Development of a Clinical Protocol for Magnetic Resonance Elastography of the Brain

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Introduction

Magnetic Resonance Imaging (MRI) is a highly versatile imaging technique with a variety of different clinical applications. Magnetic Resonance Elastography (MRE) utilizes mechanical waves with frequencies in the acoustic range to generate shear waves in the tissue of interest. A phase-sensitive MR imaging sequence is used to detect the waves propagating through the tissue [1-4], as these waves cause the displacement of underlying hydrogen nuclei. This technique quantifies the spin motion in the phase of the MR signal, with sensitivities on the level of tens of micrometres. The images produced can then be analysed to determine the wavelength of the propagating mechanical wave. An inversion algorithm is then employed to create an elastic modulus map of the tissue of interest, thereby giving an indication of the mechanical properties of the tissue (stiffness) [5].

The aim of this study is the development of a clinical MRE protocol for use in brain studies.

Materials & Method

All MRE scans were performed on a Siemens 3T Verio using both an in-house built pneumatic and a piezoelectric actuator (see Fig. 1). To measure the difference in SNR, a FLASH sequence (TR/TE 132/21.35ms, flip angle 25°, spatial resolution 0.640 pixels per mm, 1 slice, thickness 10mm, TA 68.04s, 4 timepoints (tp)) was compared to an EPI sequence (TR/TE 1500/100ms, spatial resolution 0.621 pixels per mm, 3 slices, thickness 10mm, TA 48.00s, 32 tp) using an agar:water (1:3) phantom.

Brain: A single-shot EPI phase-sensitive sequence (TR/TE 3000/100ms, spatial resolution 0.512 pixels per mm, 5 slices, thickness 2mm, TA 96.9s, 32 tp) was employed with wave frequencies ranging from 25Hz to 125Hz, in steps of 12.5Hz. Statistical parametric mapping (SPM8) was used to further study the shear moduli of white and grey matter.

Brain scans were performed on two volunteers. Frequencies were chosen to be consistent with those used in literature. The results of the brain presented are acquired from one volunteer.

Results

FLASH sequences resulted in a higher SNR in magnitude images and unwrapped phase images. Acquisition using EPI was found to be faster (seconds vs. minutes), which is appealing for use in the clinic. Usage of the piezoelectric and the pneumatic actuator resulted in similar shear moduli (G’ (storage modulus, real part) and G” (loss modulus, imaginary part), Fig. 3). The wave displacement was found to be more homogeneous for the pneumatic actuator.

Brain: Higher frequencies (>75Hz) showed a more homogeneous shear modulus, but a lower wave displacement inside the brain. Frequencies between 25Hz and 37.5Hz resulted in low signal achievement and regions missing information (“holes”) (see Fig.4,5).

Discussion and Conclusion

Both the piezoelectric and the pneumatic actuator are suitable for clinical MRE. Because of the easy handling of the pneumatic setup, it is preferred for imaging of organs located at the surface of the body.

The preferred frequency used for brain MRE is 62.5Hz. With this frequency enough signal is acquired and furthermore, a strong wave displacement is measured. SPM8 is a useful tool to segment white and grey matter to study the differences in shear modulus (see Fig.4).

The development of a clinical protocol is a trade-off between high quality and fast imaging. EPI is a reasonable compromise to gain qualitative data and to keep the acquisition time feasible for clinical use.

References