3D Pulmonary Perfusion MRI with Whole-Chest Coverage, High Temporal and Isotropic Spatial Resolution

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INTRODUCTION Quantitative MR pulmonary perfusion is important to help understand both the normal and abnormal physiology of the lung [1]. Pulmonary perfusion offers the potential for both the simultaneous evaluation of vascular anatomy and a dynamic assessment of microvascular parenchymal enhancement [2]. MR pulmonary perfusion has been a technical challenge due to the requirements for whole-chest spatial coverage, high temporal and sufficient spatial resolution. Meanwhile, undersampled Cartesian sequences have been proposed and have shown promising results for dynamic contrast enhanced MRI [3,4]. The purpose of this study was to demonstrate the feasibility of obtaining relatively high isotropic spatial resolution 3D dynamic pulmonary perfusion images of the whole chest with high temporal resolution. This was achieved using a previously developed Interleaved Variable Density (IVD) [5] sampling method with parallel imaging and Cartesian HYPR reconstruction [6] and demonstrated in normal volunteers and patients.

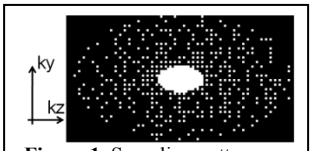

Figure 1. Sampling pattern for a typical time frame (total acceleration of ×10).

THEORY
In our technique, data for each time frame are undersampled in two ways. Specifically, the Cartesian ky-kz plane is undersampled by parallel imaging (×4), followed by applying IVD (×2.5), yielding a total acceleration factor of 10 (Fig. 1). All views within a time frame are acquired with elliptical centric (EC) order. In the reconstruction, an auto-calibration data-driven parallel imaging (ARC, [7]) is combined with a Cartesian HYPR reconstruction to suppress the coherent aliasing (caused by parallel imaging) and incoherent artifacts (caused by IVD) [6].

MATERIALS AND METHODS
After informed consent sixteen individuals were scanned (12 volunteers, 4 patients) on clinical scanners (GE Healthcare, Waukesha, WI, USA). Imaging parameters included: sagittal excitation, TR/TE = 1.8/0.5ms, 75% fractional echo, and acquisition matrix size of 100 × 56 × 100 with FOV of 40(S/I) × 22(A/P) × 40(L/R) cm^3, yielding a true 4.0mm isotropic resolution. Sixteen frames were resolved at 1.0 sec/frame with a 20-second breath-hold. The injection of 10 mL of gadobenate dimeglumine (MultiHance, Bracco Diagnostics) at 2.5mL/s was started at the same time as the scan.

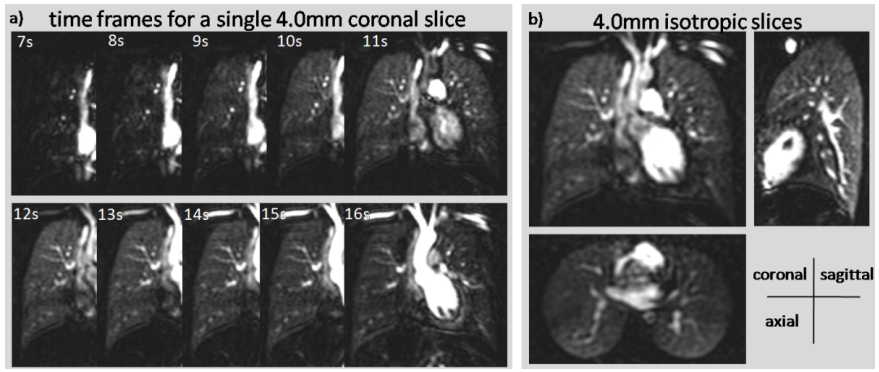

Figure 2. Healthy volunteer results (3T, 32-channel torso coil). a) Coronal reconstructions from the dynamic pulmonary perfusion MRI with 4.0mm isotropic resolution and 1.0s temporal resolution. b) Coronal, axial and sagittal slices at t=12s demonstrating whole-chest coverage and 4.0mm isotropic resolution with uniform parenchymal enhancement.

RESULTS AND DISCUSSION
This technique was successfully performed in all subjects. Representative results are shown in Figs. 2 and 3.Fig. 2(a) shows dynamic perfusion images of one healthy volunteer exam demonstrating 4.0mm isotropic resolution and the evolution of normal parenchymal enhancement. Fig. 2(b) illustrates the standard 3 plane reconstructions available from a single time-point during the peak parenchymal phase, demonstrating superb image quality across the entire volume, also note visualization of the interlobar fissural anatomy.
Fig. 3(a) shows selected slices along each axis at the peak parenchymal phase from a patient with sarcoidosis. Perfusion defects (arrows) correlate with areas of air trapping seen on CT (Fig. 3(c), black arrows). Mean transit time (MTT), relative pulmonary blood volume (rPBV) and relative pulmonary blood flow (rPBF) were also calculated [8] for the same axial slice shown in Fig. 3(a). Reduced rPBV and rPBF values (arrows) correspond with the defects seen in axial view (Fig. 3(a)).

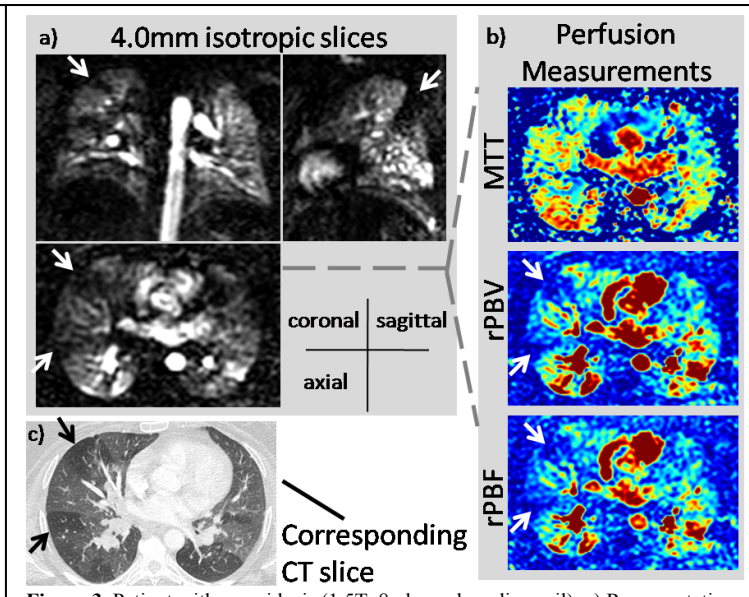

Figure 3. Patient with sarcoidosis (1.5T, 8-channel cardiac coil). a) Representative slices at the peak parenchymal enhancement phase. (b) Reduced rPBV and rPBF color coded values are observed (arrows) at the same locations. (c) A CT slice of the same patient showing air trapping (arrows). MR Perfusion defects (white arrows) correlate with areas of air trapping seen on CT (black arrows).

CONCLUSION
We show the feasibility of performing pulmonary perfusion MRI of the entire chest with very high temporal resolution and high isotropic spatial resolution using IVD, parallel imaging and Cartesian HYPR.

ACKNOWLEDGMENTS
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REFERENCES
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