# Large-FOV High Temporal Resolution Free-Breathing MR Urography using a Continuous Golden-Angle Radial Acquisition Scheme with Compressed Sensing Reconstruction: Feasibility and Comparison with Standard Cartesian Acquisition

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**Purpose**: High resolution MR urography traditionally entails dynamic post-contrast imaging of the kidneys followed by delayed imaging of the ureters and bladder, although excreted gadolinium often limits bladder visualization at the delayed time-point. Obtaining dynamic imaging of both the upper and lower tracts is challenging given the large field-of-over (FOV) and need for high spatial resolution. A recently described novel DCE-MRI technique named GRASP (Golden-angle Radial Sparse Parallel imaging) that combines continuous golden-angle radial k-space acquisition, compressed-sensing, and parallel-imaging [1,2], provides simultaneous high spatial and temporal resolution, as well as potential large anatomic coverage. In addition, due to the radial k-space scheme, GRASP images are inherently motion robust [1]. In this study, we explore the feasibility of the GRASP technique for large-FOV high spatiotemporal resolution MR urography and compare its image quality with that of a conventional breath-hold post-contrast sequence.

| Feature | FB GRASP 1s / frame (4 spokes) | FB GRASP 2s / frame (8 spokes) | FB GRASP 4s / frame (17 spokes) | BH VIBE (approx. 20 seconds) |
|---|---|---|---|---|
| **CORTICOMEDULLARY PHASE** | | | | |
| Clarity of bladder mucosa | 3.5±0.8 | 4.2±0.8 | 4.3±0.5 | n/a |
| Absence of excreted gadolinium in bladder | 5.0±0.0 | 5.0±0.0 | 5.0±0.0 | n/a |
| Sharpness of renal contour | 3.8±0.8 | 4.2±0.4 | 4.3±0.5 | 4.0±0.0 |
| Absence of respiratory motion | 5.0±0.0 | 5.0±0.0 | 5.0±0.0 | 4.0±0.0 |
| Absence of radial streaks | 3.2±0.4 | 3.8±0.4 | 3.7±0.5 | n/a |
| Absence of ghosting | 5.0±0.0 | 5.0±0.0 | 5.0±0.0 | 3.7±0.5 |
| Overall image quality | 4.0±0.6 | 4.3±0.5 | 4.5±0.6 | 4.3±0.5 |
| **NEPHGROGRAPHIC PHASE** | | | | |
| Clarity of bladder mucosa | 4.0±0.6 | 4.2±0.8 | 4.7±0.8 | n/a |
| Absence of excreted gadolinium in bladder | 5.0±0.0 | 5.0±0.0 | 5.0±0.0 | n/a |
| Sharpness of renal contour | 3.3±0.8 | 4.0±0.6 | 4.3±0.5 | 4.0±0.0 |
| Absence of respiratory motion | 5.0±0.0 | 5.0±0.0 | 5.0±0.0 | 4.2±0.4 |
| Absence of radial streaks | 2.8±0.8 | 3.7±0.5 | 3.8±0.4 | n/a |
| Absence of ghosting | 5.0±0.0 | 5.0±0.0 | 5.0±0.0 | 4.5±0.6 |
| Overall image quality | 3.3±0.5 | 4.3±0.5 | 4.5±0.6 | 4.0±0.0 |
| **EXCRETORY PHASE** | | | | |
| Clarity of renal pelvis | 3.5±0.8 | 3.7±1.0 | 3.8±1.0 | 3.7±0.5 |
| Clarity of proximal ureter | 3.2±0.8 | 3.2±1.0 | 3.7±0.8 | 3.8±0.8 |
| Clarity of mid ureter | 3.2±0.8 | 3.5±0.6 | 3.8±0.8 | 3.0±0.9 |
| Clarity of distal ureter | 3.8±0.8 | 4.0±0.9 | 3.7±0.5 | 3.3±1.2 |
| Clarity of bladder mucosa | 3.5±0.6 | 3.7±0.8 | 4.2±0.8 | 3.2±1.0 |
| Absence of excreted gadolinium in bladder | 4.2±1.0 | 3.5±1.6 | 3.3±1.5 | 2.5±1.6 |
| Sharpness of renal contour | 3.0±0.6 | 3.3±0.5 | 3.7±0.5 | 4.2±0.4 |
| Absence of respiratory motion | 4.7±0.8 | 5.0±0.0 | 5.0±0.0 | 4.0±0.0 |
| Absence of streaks | 3.0±0.6 | 3.2±0.4 | 3.5±0.6 | n/a |
| Absence of other ghosting | 5.0±0.0 | 5.0±0.0 | 5.0±0.0 | 3.8±0.8 |
| Overall image quality | 3.2±0.4 | 3.5±0.8 | 4.0±0.6 | 3.3±0.5 |

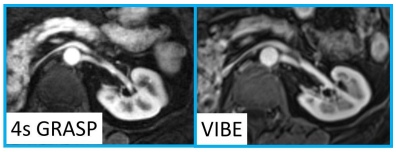


**Figure 1: Free-breathing GRASP image at 4 second temporal resolution shows comparable overall image quality compared with standard VIBE**

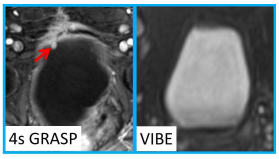


**Figure 2: Anterior bladder lesion (arrow) is well visualized using GRASP given inclusion of bladder in FOV for all time-points before gadolinium excretion. In comparison, bladder is obscured by excreted gadolinium for standard VIBE.**

**Methods**: The cohort comprised 6 patients (72±9y) who underwent 3T MR urography using GRASP DCE-MRI and who had undergone prior MR urography using conventional VIBE. GRASP was acquired continuously through the abdomen and pelvis during free breathing following contrast injection using a fat-suppressed radial "stack-of-stars" 3D FLASH sequence with golden-angle ordering (TR/TE 3.48/1.53 ms, FA 12°, ST 3 mm, 128 slices, FOV 350 x 100, matrix 256 x 256, voxel size 1.4x1.4x3.0 mm, 1,000 radial spokes, total acquisition time 3:44 min). Three dynamic data-sets were retrospectively reconstructed from this single continuous acquisition using a radial variant of the multi-coil k-t SPARSE-SENSE method [3], with a variable number of spokes (4, 8 and 17 spokes) grouped into each dynamic frame, providing temporal resolutions of 1, 2 and 4 seconds, respectively. For each reconstruction, the time-point most representative of corticomedullary (CM), nephrographic (NG), and excretory (EX) phases were selected for subsequent comparison. Intravenous diuretic (furosemide) was administered for GRASP and standard VIBE examinations. One radiologist evaluated image sets for measures of image quality (1-5 scale; 5=highest quality), and scores were compared between sequences using the Friedman test.

**Results**: Overall image quality was comparable between GRASP and standard VIBE (Table 1; Figure 1), although GRASP images had significantly less respiratory motion and significantly less ghosting compared with VIBE for all reconstructions and phases ($p<0.001$). GRASP also provided excellent bladder mucosal detail prior to filling of the bladder with excreted gadolinium; standard VIBE only visualized the bladder during the excretory phase, at which time excreted gadolinium obscured the bladder mucosa (Figure 2). GRASP with temporal resolutions of 2 seconds and 4 seconds had reduced radial streaks ($p=0.002$-$0.085$), increased renal contour sharpness ($p<0.001$ in excretory phase), and increased overall quality ($p<0.001$-$0.069$) compared with 1 second GRASP reconstructions.

**Discussion**: Our findings show that GRASP DCE-MRI is a feasible method for MR urography. This technique can be performed during free breathing, provides both high spatial and high temporal resolution (< 5 seconds per frame), and leads to reduced respiratory motion and ghosting artifact compared with standard breath-hold imaging. Furthermore, the large FOV achievable with GRASP allows bladder visualization prior to filling with excreted gadolinium. A temporal resolution for GRASP of 2-4 seconds seems preferable to 1 second due to reduced radial streak artifacts.

**Conclusion**: GRASP DCE-MRI has potential for achieving high quality comprehensive MR urography, although further optimization and validation in larger patient cohorts is warranted.

**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.