3D Cartesian Volumetric Liver Perfusion MRI with High Temporal and Isotropic Spatial Resolution

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INTRODUCTION MR liver perfusion is a non-invasive imaging method to assess the blood supply to liver tumors, providing quantitative measurements of early changes in liver tumor microvascularity with chemotherapy that may predict long-term tumor response [1]. However, quantitative liver perfusion has been challenging due to the requirement for complete liver coverage, high spatial and temporal resolution, as well as suppression of respiratory motion artifacts. Undersampling Cartesian sequences have been proposed and have shown promising results for dynamic contrast enhanced MRA [2,3]. The purpose of this study is to demonstrate the feasibility of obtaining high isotropic spatial resolution whole liver perfusion images with high temporal resolution using an Interleaved Variable Density (IVD) [4] sampling method with parallel imaging and Cartesian HYPR reconstruction [5].

THEORY For each time frame, the Cartesian ky-kz plane is undersampled by both parallel imaging (×4) and IVD (×3) [4], yielding a total net acceleration of 12 [5] (Fig. 1(b)). All views within a time frame are acquired with elliptical centric (EC) order. In the reconstruction, auto-calibrating data-driven parallel imaging (ARC, [6]) is combined with a Cartesian HYPR reconstruction to suppress the coherent aliasing (caused by parallel imaging) and incoherent artifacts (caused by IVD) [5].

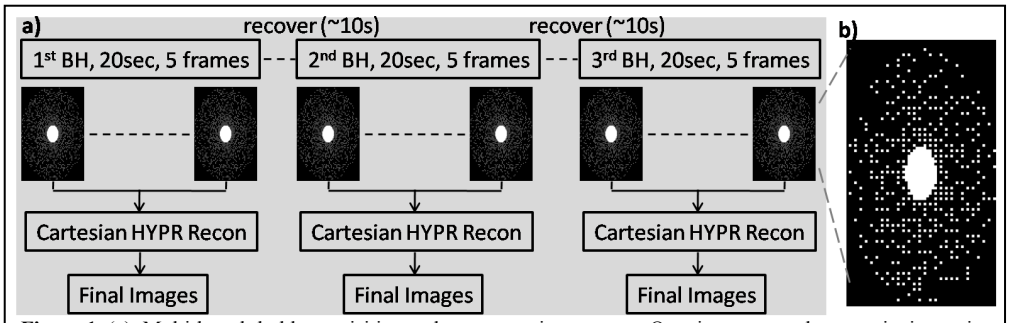

Figure 1. (a): Multi-breath-holds acquisition and reconstruction strategy. One time averaged composite image is generated for each breath-hold for the Cartesian HYPR reconstruction, and no data were shared between different breath-holds. (b): A magnified view of a typical single time frame sampling pattern, which is undersampled by both parallel imaging (×4) and IVD (×3), yielding a total acceleration of ×12.

MATERIALS AND METHODS Healthy volunteers were scanned in a supine position on a 3.0T MRI system (Discovery MR750, GE Healthcare, Waukesha, WI, U.S.A.) with a 32-channel torso coil. Informed consent was obtained from all volunteers prior to scanning. Imaging parameters included: 3D spoiled gradient echo, sagittal excitation, flip angle = 12 deg, TR/TE = 2.2/0.8ms, 75% fractional echo, and matrix size of 120 × 120 × 180 with FOV of 24(S/I) × 24(A/P) × 36(L/R) cm^3, yielding 2.0mm true isotropic resolution. Fifteen frames, resolved at 4.0 sec/frame, were separated into three breath-holds, each lasting 20 sec. The acquisition was paused between breath-holds for the volunteer to recover breath. 0.1mmol/kg of gadobenate dimeglumine (Multihance, Bracco, Princeton, NJ) was administrated at 3mL/s and the data acquisition started 10 seconds after the beginning of injection in order to capture the arterial phase during the first breath-hold. During image reconstruction, data from each breath-hold (20 sec) were averaged to form a composite image for the Cartesian HYPR constrained reconstruction [5]. There was no data sharing between different breath-holds. Fig. 1 summarizes the acquisition and reconstruction strategy.

RESULTS AND DISCUSSION Fig. 2 shows the representative axial and coronal slices at representative perfusion phases, demonstrating whole liver coverage and high isotropic resolution. For volunteer 1, early arterial phase (first column) images are shown, and the hepatic artery can be well visualized (arrow). For volunteer 2, late arterial, portal vein and hepatic vein phase images are shown. The enhancement of the portal vein and hepatic vein are well depicted in the third and fourth column in Fig. 2, respectively.. For both scans, respiratory artifacts are minimal and residual parallel imaging artifacts were not observed.

CONCLUSIONS It is feasible to obtain high isotropic spatial resolution 3D dynamic perfusion images of the whole liver with high temporal resolution using IVD, parallel imaging and Cartesian HYPR reconstruction.

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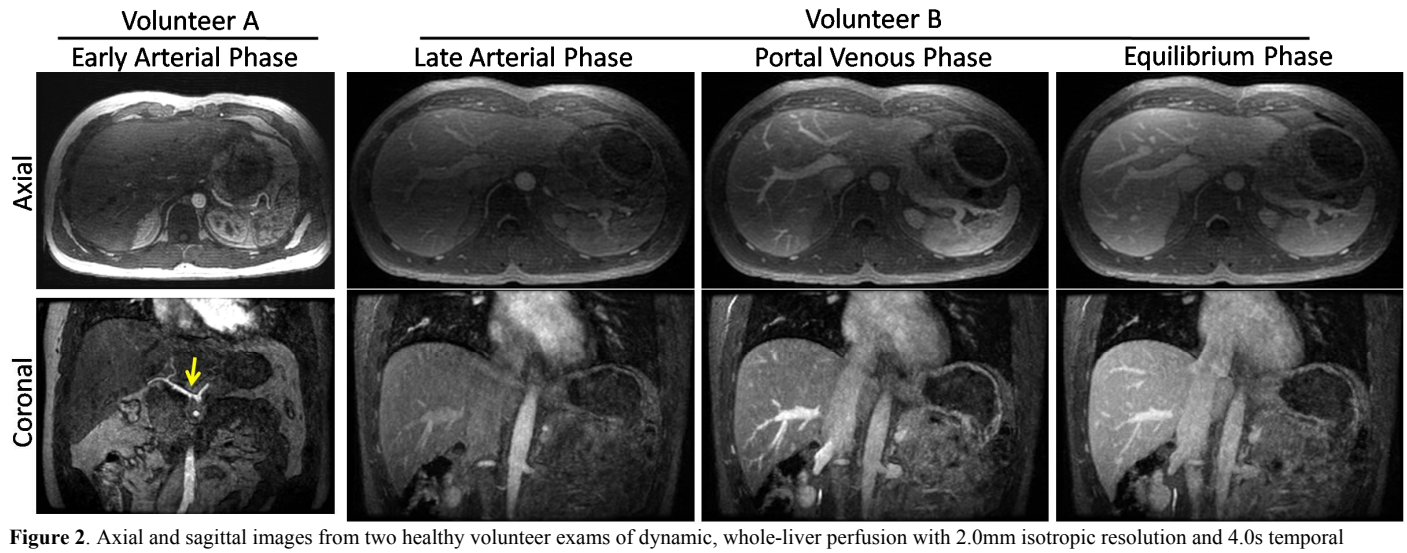

Figure 2. Axial and sagittal images from two healthy volunteer exams of dynamic, whole-liver perfusion with 2.0mm isotropic resolution and 4.0s temporal resolution. The hepatic artery (arrow) is well visualized in the first column lower image