Remotely induced cerebral strain for enhanced safety and acceptance of MR elastography of the brain

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Target audience: Physicians and physicists interested in cerebral MR elastography (MRE).

Background: Many diseases are associated with a change in the viscoelastic properties of soft tissues leading to the well known sensitivity of manual palpation. Cerebral MRE is a new modality that brings viscoelastic constants into the workscope of neuroradiologists. Previous studies demonstrated the sensitivity of cerebral MRE to a variety of neurological disorders e.g. multiple sclerosis (1), Alzheimer's disease (2) and Parkinson (3). However, MRE of the brain relies on gentle mechanical vibrations of the head usually induced by a cradle-type actuator limiting its acceptance among radiologists.

Purpose: To improve the acceptance of cerebral MRE by introducing a remote vibration generator for brain tissue based on thoracic vibrations in the low audible frequency range.

Methods: The new driver setup is shown in Fig.1. We placed a rubber mat on the patient's thorax which was mounted to a remote nonmagnetic vibration generator at the end of the patient table. Main vibration direction was along the head-feet axis. We analyzed the vibration amplitudes from 25 to 60 Hz (increments of 5 Hz) in 10 healthy volunteers. Further imaging parameters: 1.5-T scanner (Siemens Magnetom Sonata), 9 contiguous slices in both transversal and coronal views; spin-echo EPI as explained in (4), TR: 2170 ms; TE: 99 ms; FoV: 176 × 192 mm^2; matrix size 88 × 96. Elasticity reconstruction was based on multifrequency dual elasto visco (MDEV) inversion (4) providing two parameters, the magnitude |G*| and the phase angle φ of the complex shear modulus G*.

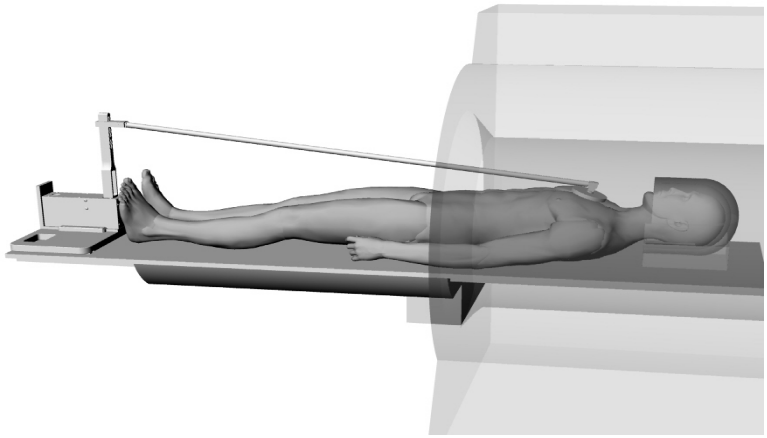

Fig.1: Driver setup for cerebral MRE based on the proposed remote head actuation by a rubber plate placed on top of the patient's chest. The nonmagnetic actuator with extended lever is driven by piezo ceramic stack.

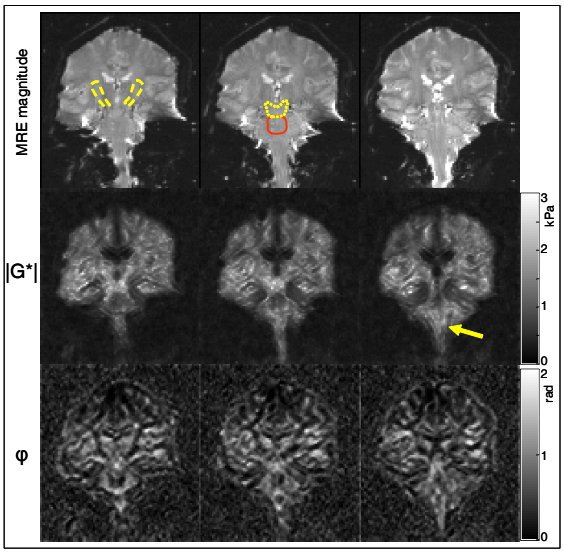

Fig.2: Three example image slices in coronal view of the brain showing MRE parameters |G*| and φ. The analyzed regions of interest in this view are shown in the MRE magnitude images and correspond to the CST (capsula interna – CI, dashed yellow line), CST (crus cerebri – CC, dotted yellow line) and pons (red line). The arrow demarcates structures of the dorsal tract.

Results: Compared to head cradle based MRE reported in (4), remote actuation produces lower cerebral wave amplitudes (e.g. 22.98 ± 11.89 µm vs. 9.88 ± 2.60 µm @30 Hz). However, considering a wave-amplitude-to-noise ratio within the whole brain of 3 sufficient for MRE, excitation frequencies below 45 Hz can be used for parameter reconstruction. Fig.2 shows example slices of |G*| and φ. Fig.3 gives regional differences of brain mechanical parameters. |G*| was lowest in the pons (0.98 ± 0.1 kPa). Within the CST, |G*| decreased in caudal-cranial direction from crus cerebri (CC, 1.69 ± 0.29 kPa) to capsula interna (CI, 1.39 ± 0.11 kPa) to white matter seen in a transversal slice above the ventricles (WM, 1.15 ± 0.16 kPa).

Discussion: The new driver avoids the subjective feeling of head vibrations although sufficiently high extrinsic wave amplitudes are produced during the MRE scan. The lower drive frequencies (25–40 Hz) combined with MDEV inversion allowed us to resolve anatomical details and provide values which agree to previous work (4).

Conclusion: Remote actuation in cerebral MRE is a gentle way of inducing shear waves into the cranial cavity without touching the head. Combined with low driving frequencies, the patient should not expect any discomfort which promises a better acceptance of cerebral MRE in the clinic.

Literature: (1) Wuerfel et al. *Neuroimage* 2010;49:2520-2525. (2) Murphy et al. *J Magn Reson Imaging* 2011;34:494-498. (3) Lipp et al. *NeuroImage: Clinical* 2013;3:381–387. (4) Guo et al. *PlOS ONE* 2013;8:e71807

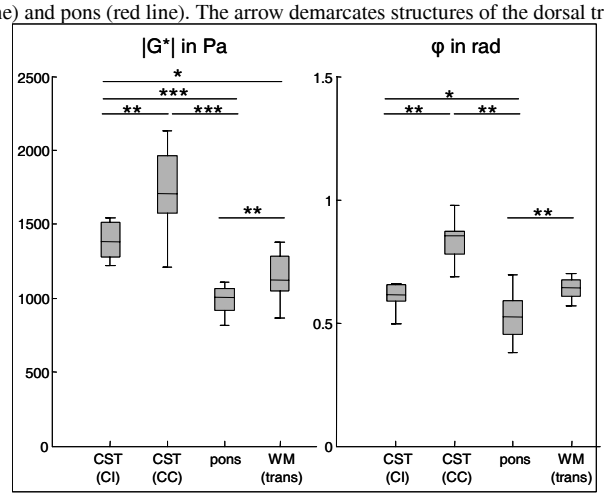

Fig.3: Regional variation of MRE parameters in the brain.