Ultra high spatio-temporal resolution liver imaging using a new view ordering scheme and a 2-point Dixon acquisition

M. Saranathan[1], D. Rettmann[2], A. S. Brau[3], B. A. Hargreaves[1], and S. Vasanawala[1]
[1]Radiology, Stanford University, Stanford, CA, United States, [2]Global Applied Science Laboratory, GE Healthcare, Rochester, MN, United States, [3]Global Applied Science Laboratory, GE Healthcare, Menlo Park, CA, United States

Purpose: Both Dynamic contrast enhanced MRI (DCEMRI) and MR angiography (MRA) are challenged by the conflicting requirements of spatial and temporal resolution. Various approaches have been proposed for high spatio-temporal resolution MRI [1-4], involving combinations of partial Fourier imaging, under-sampling, view sharing and parallel imaging to achieve high spatio-temporal acceleration. We propose DISCO (**DI**fferential **S**ubsampling with **C**artesian **O**rdering), a pseudo-random k-space segmentation scheme that minimizes sensitivity to eddy currents and motion for dynamic imaging while dispersing artifacts and residual ghosting. We demonstrate its use in fast multiphasic contrast enhanced liver imaging with a 32-channel torso-phased array coil, with no compromise in spatial resolution or coverage.

Methods: DISCO uses a variable density Cartesian undersampling scheme to generate a pseudo-random distribution of k-space. Elliptical k_y-k_z is segmented into N annular regions, each subsampled by a factor of *i* with the central region fully sampled and the outer regions progressively undersampled. For N=3, the region schedule is $AB_1C_1AB_2C_2AB_1C_3$… where X_i refers to subsampled region X (Fig 1b). Note that k-space points are confined to a Cartesian grid [3], enabling an FFT-based image reconstruction. Since each sub-region is elliptically ordered, eddy current artifacts present in random sampling are avoided while still imparting a degree of stochasticity. Temporal footprint was minimized by view sharing the undersampled views. View sharing was restricted to nearest neighbors and within a breath-hold, minimizing temporal blurring and motion mis-registration. **Experiments**- MATLAB simulations were used to compute the Point Spread Function (PSF) of sub-sampled CAPR and DISCO trajectories. As B_0 and B_1 inhomogeneities result in sub-optimal fat suppression at 3T, we used a 2-point Dixon method [5] for robust fat suppression. DISCO was incorporated into a dual-echo bipolar readout 3D SPGR sequence. Imaging parameters were as follows: 12° flip, ±167 kHz bandwidth, $TR/TE_1/TE_2$ 4.1/1.2/2.4 ms, 320x224 matrix, 30-35 cm FOV, 3 mm thick, 60 slices, self-calibrated hybrid space parallel imaging with 2x2 acceleration (along k_y and k_z). After obtaining informed consent, subjects were imaged on a GE 3T MR750 system (GE Healthcare, Waukesha, WI) using a 32-channel torso array coil optimized for high acceleration factors. For multiphasic gadolinium contrast imaging, 6 post-contrast phases were acquired with a temporal resolution of 4s in a 25s breath-hold. In order to evaluate DISCO's motion robustness and reduced temporal footprint, a second experiment was performed where volunteers were asked to hold their breath at slightly different positions in the first and second breath-holds and two sets of images reconstructed- view sharing within a breath-hold and across breath-holds.

Results: Figure 1 compares PSFs obtained from MATLAB simulations of CAPR and DISCO k-space segmentation schemes for the same total number of sampled points. Note the significant dispersal of ghosting energy in DISCO (D) compared to that of CAPR (C) due to the pseudo-random nature of sampling in DISCO. Figure 2 shows a section from a DISCO scan with view sharing across breath-holds (a) and view sharing restricted to within a breath-hold (b). Motion mis-registration artifacts are significantly reduced in (b). Figure 3 shows one pre-contrast phase (a) and 6 post-contrast phases (b-g) obtained in a patient following injection of gadolinium (single dose gadobenate dimeglumine) in 2 breath-holds (12s pre and 25s post). Note the clear separation of hepatic arterial and portal venous phases and progressive enhancement of the kidneys clearly captured due to the high temporal resolution (4s) as well the high spatial resolution and fat-suppression quality of the Dixon method.

Discussion: We have demonstrated the feasibility of DISCO in fast multiphasic whole-liver imaging owing to its high spatio-temporal resolution and excellent fat suppression of the Dixon scheme. The high temporal resolution will maximize the chances of capturing the arterial phase without the need for complex bolus timing schemes. DISCO, due its pseudo random nature, disperses artifacts much better than coherent undersampling/view sharing schemes. Further acceleration with reduction of temporal footprint may be achieved in DISCO by combining it with compressed sensing as the k-space trajectory is already pseudo-random**.**

References: [1] Korosec et al. MRM. 36:345-51 [2] J Du et al. JMRI; 20:894-900 (2004) [3] A Madhuranthakam et al. MRM 51: 568-576 (2004) [4] Mistretta et al. MRM 55:30-40 (2006) [5] Ma et al. MRM. 52:415-419 (2004)

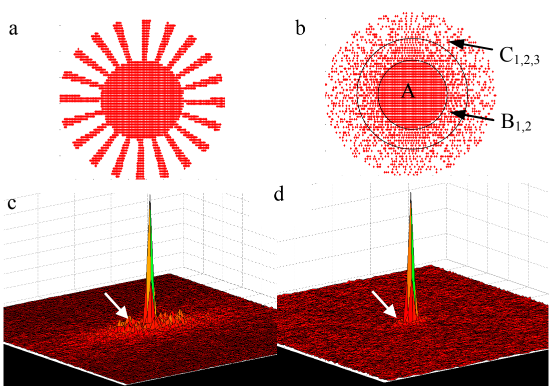

Figure 1. k_y-k_z segmentation schemes for CAPR (a) and DISCO (b) and the corresponding point spread functions (c-d). Note that the PSF for DISCO (d) shows significantly reduced artifacts around the main lobe and periphery compared to that of CAPR (c)

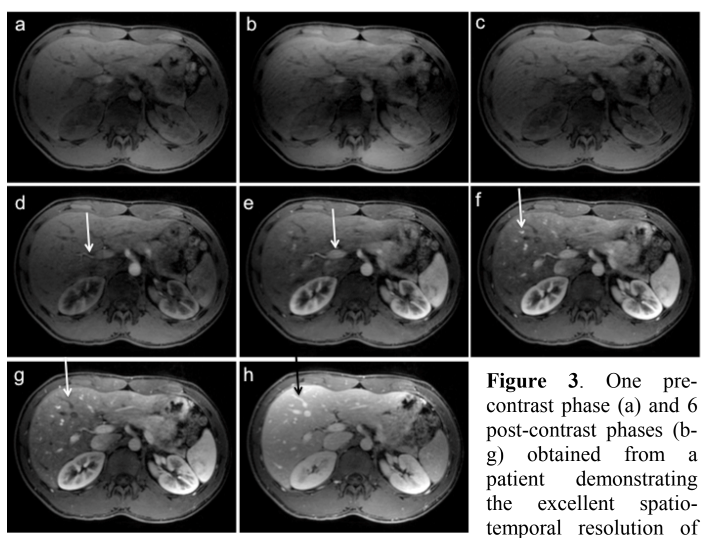

Figure 3. One pre-contrast phase (a) and 6 post-contrast phases (b-g) obtained from a patient demonstrating the excellent spatio-temporal resolution of DISCO. The temporal resolution of each phase was ~4s. The equilibrium phase is shown in (h). Post-contrast phases b-g were obtained in a 25s breath-hold. Arrows show progressive enhancement of hepatic artery (d), portal vein (e) and its peripheral branch (f), and non-enhanced (g) and enhanced hepatic vein (h).

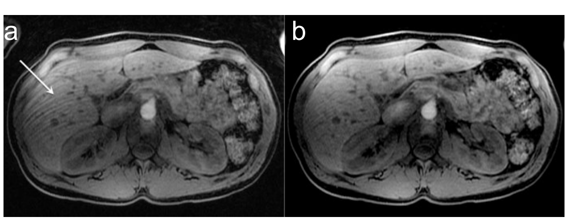

Figure 2. Section from DISCO scan with view sharing spanning across 2 breath-holds (a) view sharing restricted to within a breath-hold (b). Note the ghosting artifacts in (a) due to mis-registration of the first and second breath-holds, which is eliminated in (b), enabling the use of end-inspiration breath-holding.