Flexible Temporal Reconstruction of Continuously Acquired Dynamic Contrast Enhanced Acquisition for Simultaneous Perfusion and Morphologic Imaging of the Abdomen

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Purpose: Dynamic contrast-enhanced (DCE) T1-weighted imaging of the abdomen with high temporal resolution can be used to assess hemodynamics in organs to generate relevant physiologic metrics. Of clinical importance are measurement of single kidney glomerular filtration rate (GFR) and liver perfusion[1]. Current DCE-MRI acquisition protocols require trade-offs between temporal resolution, volumetric coverage, and spatial resolution. Furthermore, protocols with high temporal resolution require additional contrast injection for morphologic clinical interpretation, as dynamic images usually lack suitable spatial resolution and SNR. To overcome many of these limitations, our group has developed a novel acquisition and reconstruction method that combines compressed sensing and parallel imaging for golden-angle radial trajectories called GRASP (GRASP: Golden-angle RAdial Sparse Parallel)[2,3]. With GRASP, dynamic k-space data is acquired continuously in free-breathing and can be reconstructed retrospectively with flexible temporal resolution by grouping different numbers of consecutive spokes in each single-dynamic frame. However, clinical implementation of this technique in routine practice requires validation of metrics obtained with GRASP against conventional Cartesian acquisitions, as well as qualitative evaluation of image quality of the GRASP reconstructions with different temporal resolution for morphologic assessment. Therefore, the **purpose of this study** is two-fold: (1) to compare MR measure of single kidney GFR (SK-GFR) obtained with GRASP to previously validated Cartesian FLASH DCE acquisition, and (2) to compare the image quality of arterial and venous phase GRASP reconstructions at different temporal resolutions.

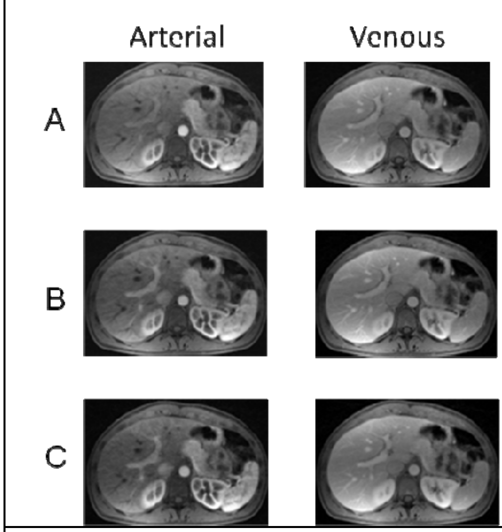

Figure 1: Arterial and Venous phase reconstructions with different spokes and temporal resolution: (A) 89 spokes at temporal resolution of 14.2 s, (B) 55 spokes at 8.8 sec, (C) 21 spokes at temporal resolution of 3.4 sec.

Methods: In this prospective HIPAA compliant IRB approved study, 5 healthy subjects were imaged twice on two consecutive days at 1.5 T (Siemens MAGNETOM Avanto, Erlangen, Germany). GRASP (3D radial FLASH) protocol entailed 2104 spokes acquired continuously over 5:37 minutes TR/TE 4.27/1.88 msec, FA 12^0, spatial resolution 1.5 x 1.5 x 3 mm, 64 slices acquired transaxially. For multi breath-hold FLASH we acquired 40 slices in coronal plane, parallel-imaging factor 3, spatial resolution 2.6 x 1.7 x 3 mm. FLASH acquisition was performed with temporal resolution of 3 seconds for the first minute and with longer temporal resolution subsequently[4]. 10 cc of gadopentate dimeglumine (Magnevist; Berlex Laboratories) intravenous contrast was injected followed by a 20-ml saline flush at a rate of 2cc/sec. Dynamic GRASP images were reconstructed by grouping consecutive 89 spokes for temporal resolution of 14.2 sec, 55 spokes for temporal resolution of 8.8 sec, and 21 spokes for temporal resolution of 3.4 sec. (**Figure 1**).

Image Analysis: Dynamic post-contrast FLASH and GRASP images with 3 sec temporal resolutions were transferred to a workstation and analyzed using in-house software[5]. Co-registration of the dynamic images across different time points was performed using mutual information algorithm. Regions of interest around the coregistered cortical and medullary regions of each kidney were used to generate concentration versus time curves[6]. A 2-compartment Bauman-Rudin renal model that doesn't require arterial input was used to generate SK-GFR[7]. The total MR-GFR (right + left SK-GFR) was compared between the GRASP and FLASH schemes to estimate GRASP GFR error (%). Two radiologists independently in a blinded fashion assessed image quality parameters on a 5-point scale, with the highest score indicating most desirable exam for the arterial and venous phase reconstructions of temporal resolution ranging from 3.4 sec to 14.2 sec.

Patient	GRASP MR-GFR	FLASH MR-GFR
1	100.7	104.9
2	89.2	91.6
3	99.7	106.3
4	104.6	112.3
5	101.1	100.6

Table 1: MR-GFR values

Results: The MR-GFR measure obtained with GRASP and FLASH for all 5 subjects are shown in **Table 1**. The average difference between GRASP and FLASH measures of MR-GFR was 4.3 ml/min/m^2 (range -0.5 to +7.7) with maximum difference of approximately 7%. The image quality parameters for the arterial and venous phases were averaged over two readers (**Table 2)**. There was no significant difference (p>0.1) in any image quality parameter between reconstructions with 21 spokes, 55 spokes, and 89 spokes.

Acquisition	Temporal resolution	Quality of Enhancement	Overall Image Quality	Hepatic Edge Sharpness	Hepatic Vessel Clarity
Arterial 21 spokes	3.4 Sec	4.5 ± 0.6	3.9 ± 0.5	4.7 ± 0.4	3.4 ± 0.7
Arterial 55 Spokes	8.8 Sec	4.6 ± 0.4	3.9 ± 0.4	4.6 ± 0.4	3.4 ± 0.7
Arterial 89 Spokes	14.2 Sec	4.5 ± 0.5	3.9 ± 0.7	4.7 ± 0.4	3.4 ± 0.7
Venous 21 spokes	3.4 Sec	4.7 ± 0.3	4.3 ± 0.3	4.9 ± 0.2	4.3 ± 0.6
Venous 55 Spokes	8.8 Sec	4.5 ± 0	4.4 ± 0.4	4.7 ± 0.3	4.2 ± 0.4
Venous 89 Spokes	14.2 Sec	4.5 ± 0.4	4.4 ± 0.2	4.8 ± 0.3	4.4 ± 0.4

Table 2: Image quality parameter scores

Conclusion and Future Direction: A single GRASP acquisition can be used to simultaneously provide morphologic and perfusion information. Thus perfusion metrics can be routinely and accurately generated in every patient undergoing contrast-enhanced imaging of the abdomen without additional acquisition time or contrast injection.

References: (1) Vivier PH et al. Radiology 2012. (2) Li et al. MRM 2013. (3). Chandarana et al. Invest Radiol2013. (4) Zhang JL et al. Am J Physiol Renal Physiol 2009 (5). Krepkin K et al AJR, 2014 (in press). (6). Bokacheva L et al. Magn Reson Med. 2007. (7). Bokacheva L et al. J Magn Reson Imaging 2009.