

High Spatial and Temporal Resolution Perfusion Imaging of Hepatocellular Carcinoma with Time-Resolved 3DPR using a 32-channel coil at 3T

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INTRODUCTION

Detection, characterization, and monitoring of hepatocellular carcinomas (HCC) in cirrhotic patients is challenging due to the variable and rapid arterial enhancement of these small lesions (1). Unlike normal liver tissue, which receives its blood primarily from the portal vein, HCC are fed primarily from hepatic arterial flow, leading to rapid and brief enhancement prior to the background liver. The ability to monitor changes in both lesion morphology and perfusion is urgently needed to evaluate the efficacy of targeted anti-angiogenic agents, allowing early termination of ineffective therapies (2). Multiple-phase CE-MRI has traditionally been used for evaluation of tumor perfusion, but suffers from limited temporal resolution (typically 20 s per frame) and an inability to consistently match the acquisitions to the desired phase of contrast enhancement. This inconsistency is particularly problematic because slight variations in timing can cause variations in observed lesion enhancement, leading to inaccurate tumor detection and treatment monitoring.

We have previously presented a contrast-enhanced, isotropic-resolution 3D radial acquisition of the liver at 1.5 T that offers significantly improved spatial and temporal resolution (3). This yielded good results when tested in volunteers with focal nodular hyperplasia (FNH), a benign lesion with arterial enhancement characteristics similar to HCC, but the SNR and image quality were inconsistent and sometimes inadequate for the diagnosis and monitoring of smaller HCC lesions. The purpose of this work is to demonstrate the feasibility of using time-resolved contrast-enhanced volumetric perfusion MRI at 3T with a 32-channel phased-array coil in order to improve SNR performance and increase spatial and temporal resolution.

METHODS

Three patients with hypervascular lesions consistent with HCC (detected with clinical surveillance MRI exams), were scanned on a clinical 3.0T scanner (MR750, GE Healthcare, Waukesha, WI) using a 32-channel phased array body coil (Neocoil, Pewaukee, WI). A time-resolved undersampled 3DPR spoiled gradient-recalled echo (VIPR-SPGR) acquisition was used during a 120 s acquisition after the injection of contrast. Specific imaging parameters included: 4 half-echoes, 12° 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. A real-time system reconstructed and displayed 3D images at a rate of 1 frame/s (each using the preceding 2 s of data) at an isotropic resolution of 4 mm, with a time lag of 250 ms, providing 3D fluoroscopic monitoring of contrast arrival (4). After injection of 0.1 mmol/kg gadobenate dimeglumine (Multihance, Bracco Diagnostics, Princeton, NJ) and a 20 ml saline chaser (both at 2.0 ml/s), the subject was instructed to conduct three 20-25 s breath-holds during the standard phases of liver enhancement: arterial, portal-venous and delayed (1:30-2:00min). A full-resolution time series of volume images (1 s temporal resolution, 2.1 mm spatial resolution) was reconstructed for each of these phases using a filter with a temporal aperture that varies with spatial frequency to optimize the tradeoff between SNR and spatiotemporal resolution (5). In addition to normal reconstruction, volume images were reconstructed with a multifrequency reconstruction (6), such that the acquired dataset demodulated at 25 Hz intervals from -400 to +400 Hz, and a spectral maximum intensity projection (MIP) is taken through this set for each pixel.

RESULTS AND DISCUSSION

In each case, the suspicious lesions could be seen when time series of axial or coronal thin-MIP reformats of the volume images were examined. It was challenging to reliably detect the lesions when only a single frame was viewed, as contrast quickly washes out of the lesions during a brief period of 5-15 s, but lesion conspicuity was significantly improved when the time series of images was presented as a CINE loop. Individual time frames from these time series showing the lesions are presented in Figure 1.

Results from this study demonstrate the feasibility of high spatial and high temporal resolution perfusion imaging over the entire liver at 3T with a 32-channel phased array coil. This approach uses a highly undersampled time-resolved 3D-radial method that detects real-time arrival of contrast and permits flexible reconstruction with variable temporal and spatial resolution. As the multi-echo T₁-weighted acquisition is sensitive to off-resonance, the faster dephasing at 3T has led to drop-outs in regions of B₀ inhomogeneity. This is particularly problematic in the liver, where inhomogeneity may be caused by proximity to the diaphragm and gas-filled loops of bowel. The multi-frequency reconstruction has proven effective at correcting these dropouts. Future work will focus on the optimization of this method and translation into quantitative estimates of tumor perfusion using a parametric model.

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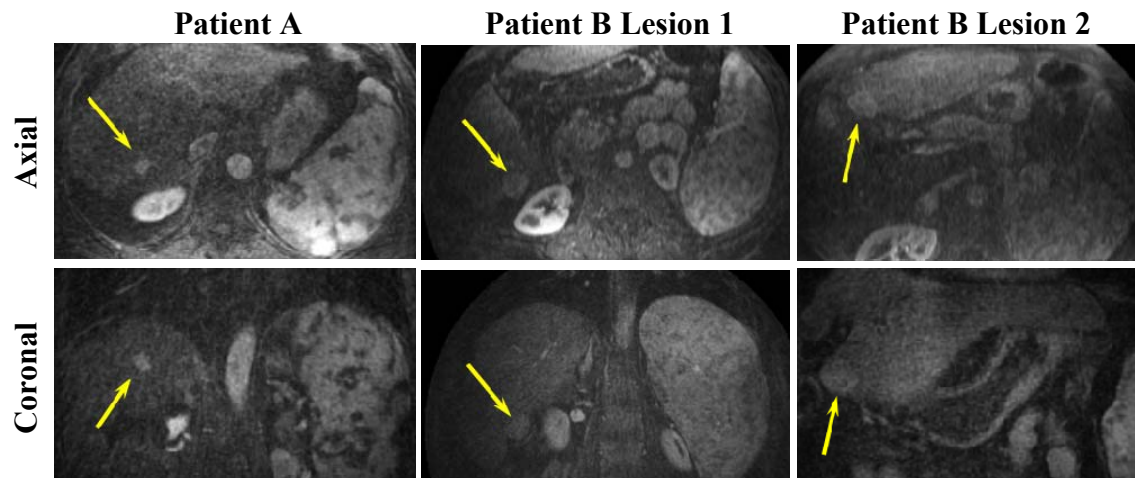


Figure 1: HCC lesions, primarily fed by the hepatic artery, are visible as regions of hyper-intense signal in these early arterial frame images. The time-resolved 3DPR acquisition allows retrospective selection of a time frame that best depicts lesion enhancement prior to confounding liver parenchyma enhancement. As the volume images have isotropic resolution, they can be reformatted into multiple viewing planes to ease interpretation of the lesion.