Magnetic Resonance Elastography in the presence of iron overload

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TARGET AUDIENCE: MR elastography, abdominal imaging, chronic liver diseases and iron overload

PURPOSE

Hepatic functional imaging, including perfusion, diffusion and MR elastography (MRE), have shown great potential in the diagnosis of chronic liver diseases. In particular, MRE's robustness in staging liver fibrosis and even detecting subjects at risk before fibrosis appears has been demonstrated in animals and then humans[1,2]. In the context of iron overload, MRI can only be used in detecting and quantifying iron content because of the dramatic drop of NMR sensitivity the presence of iron causes. Magnetic susceptibility artifacts are exacerbated with increasing magnetic field strength, and this confounds hepatic functional in high field scanners. We propose in this work to perform MRE in samples loaded with iron-dextran nanoparticles and exploit the longer T_2s and reduced magnetic susceptibility differences attainable when working at very low magnetic field. We compare the relaxation times at 6.5 mT and 1.5 T, and assess the SNR in all samples using conventional imaging sequences (spin echo (SE), gradient echo (GE), b-SSFP).

METHODS

Relaxations times of gels prepared with different iron concentrations were measured at very low (6.5 mT) and high fields (1.5 T). SE, GE, and b-SSFP scans were acquired at 1.5 T with TE/TR equivalent to those reported for MRE[3], and proton-density weighted images at low field. 3D-MRE in gels with different iron oxide (IO) concentrations was performed using acoustic waves[4] for wave generation, using 50%-undersampling and fractional encoding (ratio q between vibration and encoding frequencies = 0.5), for acquisitions of (1.5×2.5×5.7) mm^3 resolution. Total 3D acquisition time was 279 s for 20 averages. Our performances with regard to fractional encoding are simulated according to Rump *et al*[5] in Fig. 1 and compared to higher field scanner. A custom-built scanner[6,7] as well as a custom-built Litz-wire solenoid coil were used in experiments at 6.5 mT (276 kHz). A 1.5 T-Siemens scanner with a 32-channel head coil were used for high-field experiments. The magnitude images obtained at different fields are shown in Fig. 2. Mean SNR and unwrapped phase images have been processed across the entire gel with home-written routines and `robustunwrap` function[8] using MATLAB.

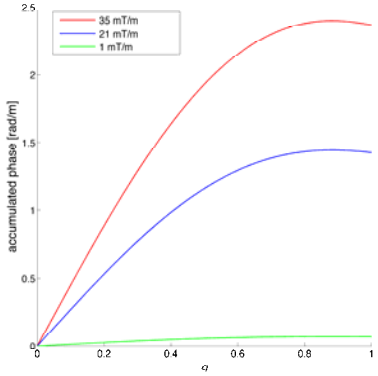

Figure 1: Accumulated phase simulated for clinical field gradient strengths (35 mT/m in red, 21 mT/m in blue), compared to the performances of our scanner (1 mT/m).

RESULTS

A decreased T_1 as well as an increased T_2 with decreasing magnetic field strength is shown in Table 1. SNR decreased with increasing iron content at 1.5 T, whereas it remained constant at 6.5 mT. MR images were homogenous across the samples at low field but were prone to dramatic drop of signal or susceptibility and banding artifacts at high field (see Table 1 and Fig. 2).

Table 1: Sample preparation, corresponding relaxation times and SNR at 6.5 mT and 1.5 T.

Sample	B_0	T_1 (ms)	T_2 (ms)	T_2^* (ms)	GE	SE	b-SSFP
PVA	6.5 mT	446	243	146	N/A	N/A	14
	1.5 T	2300	-	-	18	22	12
PVA + 1% IO	6.5 mT	72	59	52	N/A	N/A	16
	1.5 T	280	32	11	14	5	4
PVA + 2% IO	6.5 mT	47	38	37	N/A	N/A	14
	1.5 T	166	18	6	9	2	7

Fractional encoding with q = 0.5 leads to 81% accumulated phase compared to q = 1, < 5% compared to 21 mT/m, and < 3% compared to 35 mT/m.

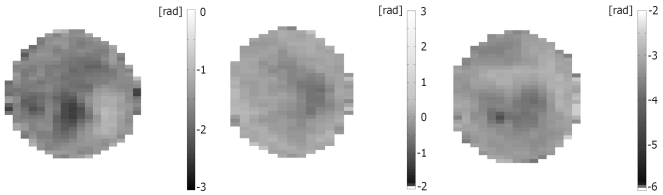

Figure 3: Unwrapped phase images of 3 PVA gels without IO, with 1%-IO, and 2%-IO (from left to right).

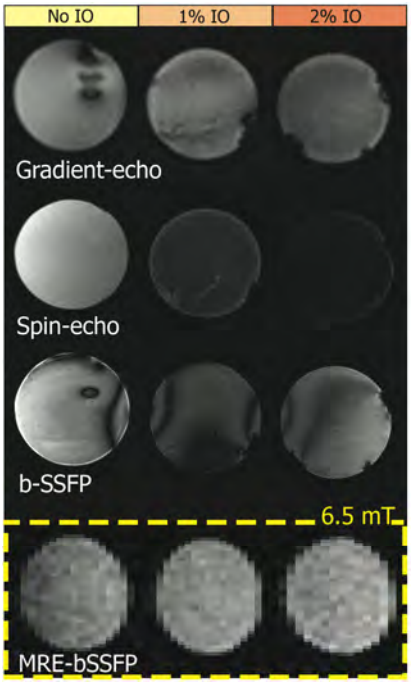

Figure 2: Magnitude images acquired with GE, SE, and b-SSFP sequences at 1.5 T compared with magnitude images of the b-SSFP-based MRE acquisition at 6.5 mT.

DISCUSSION

Even at 250× lower magnetic field, and with motion sensitivity at 6.5 mT between 21 and 35 times smaller compared to high field scanners, we were able to map motion in PVA gels with good SNR and motion sensitivity.

CONCLUSION

We have shown that MRE is possible at very low magnetic field without hyperpolarization techniques in samples simulating iron overload, and results in robust and fast artifact-free images. This work opens perspective in the study of the mechanical properties of living tissues in subjects with iron overload.

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