Development of a Clinical Protocol for Magnetic Resonance Elastography of Brain

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Aims and objectives

Manual palpation plays an important role in the clinician's routine. This is unfeasible when the tissue of interest is inaccessible, such as the brain inside the skull. Magnetic resonance elastography (MRE) has the potential to replace palpation, by objectively assessing the mechanical properties of tissue [1-5]. However, for the implementation of this technique in clinical practice there is an abundance of issues that need to be addressed. The aim of this study is the development of a clinical protocol suitable for the human brain, looking at the choice of actuator, MR sequence, wave frequency and RF coil.

Methods and materials

All MRE scans were performed on a Siemens 3T Verio using both an in-house built pneumatic actuator and a piezoelectric actuator (see Fig. 1). An agar based phantom (agar:water 1:3) was used to compare the differences in signal-to-noise ratio (SNR) of the phase images and elastograms when using a FLASH or EPI based sequence, and also SNR differences when using a 12-channels or 32-channels RF head matrix coil.

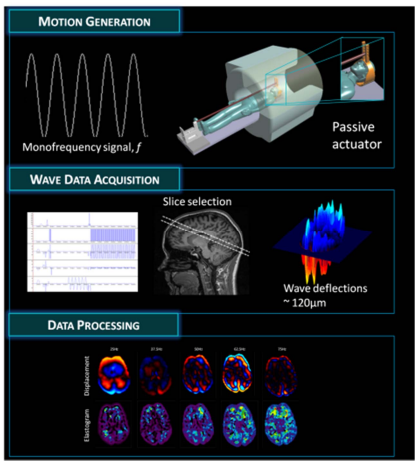

Fig. 1: Setup and workflow of an MRE experiment (top to bottom): Mechanical waves generated using the piezoelectric actuator, Wave data acquisition and Data processing. Adapted from [6]. Right: Piezoelectric setup for the liver.

For *in-vivo* imaging, a single-shot EPI phase-sensitive sequence (TR/TE 3000/100ms, spatial resolution 0.512 pixels per mm, 5 slices, thickness 2mm, TA 96.99s, 32 time points (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.

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 preferred for clinical use.

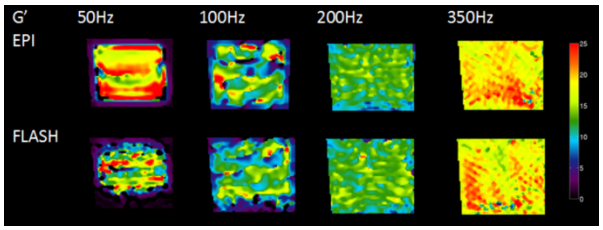

Fig. 2: Comparison of shear moduli acquired by EPI and FLASH sequences. Figures are given in KPa

Usage of the piezoelectric and the pneumatic actuator resulted in similar shear moduli (G' (storage modulus, real part) and G'' (loss modulus, imaginary part)). Similar results were obtained for the FLASH and EPI based sequence (Fig. 2). 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 resolution elastograms and regions missing information. (see Fig.3).

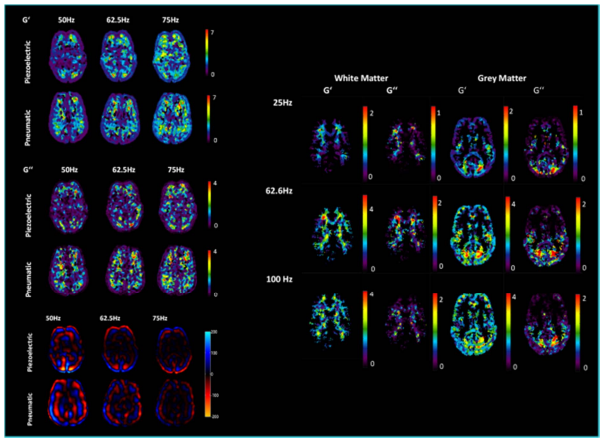

Fig. 3: Left: Comparison between pneumatic and piezoelectric actuator at 50Hz, 62.5Hz and 75Hz and Right: Shear modulus (G' and G'') for white matter and grey matter of the brain at 25Hz, 62.5Hz and 100Hz. Shear moduli are given in KPa and wave displacement is shown in microns.

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 clinical imaging.

The frequency range for brain is 50Hz to 75Hz. At these frequencies there are sufficient number of wavelengths and enough wave amplitude to allow good resolution elastograms to be calculated. The development of a clinical protocol is a trade-off between high quality elastograms and fast imaging. EPI is a reasonable compromise to gain qualitative and quantitative data preserving the acquisition times feasible for clinical use.

References

[1] Muthupillai et al., *Science, 269 (5232): 1854-1857, (1995).*[2] Muthupillai et al., *Magnetic Resonance Medicine, 36: 266-274, (1996).* [3] Ehman et al., *Physics in medicine and biology, 53 (4): 925-935, (2008).* [4] Kruse et al., *NeuroImage, 39 (1): 231-237, (2008).* [5] Uffmann and Ladd, *IEEE Engineering in Med and Biol Mag, 27: 28-34, (2008).* [6] Streitberger et al., *PloS one, 7 (1): e29888, (2012)*