Determination of Gray and White Matter Elasticity with MR Elastography

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Introduction

MR Elastography (MRE) is a non-invasive method for elasticity measurement of human tissue. An examination with MR Elastography requires a periodical mechanical stimulus. For the motion excitation of cerebral tissue an efficient method utilizing a bite bar has already been published [McCracken, ISMRM 03]. With help of this technique waves can be induced into the brain, to measure the elasticity of brain tissue. Segmentation of the brain tissue based on T2 weighted images allows for separated evaluation of white and gray matter areas. In order to determine the elasticity of white and gray matter examinations of seven healthy young volunteers were performed. The range of white and gray matter elasticity in vivo is still not clarified as already discussed by Kruse et. al. [ISMRM 99, p 258]. This study yielded values of 12.9 ± 0.9 kPa and 15.2 ± 1.4 kPa for the stiffness of gray and white matter.

Methods

Mechanical waves were induced into the brain with a bite bar attached to a piezoelectric oscillator (Fig. 1). Since the head oscillated in left to right direction, phase images in three adjacent transverse slices were acquired utilizing a phase-contrast MRI sequence with motion sensitizing gradients oriented parallel to the motion. The acquisitions were repeated with further eight different phase offsets between motion sensitizing gradients and mechanical excitation. A frequency f = 83.3 Hz and an amplitude of 600 µm were used for the excitation.

The wave vector k was determined from the derivative of the spatial phase resulting from a sinusoidal fit along all eight phase offsets. For all three slices a shear modulus can be calculated by $\mu = \rho\,(2\pi \cdot k^{-1} \cdot f)^2$. The tissue density ρ was assumed to be 1000 kg/m^3.

Image acquisition was performed with a Siemens 1.5 T Sonata Scanner (Siemens, Erlangen, Germany) and a eight channel head coil (MRI Devices, Waukesha, USA). T2 weighted images with the same orientation and resolution as the phase images were segmented with an algorithm integrated in SPM99 (Wellcome Dept. Cognitive Neurology, London, UK) yielding probability maps for gray (Fig. 3) and white (Fig. 2) matter. The probability values served as weights for the calculation of a weighted mean of gray and white matter elasticity from the reconstructed elastograms.

Fig. 1

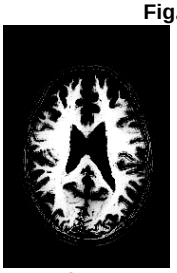

Fig. 2

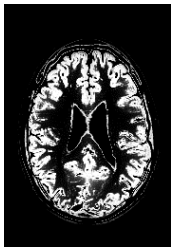

Fig. 3

Results

All volunteers tolerated the examination. In consistence with already published data [2] the mean shear modulus yielded values of 12.9 ± 0.9 kPa and 15.2 ± 1.4 kPa for gray matter and white matter, respectively. The displacement due to the induced oscillation (Fig. 4) ranges from -15 to 15 µm. Fig. 5 shows an example of an elastogram reconstructed from a dataset consisting of eight phase images acquired with the same orientation but different phase offsets The elastogram shows artifacts where the displacement crosses zero. Additionally the elastogram is not as symmetric as expected.

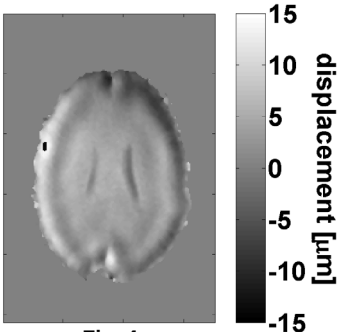

Fig. 4

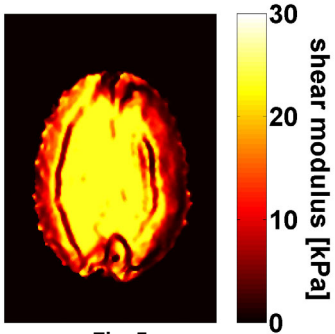

Fig. 5

Discussion

It is shown that the described setup for MRE is suitable for examination of the elasticity of cerebral tissue. With help of tissue segmentation into gray and white matter separated evaluation of these two tissue types can be achieved. The reconstructed elasticity values confirm the results of the study of Kruse et al., especially that white matter is stiffer than gray matter.

The mentioned asymmetry in the elastogram might be caused by artifacts arising with phase contrast acquisitions combined with motion in the head coil. The mentioned zero crossings in the displacement, could be detected in all acquired phase images independent from the phase offset. This interference leads to errors in the elastogram. A further problem for the reconstruction of the phase images is the small amplitude induced in the middle of the brain. This might be the reason, why different elasticity in the area of CSF, as observable in the ventricle in the segmentation maps, is not visualized in the elastogram. For further evaluation of MRE in the brain, artifacts has to be reduced and a higher oscillation amplitudes or phase-to-noise ratio would desirable.

References

[1] McCracken et al., Proc. Intl. Soc. Mag. Reson. Med. 11 (2003), p. 799
[2] Kruse et al., Proc. Intl. Soc. Mag. Reson. Med. 7 (1999), p. 258