High temporal resolution 4D contrast enhanced liver MR imaging using spiral trajectory and sliding window reconstruction

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Introduction: Dynamic contrast enhanced liver MRI provides excellent liver lesion detection and characterization [1-3]. Most malignant liver tumors like hepatocellular carcinoma receive blood through the hepatic artery, as opposed to normal liver which receives blood mainly from the portal vein. Therefore, these liver tumors will enhance earlier than normal liver, i.e. in the "arterial phase" . Current techniques rely on Cartesian sampling and accurate timing of the contrast bolus, which varies from patient to patient and may even vary from one lesion to another. Spiral trajectories (Fig.1) [4-7] sample k-space more efficiently, thus reducing scan time. Sliding window reconstructions with fast temporal updates can be implemented naturally in spiral acquisitions. This eliminates the needs for accurate bolus triggering and enables the retrospective selection of the optimal arterial phase for each lesion present.

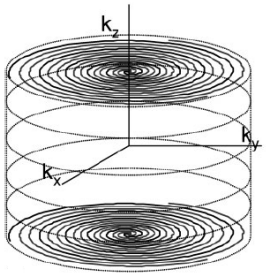

Fig.1 Stack of spiral trajectories with conventional Cartesian slice encoding and variable density spiral sampling

Materials and Methods: Experiments were conducted at 1.5T (GE EXCITE) using an 8-channel cardiac coil. A 3D spiral sequence was developed and evaluated on 5 healthy volunteers after informed consent was obtained. K-space was sampled using a stack of variable density spiral trajectories with 48 leaves per Cartesian slice encoding. The spiral leaves were acquired in interleaved groups of 12 to allow a sliding window reconstruction. Partial slice encoding was performed on the inner loop. Each of these slice loops was preceded by a spectral inversion recovery fat suppression pulse. Scanning parameters were: TR/TE=5.9/0.6ms, flip angle=12˚, BW=±125kHz, FOV=32cm, axial slice thickness=5mm and matrix size =256×256×36-40. The scan time was 11s per fully acquired phase. 20ml of Gd-DTPA (Magnevist; Berlex, Wayne, NJ) was injected 6s before the start of the scan. 4 scans were acquired at 0, 1, 3 and 5 minutes after injection. The first scan acquired three fully separate and consecutive phases (total scan time 33 s). A standard gridding reconstruction was used in combination with PILS [6]. A sliding window algorithm [7] reconstructed 9 temporal phases for the first scan (arterial phase). All reconstructions were performed on-line by the scanner host computer.

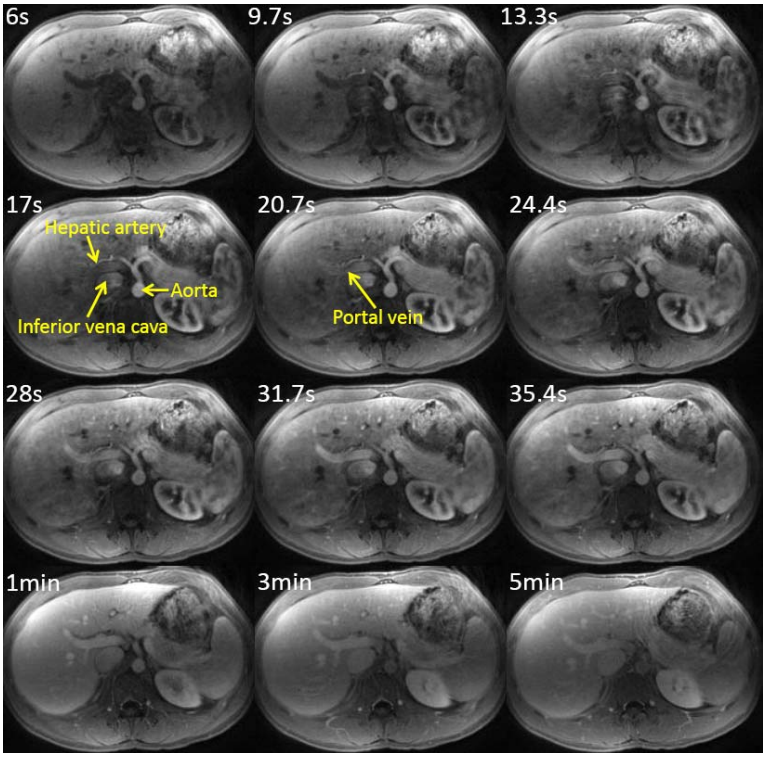

Fig.2 Contrast enhanced dynamic liver imaging after injection. Arrows indicate different enhancement characteristics of various vessels supplying blood to the liver

Results: Time resolved 3D spiral dynamic liver imaging successfully tracked contrast bolus in our experiments. Fig.2 shows a typical set of 12 phases at the same axial slice in one healthy subject. The temporal update rate is 3.7s for the first 9 phases. The hepatic artery enhanced early (10s) and washed out in the later phases (1-5min). The inferior vena cava and portal vein enhanced later (17s), followed by the hepatic veins in the 1min scan. In equilibrium phases, the liver was fully enhanced.

Discussion: The spiral trajectory accelerates liver MR imaging without sacrificing spatial resolution and allows multi-phase acquisition in one breath hold. Because of repeated sampling of the center of k-space, spiral sampling is very suitable for sliding window reconstruction allowing high quality images with high temporal update rate. It is then possible to retrospectively select the optimal hepatic arterial phase start and end. This can be used for the identification and characterization of arterially enhancing liver masses, such as hepatocellular carcinoma. Additionally, this can be used for the evaluation of hepatic arterial anatomy, which is important for preoperative planning. In the case of one volunteer, we found a small common hepatic artery (Fig.3a) and an accessory right hepatic artery replaced to the superior mesenteric artery (Fig.3b).

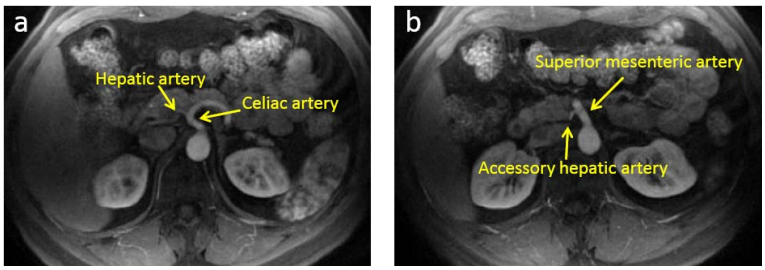

Fig.3 Arterial phase showing variant hepatic blood supply

Conclusion: We have presented a fast dynamic liver imaging sequence that allows tracking of the contrast bolus as it enhances various parts of the liver blood supply and anatomy. The high temporal update rate with high spatial resolution allows the retrospective selection of an optimal arterial phase without the need for accurate bolus timing.

References: [1] Rofsky et at. Radiology 1999;212:876-884. [2] Lee et al. Radiology 2000;215:365-372. [3] Semelka et al. Radiology 1992; 183:687-694. [4] Meyer et al.MRM 1992;28:202-213. [5] Spielman et al. MRM 1995;34:388-394. [6] Kressler et al. MRM 2007;58:535-543. [7] Zhu et al. MRM 2004;52:14-18.