

Dynamic 3D contrast enhanced liver imaging using a novel hybrid cartesian-radial acquisition with flexible temporal and spatial resolution

P. Spincemaille¹, B. Reig¹, M. R. Prince¹, and Y. Wang¹
¹Radiology, Weill Cornell Medical College, New York, NY, United States

Introduction. An important feature of liver MRI is dynamic, multi-phase Gd enhanced acquisition to distinguish tissues supplied by hepatic arterial blood from those supplied by the portal vein [1,2]. This allows detection and characterization of liver lesions such as hepatocellular carcinoma which typically enhances early in the arterial phase and washes out rapidly. Current clinical practice relies on a series of single fast volumetric acquisitions after the injection of Gd. The delay between injection and the start of the scan for optimal visualization is patient and lesion dependent. In this work, a novel hybrid Cartesian-radial acquisition method combined with an adapted golden ratio dynamic imaging view order is proposed that allows retrospective selection of both the temporal position and window for optimally visualizing the arterial phase without the need for accurate bolus timing.

Materials and Methods. The sampling trajectory, Fig 1, is based on a Cartesian acquisition but replaces the sampling of the ky-kz grid with true radial trajectories. These trajectories are adapted to a non-square FOV by changing the angular spacing between consecutive projections depending on the angle [3] and by changing the sample spacing along each projection. It is further adapted by changing the k-space extent per projection to reflect an angularly changing resolution. This is necessary to allow the radial acquisition to match any arbitrary Cartesian acquisition where the phase FOV and resolution are generally different from the slab and slice thickness. The inherent anti-aliasing property of the linear readout is preserved and issues with centering radial projections due to gradient and receiver imperfections are avoided. A golden ratio view order [4] allows a 3D reconstruction with a flexible temporal footprint and update rates up to 1Hz. Projection angles using the golden ratio update step are rescaled to conform to the required distribution of angles that is determined by the non-uniform FOV along the angular direction. Partial projections were used for further speed up. Fat suppression was achieved using a spectrally selective inversion pulse combined with a partitioning of each projection into interleaved segments. Experiments were performed on 5 healthy volunteers (2 female, 3 male, age 28±6y) and 2 female patients (ages 49y and 32y) on a GE Excite 1.5T using 20 cc of Gd-DTPA (Magnevist, Bayer) in volunteers and 10cc Gd-EOB-DTPA (Eovist, Bayer) in patients. Data were collected from 8 to 38s after starting injection to obtain data encompassing the arterial phase. Data collection was repeated at 1min (venous), 3min (intermediate) and 5 min (equilibrium) post injection. Scanning parameters were: axial plane, 320x256x36-42 matrix, 34x30-34cm FOV, 5mm slice, FA 15°, BW ±90.91kHz, 30s scan time under breath-hold at inspiration. All images were reconstructed using conventional regridding on-line using a computing cluster connected to the scanner. From the first (arterial phase) scan a second reconstruction was performed to obtain 20 sub-phases each using 8s of data with a 1.1s update rate. Non-cartesian SENSE [5] was used to remove undersampling, streaking artifacts.

Results. Contrast enhanced dynamic liver images were successfully obtained in all volunteers. An optimal arterial phase was identified and reconstructed for each subject from subset of the initial 30s of data. Fig 2 shows four sub-arterial phases in one patient. The right hepatic artery is only clearly visible in the early phases before the liver has taken up Eovist. A slowly peripherally enhancing cholangiocarcinoma can be seen in the arterial, venous and delayed phases. Fig 3, four selected sub-sets of the arterial phase shows the successive enhancement of the aorta, hepatic artery, inferior vena cava, portal vein and liver parenchyma. Signal intensity curves (Fig 4) can be used to select temporal subsets of the data to optimize tissue specific contrast.

Discussion and conclusion. We have demonstrated the feasibility of using a hybrid Cartesian-radial acquisition for the acquisition of high temporal-high spatial resolution 3D contrast enhanced liver imaging. The golden ratio view order adapted for an angularly varying FOV allows flexibility in reconstructing images with any desired temporal footprint at any point in time. This allows an optimal visualization of the Gd bolus in the liver with retrospective selection of optimum arterial phases for each patients and each lesion of interest.

References [1] Semelka RC et al., Radiology 1992; 183:687-694 [2] Rofsky NM et al. Radiology 1999; 212:876-884 [3] Larson PZ et al., IEEE Trans Med Imaging 2008;27(1):47-57. [4] Winkelmann S et al., IEEE Trans Med Imaging 2007;26(1):68-76. [5] Pruessmann KP et al. Magn Reson Med 2001;46(4):638-651.

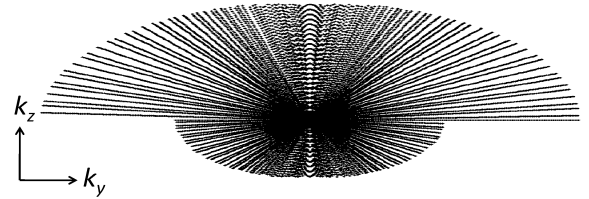


Fig. 1 The first 150 projections of the hybrid Cartesian-radial trajectory in ky-kz plane with a golden ratio view ordered dynamic acquisition and elliptical resolution and elliptical FOV. Prescribed scanning matrix was 384x384x48 with a 34x31x19cm³ FOV. Each point along each partial projection is acquired in one TR.

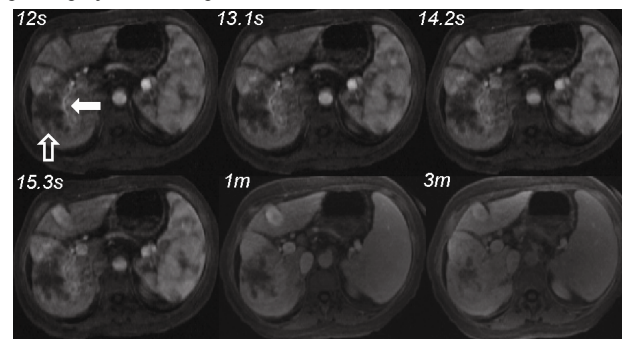


Fig. 2 Four arterial phases, one venous and one intermediate phase after EOVIST injection in a female patient with peripherally enhancing cholangiocarcinoma (open arrow) and portal hypertension. Timing after injection is indicated. Before liver takes up Gd, the right hepatic artery can be clearly seen in the early arterial phases (solid arrow).

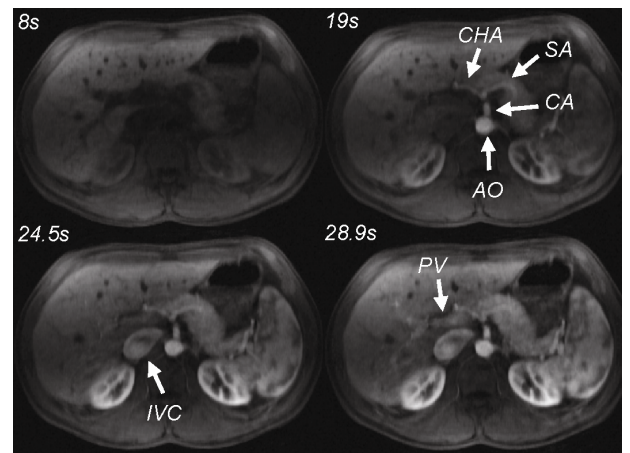


Fig. 3 Four selected arterial sub-phases in a healthy male subject. Timing between the start of injection and the start of each phase is indicated. Enhancement characteristics of the aorta (AO), celiac (CA), splenic (SA) and common hepatic (CHA) artery, the inferior vena cava (IVC) and portal vein (PV) are clearly visualized.

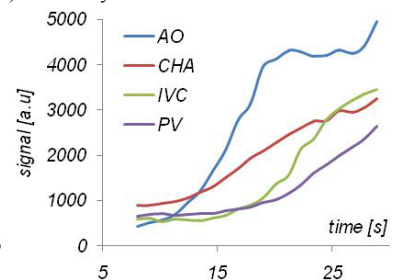


Fig. 4 Signal intensity curves for the various vessels surrounding and supplying the liver measured at the slice shown in Fig 3 (see Fig 3 for abbreviations).