Original Research

In Vivo Magnetic Resonance Elastography of Human Brain at 7 T and 1.5 T

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Purpose: To investigate the feasibility of quantitative in vivo ultrahigh field magnetic resonance elastography (MRE) of the human brain in a broad range of low-frequency mechanical vibrations.

Materials and Methods: Mechanical vibrations were coupled into the brain of a healthy volunteer using a coil-driven actuator that either oscillated harmonically at single frequencies between 25 and 62.5 Hz or performed a superimposed motion consisting of multiple harmonics. Using a motion sensitive single-shot spin-echo echo planar imaging sequence shear wave displacements in the brain were measured at 1.5 and 7 T in whole-body MR scanners. Spatially averaged complex shear moduli were calculated applying Helmholtz inversion.

Results: Viscoelastic properties of brain tissue could be reliably determined in vivo at 1.5 and 7 T using both single-frequency and multifrequency wave excitation. The deduced dispersion of the complex modulus was consistent within different experimental settings of this study for the measured frequency range and agreed well with literature data.

Conclusion: MRE of the human brain is feasible at 7 T. Superposition of multiple harmonics yields consistent results as compared to standard single-frequency based MRE. As such, MRE is a system-independent modality for measuring the complex shear modulus of in vivo human brain in a wide dynamic range.

Key Words: magnetic resonance imaging; brain; elastography; ultra high field; motion encoding; viscoelasticity
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MANY DISEASES are associated with changes in the mechanical properties of body tissue. For this reason palpation is one of the simplest and oldest yet very effective diagnostic methods for soft tissue assessment near the body surface. Elastography based on ultrasound (1,2) or magnetic resonance (3,4) extends our sensation of soft tissue stiffness from the subjective impression of the palpating physician to an objective quantitative measurement as well as beyond the surface into regions of the body which are either difficult to palpate or even traditionally not palpable (5–11). For example, the quantification of brain elasticity has become accessible in vivo through recent developments in magnetic resonance elastography (MRE) without opening the skull by surgical intervention (12–20). Thus, MRE opens the door for a noninvasive measurement of the mechanical structure of the brain in its physiological environment. Micromechanical properties of hierarchic systems are known to scale to global viscoelastic properties given by the dispersion of the complex modulus of a material (21). In recent studies of cerebral MRE the dispersion of the complex modulus of the brain was found to be sensitive to age-related changes of the mechanical matrix of the brain (22) as well as to tissue degradation due to multiple sclerosis (23). In the near future, cerebral MRE might assist neurosurgeons in operation planning, might help biomechanics to clarify brain damage mechanisms occurring at head impact, and might serve as a new quantitative MRI modality for an early detection of neurodegenerative diseases.

Currently, whole-body MRI including imaging of the human brain is proceeding toward ultrahigh magnetic fields at 7 T in order to profit from enhanced MR signal to improve either the signal-to-noise ratio (SNR) or the spatial resolution (24). MRI at 7 T still poses a challenge because of increased B_1-field inhomogeneity, stronger susceptibility artifacts and changed relaxation times, primarily shortened T_2^*. To date the utilization of 7 T magnetic fields in MRE was only preliminarily tested (25) and there exists no analysis of MRE-related quantitative viscoelastic parameters based on data acquired at different magnetic field strengths. The prediction of the results of MRE at different field strengths is not trivial since MRE requires