Free breathing abdominal DCEMRI with high spatio-temporal resolution

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Purpose: Dynamic contrast-enhanced abdominal imaging is commonly performed in a series of breathholds following injection of Gadolinium contrast. In many patients, breathholding is not possible or unreliable, leading to ghosting and blurring. Free-breathing radial VIBE [1] or navigator gating [2] can address this problem, but with a temporal resolution penalty. Here, we used a navigator-gated 3D SPGR sequence with a combination of parallel imaging, viewsharing and pseudo-random variable density k-space sampling. This enables free-breathing dynamic contrast enhanced abdominal imaging at high temporal and spatial resolution.

Methods: A high spatio-temporal resolution liver imaging method was recently reported called DISCO (DIfferential Sub-sampling with Cartesian Ordering) [3,4]. In DISCO, elliptical k-space is segmented into a central region (A) and pseudo-random subsampled outer regions (B_1, B_2, B_3), resulting in a point spread function and artifacts that are much less coherent than sequential or centric schemes. We modified this approach to acquire each "A" region or sub-partitions of the "B_i" regions in successive end-expiratory periods (Fig 1). The number of sub-partitions depended on the respiratory rate (typically 3). A cylindrical navigator-echo was used to track the diaphragm position prospectively using an edge detection algorithm. This algorithm minimized any effects of liver signal enhancement. The k-space points are confined to a Cartesian grid, enabling fast FFT-based image reconstruction. Nearest-neighbor view sharing of the "B_i" regions was used to create full k-space data at each time point followed by parallel imaging reconstruction.

Experiments- DISCO and navigation were incorporated into a dual-echo bipolar readout 3D SPGR sequence. A 2-point Dixon method [5] was used for robust fat-water separation. Imaging parameters were as follows: 15° flip angle, $\pm$167 kHz bandwidth, TR/TE_1/TE_2 4.3/1.2/2.4 ms, 320x224 matrix, 30-35 cm FOV, 3.2 mm thick, 60 slices, ARC 2D parallel imaging with 2x2 net acceleration. With informed consent/assent, patients were imaged on a GE 3T MR750 system (GE Healthcare, Waukesha, WI) using a 32-channel torso array coil. For multiphasic gadolinium contrast abdominal imaging, 5-8 post-contrast phases were acquired with a frame rate of 12-13s/phase. The sequence was also assessed for MR urography before and after administration of a dieuretic agent (furosemide) where ~50 phases were acquired for each run, with a frame rate of 12-13s/phase.

Results: Figure 2 shows thick slabs MIPS from a pre-contrast and 5 consecutive post-contrast phases of a navigated DISCO acquisition performed on a 7-year old patient referred for neuroblastoma surveillance. Note the high spatial and temporal resolution as seen been by the progressive enhancement of the liver and the kidneys as well as the capture of arterial phase. The frame rate was approximately 12s, comparable to conventional breath-hold multi-phasic liver imaging. Figure 3 shows 4 representative phases an MRU on a 5-year old patient. The MIP of the arterial phase (24s) is shown highlighting the spatio-temporal resolution as well as the effectiveness of the Dixon fat-water separation method. The Patlak plots computed from the data are also shown.

Discussion: We have developed a free-breathing fast multi-phasic abdominal imaging method and demonstrated its clinical feasibility. Due to acceleration gains from parallel imaging and view sharing, temporal resolution was still comparable to conventional dynamic imaging (~12s), despite navigator gating. The use of Dixon fat-water separation afforded excellent fat suppression and eliminated the need for mask subtraction for generation of arterial/angiographic phase MIPs.

References: [1] Chandarana et al. Invest Radiol. 46:648-53 (2011) [2] Vasanawala et al. Ped. Radiol. 40:340-4 (2010) [3] Saranathan et al. JMRI 35:1484-92 (2012) [4] Clarke et al. Proc ISMRM p4015 (2012) [5] Ma et al. MRM. 52:415-419 (2004)

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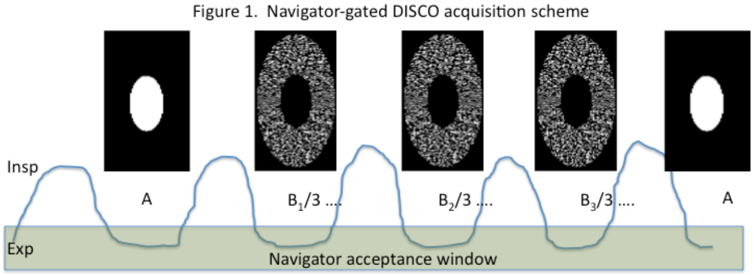
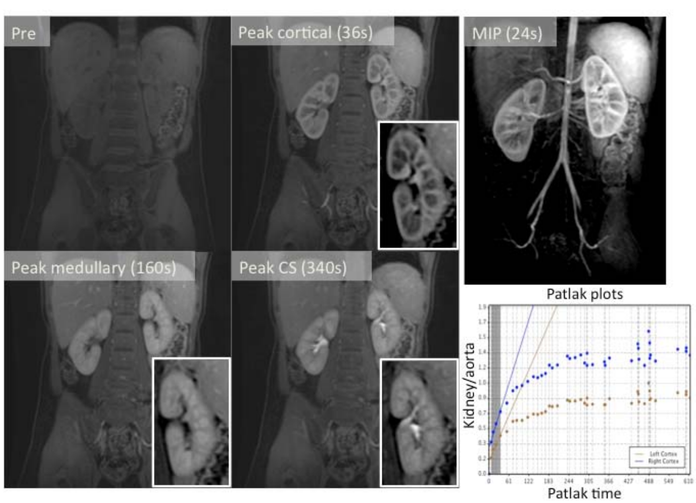
Figure 1. Navigator-gated DISCO acquisition scheme





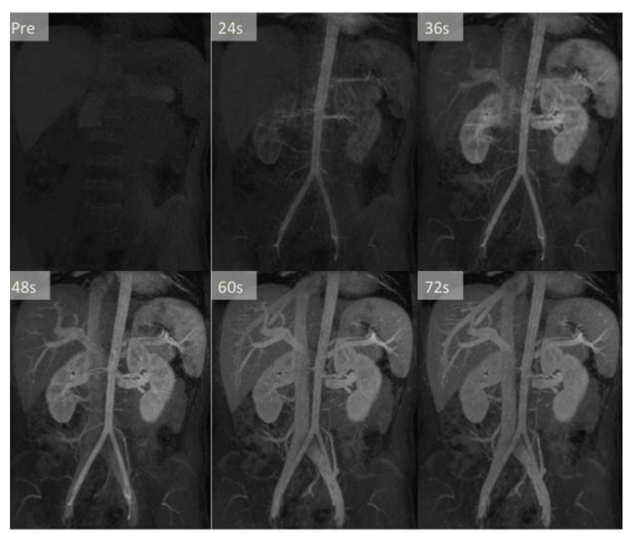


Figure 2 (above) Thick slabs MIPS from a pre-contrast and 5 post-contrast navigated DISCO phases on a 7-year old patient. Note the high spatio-temporal resolution (12s per frame) as seen been by the progressive enhancement of the liver and the kidneys. Figure 3 (left) shows pre-contrast and peak cortical, medullary and collecting system enhancement phases acquired on an MRU from a 5-year old patient. The arterial phase is clearly depicted in the 24s MIP. Patlak plots (bottom right) show varying Patlak numbers between the left and right cortex.