Comparison of dynamic MR elastography of living brain at 7 T and 1.5 T

U. Hamhaber[1], D. Klatt[2], B. Beierbach[2], S. Papazoglou[2], M. Hollmann[3], J. Stadler[4], I. Sack[2], J. Bernarding[3], and J. Braun[1]

[1]Institute of Medical Informatics, Charité - Universitätsmedizin Berlin, Berlin, Berlin, Germany, [2]Department of Radiology, Charité - Universitätsmedizin Berlin, Berlin, Berlin, Germany, [3]Institute of Biometry and Medical Informatics, Otto-von-Guericke University, Magdeburg, Sachsen-Anhalt, Germany, [4]Leibniz Institute for Neurobiology, Magdeburg, Sachsen-Anhalt, Germany

Introduction: Dynamic magnetic resonance elastography (MRE) allows the determination of mechanical properties of human soft tissues *in vivo* by introducing low frequency shear waves into the body and measuring the resulting deflection field [1]. It has been shown that MRE is capable to measure elastic and viscous properties of the brain at 1.5 and 3 T [2-4]. So far, no viscoelastic parameters of the brain have been determined by MRE at 7 T. Preliminary experiments reported in the literature indicate the challenges of ultrahigh-field MRE given by increased B1-field inhomogeneity, stronger susceptibility artifacts, different relaxation times and shortened T_2^* [5]. On the other hand optimizing imaging parameters and taking into account the increased signal-to-noise at 7 T allowing increased spatial resolution will ultimately lead to better image quality in high-field MRI. Therefore, the objective of this study is to investigate (i) whether the quantification of viscoelastic properties is possible for MRE at 7T, and (ii) if the obtained viscoelastic parameters are equal to those measured at 1.5 T.

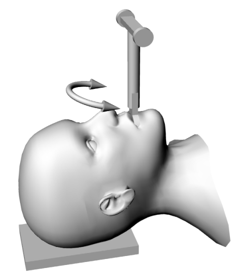

Fig. 1: Excitation device and resulting head motion (arrow) consisting of a combined nodding and left-to-right motion.

Methods: All experiments were performed on a healthy male volunteer according to the local board of ethics on whole body scanners 1.5 T Magnetom Sonata and 7 T Magnetom (Siemens, Erlangen, Germany). A custom-built bite bar [6] was used to generate shear waves in the brain of the volunteer (fig. 1). Both, a single-frequency excitation mode (f = 25.0, 37.7, 50.0 and 62.5 Hz) and a multiple-frequency mode were performed at 1.5 T and 7 T. In the multiple-frequency mode the said frequencies were applied simultaneously and magnetically encoded by a broadband-motion encoding gradient (MEG) while single-frequency vibrations were encoded by MEG of matched frequency. Axial slices positioned about 5-10 mm above the lateral ventricles were acquired with a motion sensitive spin-echo EPI sequence [6] (FOV: 192x192 mm², resolution: 64x64, slice thickness: 6 mm, TR: 3s, TE: 60-80 ms). Using single frequencies one cycle of the respective vibration was sampled by $\Delta t = f^{1}/20$. Using superposed multiple excitation frequencies 80 ms were sampled with Δt = 2 ms. The wave image series were temporally Fourier transformed and the resulting complex wave images were spatially filtered and evaluated by Helmholtz inversion to reconstruct the complex shear modulus. Spatial averaging was applied over complete brain slices and mean shear wave speeds and damping coefficients were calculated for a damped planar wave approach.

Results: Figs. 2 and 3 show a comparison of wave images acquired at 1.5 and 7 T by different wave excitation modes. It is apparent from visual inspection that similar wave patterns have been acquired in all experiments. This observation is supported by the values of wave speed and wave damping calculated by wave inversion as summarized in table 1. For both, single-frequency and multiple-frequency excitation, the wave speeds show similar frequency dependencies at 1.5 and 7 T, with slightly lower values for the 7 T experiments. The damping coefficients agree very well in all experiments.

Table 1: Shear wave speeds c and damping coefficients γ spatially averaged within the brain after wave inversion.

Single-frequency excitation mode				
	1.5 T		7 T	
f [Hz]	c [m/s]	γ[1/m]	c [m/s]	γ[1/m]
25.0	1.18	26	1.09	29
37.5	1.31	31	1.24	31
50.0	1.47	32	1.37	33
62.5	1.64	34	1.55	33
Multiple-frequency excitation mode				
	1.5 T		7 T	
25.0	1.07	28	1.00	29
37.5	1.29	30	1.30	31
50.0	1.43	32	1.42	36
62.5	1.62	33	1.55	34

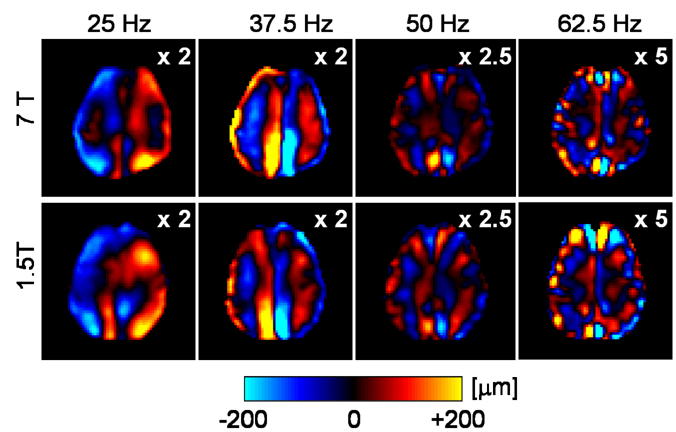

Fig. 2: Out-of-plane displacement wave images for different frequencies acquired with single-frequency excitation mode. Wave patterns change due to different driving frequencies. Wave images are scaled by the factors given in the right upper corners.

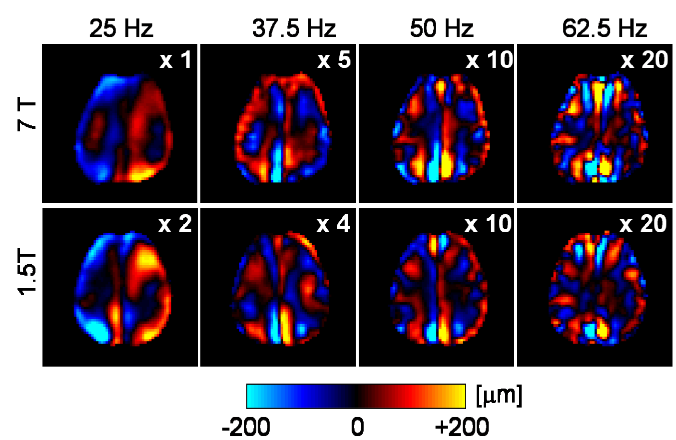

Fig. 3: Out-of-plane displacement wave images of the frequency components acquired with multiple-frequency excitation mode. Wave patterns change due to different driving frequencies. Wave images are scaled by the factors given in the right upper corners.

Discussion: 7 T MRE was successful although a reduced matrix size of 64x64 pixels had to be used in order to compensate for shorter T_2 relaxation times. There is a very good agreement between wave patterns, shear wave speeds and shear damping coefficients at 1.5 T and 7 T in single-frequency and multiple-frequency mechanical excitation modes. Minor differences in the viscoelastic parameters may be caused by slight image distortions at 7 T due to large susceptibility variations. The shown results are very encouraging since the large variety of experimental conditions did not substantially affect the consistency of the measured data. Both wave speed and wave damping values agree well with literature data [2]. Despite the special demands imposed by 7T, MRE images exhibited a high quality allowing the reliable deduction of the viscoelastic parameters. Further improvements to fully exploit the 7 T capabilities will be the implementation of parallel imaging to reduce TE and to increase SNR.

References:

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