to sparse representation in an appropriate transform domain, and by making use of encoding capabilities of the receive coils, GRASP provides simultaneous high spatial and temporal resolution during free-breathing, as previously demonstrated in the liver [4]. This study aims to demonstrate the feasibility of performing high-spatiotemporal-resolution DCE-MRI of the prostate with GRASP and to compare image quality and lesion depiction between GRASP and conventional DCE-MRI in patients with biopsy-proven prostate cancer.

Methods: 20 men on active surveillance for prostate cancer (mean age 67±9y) were included in this retrospective IRB-approved study. Subjects underwent prostate MRI on two separate dates, once using standard DCE-MRI and once using GRASP. Imaging was performed at 3T (Siemens MAGNETOM Trio) using a pelvic phased-array coil. Standard DCE-MRI was acquired with a 3D FLASH sequence with TR/TE 2.84/0.94 ms, flip angle 16°, slice thickness 3 mm, 24 slices, FOV 240 x 240, matrix 128 x 128, no parallel imaging, providing a voxel size of 3.0 x 1.9 x 1.9 mm and 5.5 sec temporal resolution. GRASP was performed using a fat-suppressed radial "stack-of-stars" 3D FLASH sequence with golden-angle ordering with TR/TE 4.10/1.89 ms, flip angle 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 were acquired over 5:38 min and reconstructed using a radial variant of the multi-coil k-t SPARSE-SENSE method [5] with temporal TV constraint. 21 consecutive spokes were grouped into each dynamic frame, providing a temporal resolution of 2.3 sec per dynamic frame. Reconstruction time was about 25 min using a multi-thread C++ implementation of the algorithm on a 64-core computer. Two radiologists scored measures of subjective image quality on a 5-point scale (5=highest image quality), and also assessed conspicuity and size of the dominant lesion. The more experienced observer recorded the contrast arrival time in the dominant tumor and benign peripheral zone for each sequence. Statistical tests comprised paired Wilcoxon tests and Pearson correlation coefficients.

Table 1: Comparison of Standard (Stand.) DCE-MRI and GRASP

	Reader 1			Reader 2		
Feature	**Stand.**	**GRASP**	**p**	**Stand.**	**GRASP**	**p**
Clarity of capsule	4.0±0.9	4.7±0.6	**0.007**	3.9±0.7	4.7±0.5	**<0.001**
Clarity of PZ/TZ boundary	3.1±0.8	4.6±0.7	**<0.001**	3.6±0.7	4.5±0.7	**<0.001**
Clarity of urethra	2.1±0.8	3.8±1.0	**<0.001**	1.6±0.8	3.3±0.6	**<0.001**
Image sharpness	3.1±0.4	4.8±0.4	**<0.001**	3.3±0.6	4.8±0.4	**<0.001**
Overall image quality	3.1±0.4	4.7±0.5	**<0.001**	3.3±0.6	4.6±0.5	**<0.001**
Lesion conspicuity	3.2±1.2	4.5±0.8	**<0.001**	3.2±1.2	3.9±1.1	**0.020**

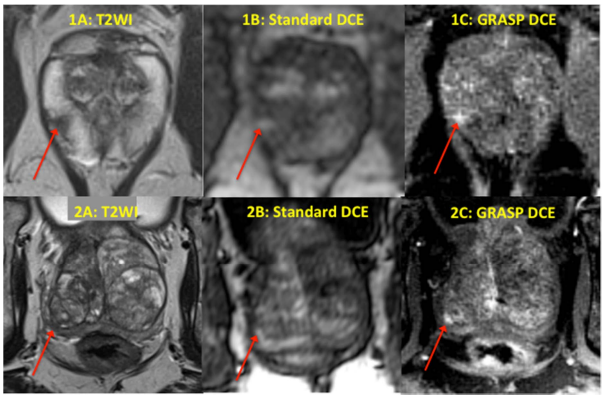

Figure 1, 2: T2WI (A), standard DCE (B) and GRASP DCE (C) images in two patients with prostate cancer. Note better depiction of anatomic details and of index tumor (arrow) in GRASP than standard DCE.

Results: Figures 1 and 2 compare images from two patients obtained with both standard DCE-MRI and GRASP. Table 1 shows results of the image quality assessments. There was significantly better image quality for GRASP than for standard DCE-MRI in all subjective quality measures from both observers, including clarity of the prostatic capsule, peripheral/transition zone (PZ/TZ) boundary, and urethra (p≤0.007). There was also significantly better conspicuity of the dominant lesion for GRASP for both readers (p≤0.020) and greater inter-reader correlation in terms of lesion size (GRASP: r=0.691-0.824, standard: r=0.495-0.542). In 8/20 cases, earlier contrast arrival time in the tumor than in the benign PZ was observed only with GRASP, while in no case was earlier contrast arrival in the tumor observed only with standard DCE-MRI

Discussion: Our proof-of-principle study demonstrates that prostate DCE-MRI with GRASP is possible in routine patients and enables improved resolution, both spatially and temporally, when compared to standard DCE-MRI. Prostate imaging is a particularly well suited application for GRASP due to the high degree of spatiotemporal correlation in the data acquired over several minutes. In addition, GRASP benefits from a high robustness to motion artifacts, which conventionally can degrade image quality if involuntary bowel motion occurs. Our preliminary data show that GRASP has the potential to improve the image quality, clarity of anatomic details, and spatiotemporal definition of focal lesions compared to standard DCE-MRI. Future studies are warranted to further assess the diagnostic performance of GRASP for the detection of prostate cancer in larger patient cohorts.

Conclusion: GRASP achieves high spatiotemporal resolution in DCE-MRI of the prostate, improving image quality and lesion depiction. It may serve as a viable solution to overcome resolution limitations of standard DCE-MRI techniques.

Ref: [1] Feng L, et al. MRM 2013; [Epub]. [2] Lustig M, et al. MRM 2007; 58:1182-95. [3] Pruessmann K, et al. MRM 2001; 46:683-51 [4] Chandarana H, et al. Invest Radiol 2013; 48:10-6. [5] Otazo R, et al. Magn Reson Med 2010; 64:767-76.