High resolution magnetic resonance elastography of the human eye in vivo: a feasibility study

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Target audience: Radiologists and engineers interested in the diagnosis of eye diseases and the mechanical properties of the eye

Background: MR elastography [1] is sensitive to viscoelasticity and pressure related parameters [2] in soft biological tissue. Recent developments in multifrequency MRE (MMRE) have enabled researchers to generate high-resolution maps of viscoelastic parameters [3]. The present study is targeted on the feasibility of in vivo high resolution MMRE of the eye as a potential imaging marker for an altered eye pressure and for the mechanical characterization of eye cancer.

Purpose: To test the feasibility of in vivo high-resolution mechanical imaging of the human eye.

Methods: A modified goggle was used for inducing shear waves inside the eye. A gel pad was inserted to prevent strong susceptibility changes. In Fig. 1 the setup of the actuator is shown which was constructed to facilitate mainly two functions: (i) mechanical support of the eye RF-coil inside the head coil (Figs. 1a, 1b) and (ii) to transmit the vibrations into the eye which were generated by a piezo-electric driver [4] and transferred to the goggle by a carbon fiber rod (Fig. 1c). 3D MMRE was performed on a 3T MRI scanner (Siemens Skyra). The magnitude |G*| and phase angle φ of the complex shear modulus were analyzed by inversion of full wave fields data at 2 harmonic drive frequencies of 90 and 100 Hz [4]. MRE sequence parameters: 25 transverse slices of 1×1×1 mm^3 resolution, 8 wave dynamics, 3 orthogonal wave field components (1200 images in total), TR/TE = 4150/44 ms, FoV = 128×128 mm^2, matrix size 128×128, parallel imaging with a GRAPPA factor of 4, amplitude and frequency of motion encoding gradient: 24 mT/m, 100 Hz; total scan time <4 min.

Fig. 1: Driver setup for MRE of the eye. The modified goggle fits inside the head coil and is connected with a carbon fibre rod to a piezo ceramic based driver [4] placed at the foot end of the patient table.

Results: Fig.2 shows a representative wave image of the eye of a volunteer at 100 Hz drive frequency. From this data, the shear wavelength in the vitreous body was determined with 10.4 mm which corresponds to a shear modulus of 1077 Pa assuming a density of 1 kg/l. Fig. 3 illustrates 5 slices of T2-weighted images (MRE magnitude signal) used for the assignment of regions of interest (ROI) and the MMRE parameter maps, |G*| and φ. Mean viscoelastic parameters (± intra-ROI standard deviation) were |G*| = 1084 ± 366 Pa and φ = 1134 ± 440 Pa.

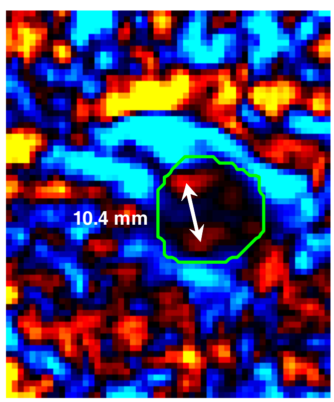

Fig.2: Example wave image corresponding to 100 Hz vibration frequency. The green line demarcates the boundaries of the eye.

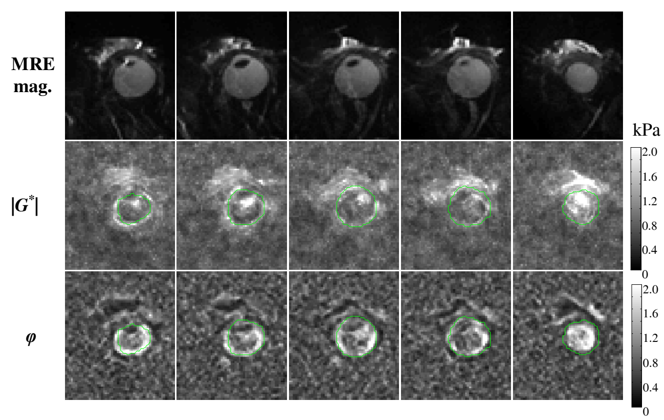

Fig.3: Experimental data and maps of viscoelastic parameters. Upper row: MRE magnitude images. The gel pad is partly visible on top of the eyelid. Middle and bottom row: magnitude and phase angle of the complex shear modulus G*.

Discussion: This study demonstrates the feasibility of in vivo MRE of human eyes. The spatially averaged |G*|-value well agrees to the estimation of the shear modulus by shear-wavelengths in an elastic body. Furthermore, the results are in agreement to the in vivo shear modulus of the vitreous body in mice of 895 ± 122 Pa [5] whereas differences exist to studies on ex vivo eyes where lower values were reported [6]. Further experiments are needed in order to investigate possible differences between physiological conditions and ex vivo mechanical tests as well as to exploit a wider range of drive frequencies in order to better understand possible influences of the eye geometry to the measured MMRE parameters [7].

Conclusion: This study presents the first high resolution mapping of viscoelastic constants of the human eye in vivo. In the future, our method may be added to clinical examinations in order to support the clinical diagnosis of ocular diseases.

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