# Multiple Phase CE-MRA of the Liver using Time-Resolved 3DPR

**E. K. Brodsky[1], D. L. Isaacs[1], W. F. Block[2,3], and S. B. Reeder[1,2]**

[1]Radiology, University of Wisconsin - Madison, Madison, WI, United States, [2]Medical Physics, University of Wisconsin - Madison, Madison, WI, United States, [3]Biomedical Engineering, University of Wisconsin - Madison, Madison, WI, United States

## INTRODUCTION

The detection and characterization of hepatocellular carcinomas (HCC) in cirrhotic patients is challenging due to the variable and rapid arterial enhancement of these small lesions (1). Multiple-phase CE-MRI is commonly used, but suffers from limited temporal resolution (typically 20 s per frame) and an inability to match the acquisitions consistently to the desired phase of contrast enhancement. This inconsistency is particularly problematic for monitoring studies that follow small enhancing nodules of indeterminate etiology (e.g. dysplastic vs. malignant nodule), as slight variations in enhancement can lead to inaccurate assessment for changes of these nodules. We present a 3D volumetric non-Cartesian, contrast-enhanced, isotropic-resolution acquisition of the liver with real-time monitoring that significantly improves temporal resolution (as low as 1s per 3D volume), allowing breath-holds to be matched to the desired enhancement phase, and allowing retrospective selection of the temporal window showing optimal lesion contrast.

## METHODS

The acquisition was tested on three volunteers, two with cirrhosis and one with a known focal nodular hyperplasia (FNH), a benign lesion with arterial enhancement characteristics similar to HCC. Each volunteer was scanned on a GE Healthcare 1.5 T scanner using a 120 s time-resolved undersampled 3D-PR spoiled gradient-recalled echo (VIPR-SPGR) acquisition with 4 half-echoes, 25° flip, ±125 kHz bandwidth, and coverage of the entire lower chest and liver with a 1.6 mm isotropic spatial resolution and one interleaved sub-frame acquired every second. The real-time system reconstructs and displays a 3D image at a rate of 1 frame/s (each using the preceding 2 s of data) at an isotropic resolution of 6 mm, with a time lag of 250 ms, providing 3D fluoroscopic monitoring of contrast arrival (2). After injection of 20 ml of gadobenate dimeglumine (Bracco Diagnostics), the subject was instructed to conduct three 24 s breath-holds during the standard phases of liver enhancement: early arterial, mid-arterial and portal venous. A full-resolution time series of volume images was reconstructed for each of these phases using filter with a temporal aperture that varies with spatial frequency to optimize the tradeoff between SNR and spatiotemporal resolution (3). An additional 30 s breath-held VIPR-SPGR scan was conducted 3-4 minutes after the injection, providing a delayed-enhancement image.

## RESULTS AND DISCUSSION

The real-time imaging acquisition was successful for all volunteers, providing adequate warning of contrast arrival to coach the subject through several breathing cycles prior to each breath-hold (important to maximize length of expiratory breath-holds). Due to a long delay (30 s) between injection and arterial enhancement on the FNH patient, the 120 s scan period ended before a full image could be acquired during the portal venous phase. This highlights the importance of the fluoroscopic monitoring, but also indicates that a longer total scan period is required for robustness.

The multi-phase image sequence allows one to distinguish the contrast kinetics of liver vessels, parenchyma, and lesions. The isotropic resolution and large 3D FOV also allows for evaluation of abnormalities in other reformatted planes. Figure 1 demonstrates the isotropic resolution with axial and coronal slices from an arterial, portal venous, and delayed frame. Figure 2 shows enhancement curves in the hepatic artery, FNH, portal vein, and liver parenchyma with 4 s temporal resolution. Also in Figure 2 are curves showing the mean magnitude and phase of DC signal from each interleaved sub-frame, which allows retrospective confirmation of the breath-hold interval (4), compared to actual breath-hold intervals (manually recorded and depicted on the graph).

## REFERENCES AND ACKNOWLEDGEMENTS

**1.** van den Bos *et al.*, JMRI In Press ('07) **2.** Brodsky *et al.*, MRM 56(2):247('06) **3.** Barger, *et al.*, MRM 48(2):297('02) **4.** Reeder, *et al.*, Proc. 14th ISMRM, 1957('06)

This research was supported by GE Healthcare and Bracco Diagnostics. SBR is supported by an RSNA Research Scholar Grant.

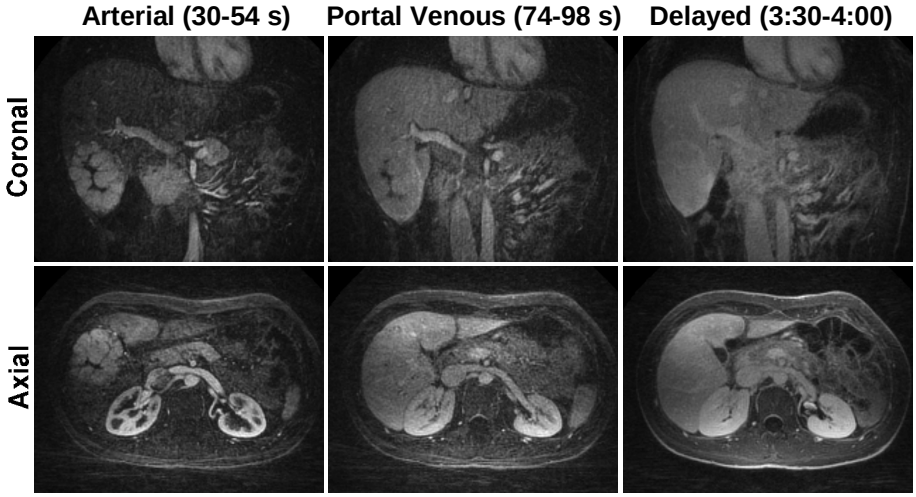


***Figure 1:*** *Coronal and axial reformats of the volume images from each imaging phase demonstrate excellent arterial-phase conspicuity of the rapidly-enhancing FNH, which receives arterial blood directly from the hepatic artery. By the portal venous phase, enhancement of normal liver tissue has substantially reduced FNH contrast and only the central scar is visible. An image acquired at this time would miss small hypervascular lesions. By 4 minutes post-injection, the lesion is in the equilibrium phase and difficult to distinguish from the adjacent normal hepatic parenchyma. The isotropic resolution allows reformats without loss of resolution, allowing evaluation of abnormalities in any desired plane, with very high isotropic spatial resolution (1.6x1.6x1.6 mm$^3$).*

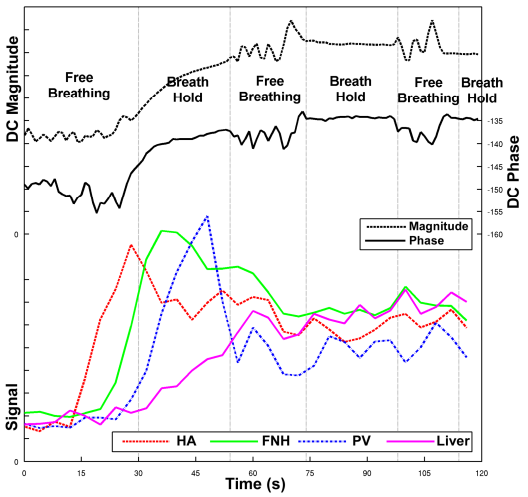


***Figure 2:*** *An advantage of the 3DPR acquisition is that it can be reconstructed in a variety of ways to optimize the SNR/resolution tradeoff for different applications. Trading off spatial for temporal resolution allows the generation of these time courses, showing the progressive enhancement of each liver tissue. Temporal resolution is 4 s and ROI volumes range from 0.2-2.0 cm. Good depiction of enhancement is shown, even during periods of free breathing.*