DCE Pulmonary Perfusion Imaging with High Spatial-Temporal Resolution using DISCO

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INTRODUCTION: Dynamic Contrast Enhanced (DCE) MR pulmonary perfusion is an important tool to understand physiology of the lung [1]. With this time-resolved technique, the first pass of a contrast agent can be captured and visualized in multiple dimensions, providing the potential for simultaneous evaluation of vascular anatomy and a dynamic assessment of parenchymal microvascular enhancement [2]. To accurately depict perfusion dynamics, a spatial resolution on the scale of the functional gas-exchange unit (~4mm) is required [3]. The necessity for large anatomic coverage can make acquiring high temporal resolution data with this spatial resolution challenging. Recently, a novel Cartesian view-ordering scheme, called DISCO (Differential Subsampling with Cartesian Ordering) [4], has been proposed and has shown promising results for other DCE MR applications including liver [5]. In this work, we demonstrate the feasibility of using DISCO combined with 2D parallel imaging for DCE pulmonary perfusion.

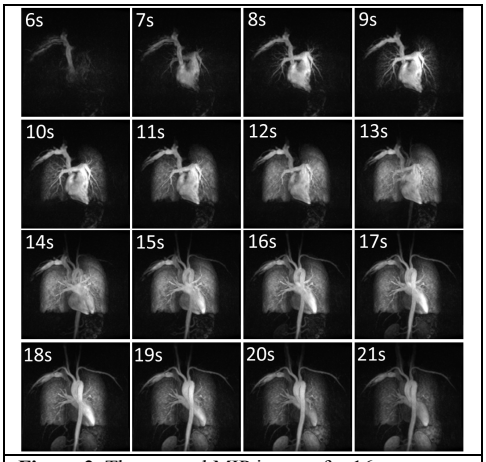

Figure 2. The coronal MIP images for 16 consecutive time frames with 1.0 sec temporal resolution and 4.0 mm isotropic spatial resolution.

THEORY: The DISCO sampling pattern for a typical time frame is shown in Fig. 1. In this scheme, the center of k-space is fully-sampled for every time frame. The peripheral region of k-space is first undersampled regularly by a conventional parallel imaging scheme, then further pseudo-randomly undersampled to achieve a higher temporal frame rate. In contrast to the method described in Ref. [6], an elliptical centric view-ordering is employed to reduce the temporal footprint over which the higher energy k-space lines are acquired. A temporal nearest neighbor view-sharing approach [7,8] is used to construct regularly undersampled k-space from the pseudo-random undersampling and is followed by standard 2D parallel imaging reconstruction to synthesize the remaining un-sampled points (ARC, [9]).

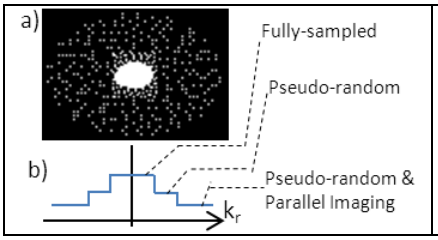

Figure 1. (a) DISCO sampling pattern for a typical time frame, with elliptical centric view-ordering. (b) Sampling density as a function of k_r. There are three regions that are sampled differently.

MATERIALS AND METHODS: Seven (7) healthy subjects were recruited in this HIPAA-compliant, IRB-approved protocol. Informed consent was obtained prior to all scanning. All exams were performed on a 1.5T clinical scanner (MR450w, GE Healthcare, Waukesha, WI, USA) with an 8-channel cardiac array. Imaging parameters were FOV = 40(S/I) × 28(A/P) × 40(L/R) cm^3, TE/TR = 0.6/1.7 ms, FA = 12º, BW = ±125kHz, parallel imaging acceleration 2 × 2. The acquired unique frame rate was 1.0 sec/frame. Total scan time was limited to 22 seconds to fit within a single breath-hold. A 0.5× dose of gadobenate (MultiHance, Bracco Diagnostics) was injected simultaneously at the start of the acquisition. After reconstruction, the peak parenchymal phase was selected and presented to a cardiothoracic radiologist with MRI expertise for scoring using a 4-point scale. Overall image quality (0=non-diagnostic,3=excellent) and artifact level (0=no,3=severe artifacts) were assessed.

RESULTS

Fig. 2 shows the coronal maximum intensity projection (MIP) images from one healthy volunteer scan. The temporal dynamics of the bolus can be well observed with the 1.0 sec/frame temporal resolution. From this time series, the peak parenchymal enhancement phase can be selected (here t = 13s), and the 3D volume at this time point can be visualized in any orientation with 4.0 mm isotropic spatial resolution, as demonstrated in Fig. 3(a). Furthermore, Fig. 3(b) shows the temporal waveform measurements obtained on three regions of interest (ROI): pulmonary artery (blue), parenchyma (green), and aorta (red). The relative pulmonary blood volume is also shown in Fig. 3(c). The average overall image quality score for all volunteers was 2.57± 0.20, and the artifact level score was 1.00 ± 0.31. Please see Table 1 for details.

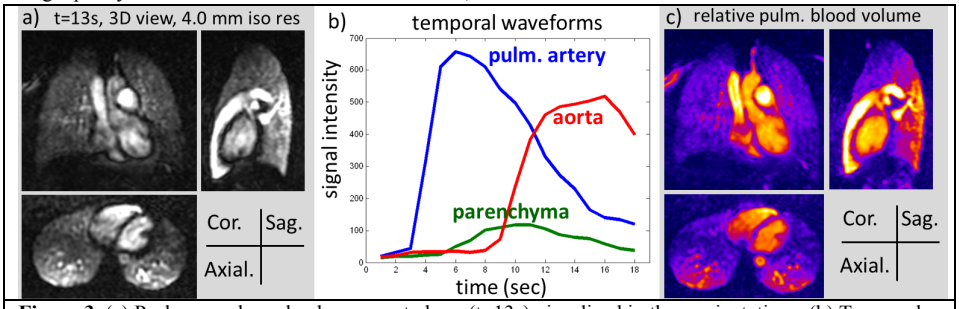

Figure 3. (a) Peak parenchymal enhancement phase (t=13s) visualized in three orientations. (b) Temporal waveforms measurement on pulmonary artery (blue), parenchyma (green) and aorta (red). (c) Relative pulmonary blood volume calculated as area under the curve. The higher signal at the posterior side due to gravitational effect can be well visualized.

DISCUSSIONS: This 4D imaging technique for DCE pulmonary perfusion has several potential clinical advantages. It eliminates bolus timing issues and consistently captures the peak parenchymal enhancement phase for detection of perfusion defects. Furthermore, the temporal waveforms obtained on a voxel by voxel basis provide significant potential for quantitative analysis and perfusion modeling.

CONCLUSIONS: In this work we demonstrate the feasibility of DISCO with nearest neighbor view-sharing for DCE pulmonary perfusion. The proposed 22-sec single breath-hold imaging protocol was shown to provide very reliable high quality visualization of the peak parenchymal enhancement of the lungs.

REFERENCES: [1] Hatabu et al., MRM 1999;47:1033-1038 [2] Nael et al., JMRI 2006; 24:333-339 [3] Hopkins et al., JMRI 2010;32:1287-1301 [4] Rettmann et al., ISMRM 2010, p3044 [5] Saranathan et al., ISMRM 2011, p2941 [6] Lim et al., AJNR 2008; 29: 1847-1854 [7] Riederer et al., MRM 1988;8:1-15 [8] Korosec et al., MRM 1996;36:345-351 [9] Brau et al., MRM 2008; 59:382

Table 1. Radiologist Scoring Histogram (N = 7)

Image Quality		Artifact Level	
3: Excellent	4/7	3: Severe	0
2: Good	3/7	2: Moderate	2/7
1: Fair	0	1: Minor	3/7
0: Non-diagnostic	0	0: No artifact	2/7