Quantitative self-gated free breathing 4D DCE MRI of the liver with retrospectively selectable temporal resolution

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Target Audience Those interested in body MRI and high spatiotemporal resolution quantitative liver imaging.

Purpose The goal of this work is to develop a quantitative high quality free breathing 4D DCE examination of the liver, where the temporal resolution can be retrospectively picked to fit the needs of the exam.

Introduction Liver MR is extremely challenging because of the combination of large volume coverage, high desired spatial resolution, breath-holding problems, and rapidly changing contrast in the critical post-contrast images. Typical post contrast sequences presently require 15-20 s breath-holds, which effectively preclude time-course analysis, and frequently result in motion-corrupted exams upon breath-hold failure. Recently, a multi-shot radial EPI sequence was introduced which fills 3D spherical k-space by rotating the sampling pattern[1]. After acquiring k-space data, a subset of the radial shots can be selected, offering a tradeoff between undersampling and the desired temporal resolution. We demonstrate here the use of this acquisition pattern to obtain high quality DCE images of the whole liver at high spatial resolution and retrospectively selectable temporal resolution, and use the phase waveform at the center of k-space for self-gating and image registration. The result is an exam where both excellent image quality (for radiologist review of selected time points) and excellent temporal resolution (for timecourse/quantitative analysis) can be selected post hoc, as needed.

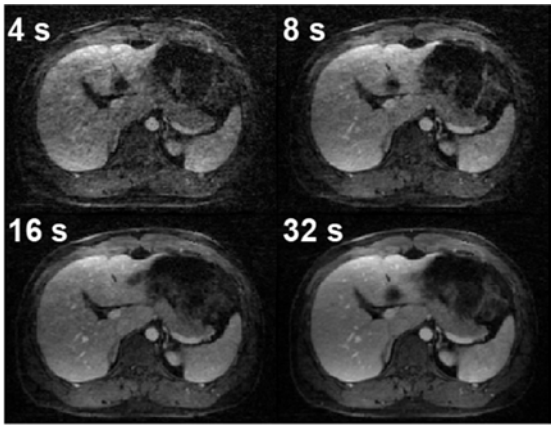

Fig. 1: Images at 50 s post-injection reconstructed at 4, 8, 16 or 32 second temporal footprints (as labeled).

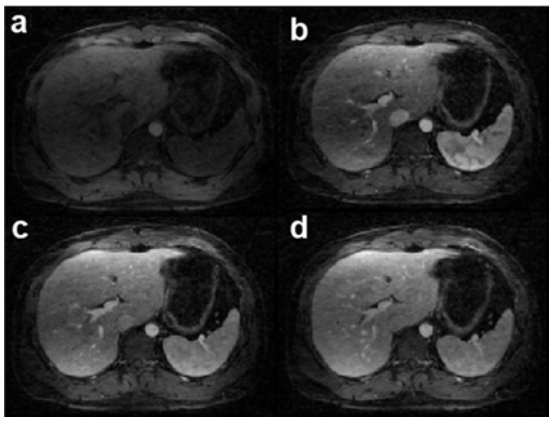

Fig. 2: Images before (a) and during (b-d) contrast agent uptake reconstructed at 16 second intervals

Methods Two subjects were scanned on a 3T Siemens Verio system in compliance with the local IRB. Images were acquired using multi-echo 3D radial FLASH (TR=8.4 ms, resolution = 1.8 mm isotropic, FOV=380 mm, 9 radial lines per shot). 4096 unique shots were repeated 8 times (total imaging time: 4 min 36 s). A contrast injection of 0.1 mmol/kg Gadobenate Dimeglumine contrast (Bracco Diagnostics, Princeton NJ) was administered approximately 70 s into the scan. A field map was estimated from the multi-echo dataset and used to correct for susceptibility related distortions[1]. Self-navigation was performed by defining a pencil-beam navigator through the dome of the liver on a low resolution series of volumes reconstructed at 0.5 s intervals. The derived motion parameters were used to divide the acquired projections into a series of respiratory motion bins. All projections over the full scan that fell within a given bin were used to reconstruct a timecourse average volume for each respiratory position. Nonlinear registration[2] of these volumes to the volume corresponding to the central bin was performed and the registration parameters were stored for later reuse on subsampled image volumes. A series of reconstructions were then performed to yield images with temporal footprints of 4, 8, 16 and 32 s. In each case, the images corresponding to each respiratory bin were gridded (via NUFFT) independently and then the precomputed nonlinear registration to the reference position was performed before summation across bins to give a motion corrected image series. A dual-input single-compartment model[3] was used to fit a signal timecourse extracted from images reconstructed at 4 s/volume temporal resolution. Signal timecourses from the celiac artery (arterial input), portal vein and liver parenchyma were converted to contrast agent concentrations. Arterial fraction, distribution volume and mean transit time were calculated.

Results and Discussion A set of image volumes reconstructed at 4, 8, 16 and 32 s temporal footprints are shown in Fig. 1. All of these volumes are centered at approximately 50 s after contrast injection. The tradeoff between temporal resolution and SNR/image quality is very apparent in these images. Four timepoints surrounding the contrast uptake (baseline, 16 s, 32 s and 48 s after contrast) for a different slice using the 16s footprint reconstruction (similar to the present clinical standard) are shown in Fig. 2a-d. Images of this temporal footprint and quality could be presented to radiologists, for traditional image interpretation. Faster temporal resolution images can be reconstructed for quantitative analysis for the same data, where increased image artifacts can be tolerated for greater temporal fidelity of data. A liver parenchymal timecourse for 4 s temporal footprint data from a representative voxel is shown in Fig. 3, along with the model fit. The fitted values of arterial fraction = 22.5%, portal fraction = 71.5%, and distribution volume = 34.3%, mean transit time 4.2 s, which are in physiologically acceptable ranges[4].

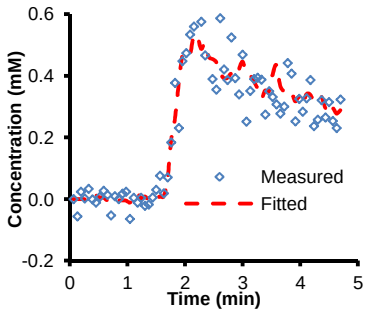

Fig 3: Liver parenchymal signal timecourse (4 s temporal resolution) and model fit from a single pixel.

Conclusion The results show that our acquisition scheme can be used to obtain high quality, self-gated and registered images with retrospectively selectable temporal resolution. The high temporal resolution images can in turn be used for quantitative timecourse analysis while the broader temporal footprint images could be used for traditional radiologist interpretation.

References 1. Lee GR et al. MRM 2012 (In Press: doi: 10.1002/mrm.24256). 2. Andersson et. al. FMRIB Technical Report TR07JA2, 2007. 3. Materne R, et al. MRM, 2002;147:135-142. 4. Van Beers BE, et al. AJR, 2001;176:667-673.

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