Finger tapping experiment observed by brain Magnetic Resonance Elastography

O. Holub[1], S. Lambert[1], K. Schregel[2], L. Bilston[3], S. Patz[4,5], and R. Sinkus[1]

[1]Imaging Sciences and Biomedical Engineering, King's College London, London, London, United Kingdom, [2]University Medicine Goettingen, Institute of Neuroradiology, Goettingen, Goettingen, Germany, [3]University of New South Wales, Neuroscience Research Australia, Sydney, New South Wales, Australia, [4]Brigham and Women's Hospital, Radiology, Boston, Massachusetts, United States, [5]Harvard Medical School, Radiology, Boston, Massachusetts, United States

Target Audience: Researchers interested in neuro-imaging, fMRI and tissue properties (measured via MR-Elastography)

Purpose: To develop a novel non-invasive imaging modality for functional imaging of the human brain using magnetic resonance. To investigate temporal changes of material properties of human brain tissue due to intended active functional stimuli.

Methods: MR-Elastography (MRE) is a novel imaging method which allows assessing biomechanical properties of tissue *in-vivo*. To this point, MRE was mainly used to investigate changes of pathological tissues such as for instance cancer or fibrosis. This work describes the potential of MRE in the context of human functional MRI. Here, spatio-temporally localized biomechanical images are acquired while conducting a simple finger tapping task. The observed response is then correlated to its anatomical localization, here in particular to the senso-motoric cortex similarly to experiments conducted using classical fMRI[1]. A dedicated MRI compatible brain MRE transducer has been developed and adopted for bi-lateral mechanical excitation. External vibrations (30Hz) were transmitted into brain by placing the two pistons on the zygomatic bone. MRE was conducted on healthy volunteers in a full-body 3.0T MRI system (Achieva scanner, Philips Healthcare, Eindhoven, Netherlands) using a gradient spoiled FFE sequence using TE/TR=9.21/104 ms with motion sensitized gradients at 118Hz and amplitude of 60mT/m, 64x64 matrix, 9 slices, and an isotropic image resolution of 3x3x3mm^3). This 3mins sequence was repeated two times while asking the volunteer to relax, and subsequently two times while he was actively tapping with ALL right hand fingers. MRE reconstruction was performed using a direct MRE inversion of the wave equation[2]**.** Specifically, raw-data were smoothed using a 3D Gaussian filter (σ=1.5 pixels, support 3x3x3 pixels), the 3D curl of the wave was subsequently evaluated via a 2nd order 3D polynomial fit to a cube of 3x3x3 pixels, and the 3D Laplacian of the curl was calculated via a 3rd order 3D polynomial fit to 5x5x5 pixels.

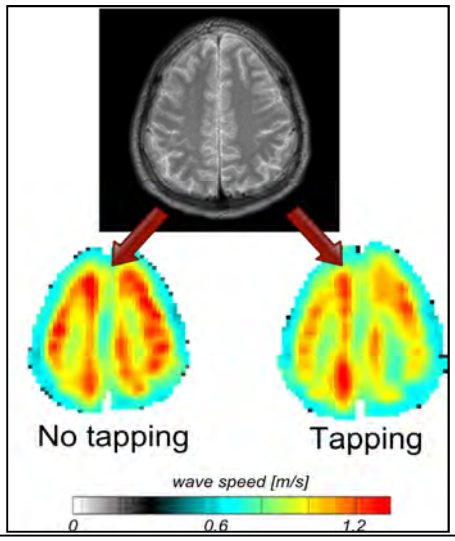

Figure 1. Experiment conducted in the reference state ("no-tapping") indicated a notable difference to the task-conducting

Results & Discussion: In this analysis only the shear wave phase velocity C_p (speed) was considered since it demonstrated the highest degree of reproducibility (compared to the shear attenuation). Sets of images in the each dataset (no tapping/tapping) showed a consistent speed distribution. Averaged maps of C_p indicated sufficient signal stability/reproducibility to well recognize the expected anatomical structures (Figure 1). Once subtracted, wave speed indicated a localized activation resulting in a decrease of observed apparent tissue stiffness (Figure 2).

Discussion and Conclusion: Results indicate that the human brain tissue is subject to substantial temporal changes of its material properties while conducting functional tasks. In fact, changes of the apparent stiffness were spatio-temporally correlated to the senso-motoric cortex and exceeded ~30% of speed change. A possible explanation is the sudden increase of cerebral blood volume (CBV) and cerebral blood flow (CBF) which is a known mechanism explored via fMRI. Elevated CBV leads to an increased volume fraction of blood to tissue per voxel which might result in an "apparent" decrease (i.e. softening) of the mechanical shear properties of the brain parenchyma. Whether this effect is only a secondary effect of the increased presence of blood per voxel, or whether the brain tissue changes its properties due to temporal compression is yet to be investigated. However these results provide the first evidence of functional MRE (fMRE) deployed in humans.

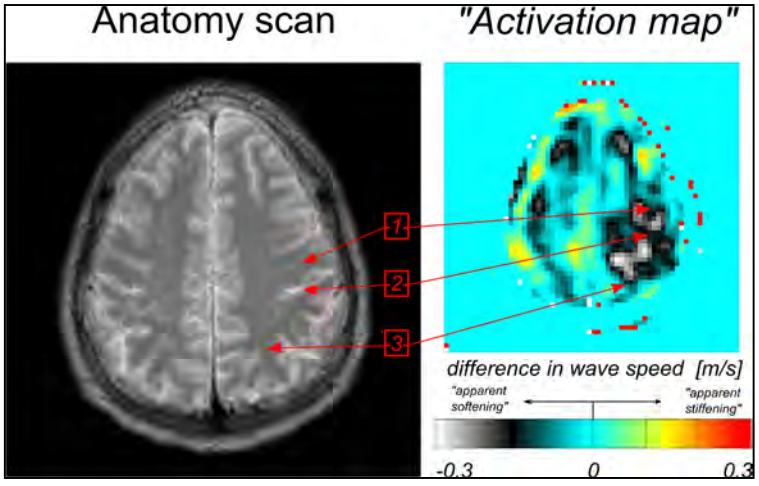

Figure 2. Activation map was obtained by subtracting "finger-tapping" speed map from the reference "no-tapping" speed map. Notable softening (~-0.25m/s) was observed in *precentral gyrus* (1), *postcentral gyrus* (2) and *parietal lobe* (3).

NOTE: This study has been conducted in parallel with work done by our collaborating team-members where the same technique has been tested in mice subjected to passive auditory stimuli. In their abstract, also submitted to ISMRM 2015, they demonstrate equally notable spatio-temporal changes in cortical stiffness due to neural stimuli. Interestingly, contrary to our results in humans, they observe an increase in stiffness. Although these results need further investigation, it is likely that this intriguing difference originates from very different experimental conditions for MRE. Results presented in mice are based on data obtained at probing wavelengths and image resolution which are one order of magnitude below the experiments performed in humans (i.e. 3mm vs 30mm wavelength, and 0.25mm vs 3mm resolution). Short wavelengths provide sensitivity via multiple scattering to microarchitectural alterations, while our study is rather based on a temporal but substantial change of blood content per voxel. Both groups believe that these results are not contradictory as different mechanisms are observed.

References: [1] Witt et al., 2008, NeuroImage 42, pp. 343–356; [2] Sinkus et al., 2005, Magnetic resonance imaging 23(**2**), pp. 159—165; [3] Ulmer S., Jansen O. (eds.), 2010, fMRI - Basics and Clinical Applications, Springer-Verlag Berlin Heidelberg