Magnetic resonance fingerprinting (MRF) for rapid quantitative abdominal imaging

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Target Audience This work targets those interested in fast quantitative imaging and abdominal MRI.

Purpose Quantitative parameter measurement in the abdomen is extremely challenging due to the anatomy (large organs), field inhomogeneities and extreme physiological motion. Recently, we have introduced a revolutionary paradigm for MRI acquisition, reconstruction, and analysis of MR data, termed MR fingerprinting (MRF), for rapid, efficient, and simultaneous quantification of multiple tissue properties[1]. The goal of this study is to develop and validate a robust MRF technique for accurate and high-resolution quantification of multiple tissue properties in abdomen within one clinically feasible breath-hold.

Methods MRI experiments were performed on a Siemens 3T Skyra scanner with 32 receive channels. The original MRF acquisition proposed for brain imaging was based on an inversion-recovery balanced steady state free-precession (IR-bSSFP)[1]. However, this sequence is extremely sensitive to magnetic field inhomogeneities, and thus is poorly suited for high-field abdominal imaging. To overcome this problem, we have developed an MRF method based on another steady-state sequence, namely fast imaging with steady-state free precession (FISP). As in the original MRF demonstration, highly undersampled images were acquired while using FISP-MRF with randomized repetition times and flip angles. Each image was reconstructed using NUFFT with only one spiral interleave (acceleration factor: 48). Other imaging parameters were: FOV= 44×44 cm; matrix size 224×224; slice thickness 5 mm. 1500 undersampled images were acquired in 17 s. Another major concern for the application of FISP-MRF for high-field abdominal imaging is the transmit field (B1) inhomogeneities encountered over the large FOV. In this study, a B1 field map was acquired in a separate scan using the Bloch-Siegert technique[2]. For fast imaging purposes, a spiral readout was used and the total acquisition time for a B1 map was 1.8 s.

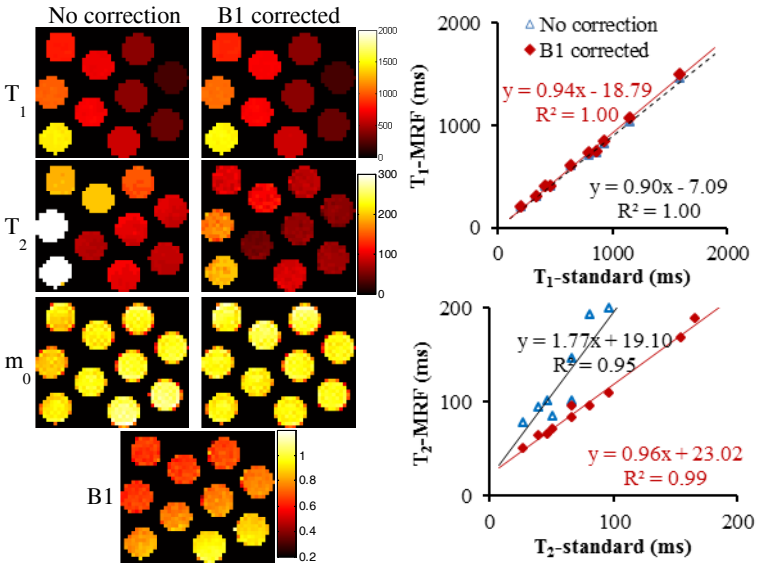

Fig. 1. T_1, T_2, and proton density (m0) maps of a water phantom before and after B1 correction. Significant changes in T_2 values were observed after the B1 correction, which is in good agreement with standard values.

To retrieve tissue properties (T_1, T_2 and proton density) from the MRF experiment, a dictionary including the signal evolutions from all possible combinations of parameters for a T_1 range of 100 to 3000 ms, T_2 range of 20 to 500 ms, and B1 range of 50% to 150% was calculated using Bloch simulations. The acquired signal in each pixel of highly accelerated images was matched to an entry from this dictionary using orthogonal matching pursuit[3], which in turn yields all underlying parameters that were used to form the dictionary entry.

The accuracy of the FISP-MRF method was first validated using a water phantom. A passively coupled transmit surface coil was used to generate a highly non-uniform B1 field for the phantom. The results were compared to values obtained using the standard methods (an inversion-recovery single-echo spin-echo sequence for T_1 measurement and turbo spin-echo sequence for T_2 measurement). After phantom validation, quantitative measurements using FISP-MRF were performed on six asymptomatic subjects. For each subject, the FISP-MRF and Bloch-Siegert measurements were acquired consecutively in a single breath-hold of ~19 s.

Results and Discussion Fig. 1 presents the T_1, T_2, and proton density maps acquired using FISP-MRF method before and after B1 correction. A maximum of 50% change in B1 magnitude was observed, which caused substantial changes in the parameters. Unlike conventional methods which typically show a dependence of T_1 on the B1, our MRF results consistently show a dependence of T_2 on B1. However, after the B1 correction, both T_1 and T_2 values are in good agreement with values acquired using standard methods. Fig. 2 presents T_1 and T_2 maps obtained from a normal volunteer. A significant difference in T_2 was observed in the liver with and without correction (from 70 to 35 msec). The latter is clearly in better agreement with the literature[4]. Banding artifacts seen in the maps acquired with the bSSFP-MRF method (not shown) were eliminated as expected with the FISP-MRF method.

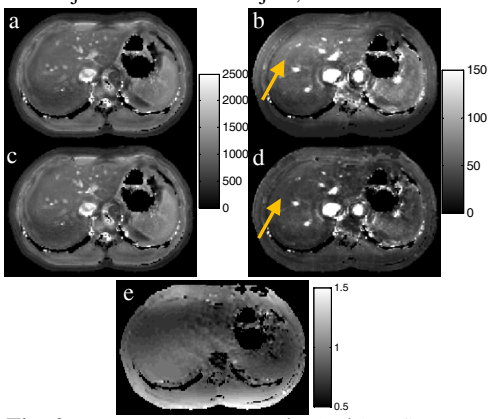

Fig. 2. Parameter maps acquired with FISP-MRF. (a&b) T_1 and T_2 maps before B1 correction. (c&d) T_1 and T_2 maps after B1 correction. (e) The corresponding B1 map. More uniform T_2 maps were obtained after B1 correction as indicated by the arrows.

Conclusion In this study, a rapid and robust technique for quantitative abdominal imaging was developed using an FISP-MRF acquisition in combination with a Bloch-Siegert B1 mapping method. This technique allows accurate and simultaneous quantification of multiple tissue properties in abdomen within one clinically feasible breath-hold.

References

1. Dan M, et al. Nature, 2013. 2. Sacolick LI, et al. MRM, 2010. 3. Doneva M, et al. MRM, 2010. 4. De Bazelaire CMJ, et al. Radiol, 2004.

Acknowledgements Siemens Healthcare and NIH grants 1R01EB017219, 1R01DK098503 and R00EB011527.