In vivo magnetic resonance elastography of the human intervertebral disk: Preliminary results

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Target audience: Physicians interested in the *in vivo* mechanical characterisation of the human intervertebral disk.

Background: The noninvasive detection and quantification of the human intervertebral disk by MR elastography (MRE) could be beneficial for the diagnosis of chronic disk degeneration. MRE is potentially capable to measure the altered mechanical behaviour of the disk in the course of degeneration due to water loss and inherent changes in the material composition which would exceed the morphological information used for the Pfirrmann score (1).

Purpose: To test the feasibility of *in vivo* mechanical characterisation of the human intervertebral disk using 3D multifrequency MRE (3DMMRE).

Methods: 15 volunteers were examined within this study, one of whom was measured 7 times on 7 different days. A dorsal plate transducer connected to a nonmagnetic driver was used for 3DMMRE with 5 harmonic drive frequencies of 50, 55, 60, 65 and 70 Hz. Full wave field data at 8 dynamics were acquired in 10 transverse slices of 2x 2x2 mm^3 resolution positioned through 2 consecutive discs. Total measure time was below 8 min including 2 averages for increasing SNR. Further imaging parameters: TR = 1960 ms, TE = 68 ms, FoV = 256 × 208 mm^2, matrix size 128×104; GRAPPA factor of 2; motion encoding gradient (MEG) frequency = 40 Hz for 50, 55 and 60 Hz vibration and 80 Hz for 65 and 70 Hz vibration frequencies. MEG amplitude = 30 mT/m. Parameter recovery was based on multifrequency dual elasto visco (MDEV) inversion (2) yielding the magnitude |G*| and the phase angle φ of the complex shear modulus.

Results: An example of the complex-valued curl-field in a central image slice of the disk of one volunteer is shown in Fig.1. Fig.2 shows |G*| parameter maps of two slices, one in each disk as demarcated in the sagittal view on the left hand side. A decrement of elasticity from disc L3/L4 to disc L4/L5 is well visible indicating altered mechanical properties. In addition to MRE, morphological staging according to the T2 weighted morphology based Pfirrmann score was performed. |G*| was averaged within manually selected regions of interest corresponding to the central part of the nucleus pulpous in each disc. Mean viscoelasticity values in that region were |G*| = 4.34 ± 1.2 kPa and φ = 1.6 ± 0.17. Repeated experiments in one volunteer showed a good reproducibility with a mean values |G*| = 5.23 ± 0.6 kPa and φ = 1.67 ± 0.14 kPa. Fig. 3 shows the averaged |G*| values of all volunteers as well as the reproducibility in one volunteer. A negative correlation between |G*| and the morphological Pfirrmann score was observed (R = -0.4067, P = 0.0075).

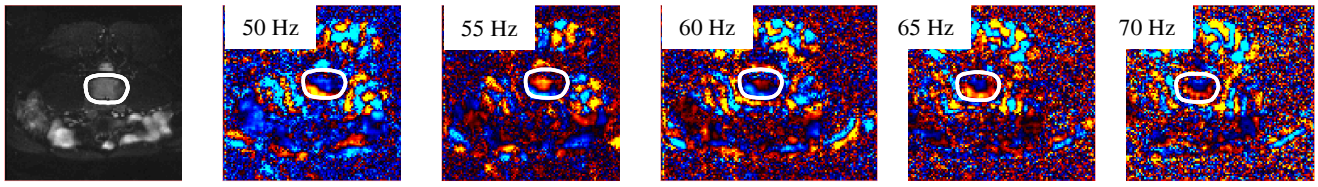

Fig. 1: Sections of transversal wave images (real part of 1 complex-valued curl component) at 5 drive frequencies as well as the MRE magnitude image for anatomical reference

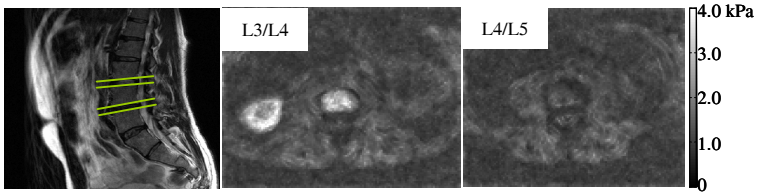

Fig. 2: T2 weighted image and corresponding |G*| maps for the displayed discs

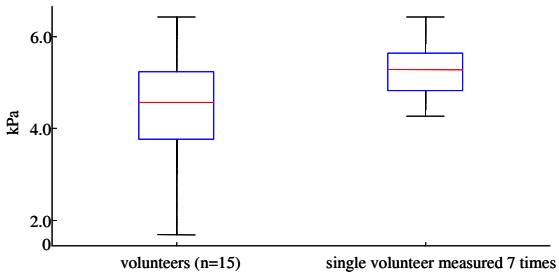

Fig. 3: Boxplot of |G*| values of the 15 volunteers (left) and the reproducibility measurement of one volunteer (right)

Discussion: Degeneration of the vertebral disk is often associated with chronic back pain and constitutes a major public health problem in western industrialized societies (2). So far the prevailing classification of intervertebral disk degeneration is relies on MRI morphology such as internal disk signal intensity, the distinction between Nucleus pulposus and Annulus fibrosis as well as the disk height. These parameters however do not allow direct conclusions about the material's and structural conditions of the disk and are thus error prone. Using 3DMMRE it was possible to in vivo characterise the mechanical properties of the human disk. Our preliminary results show good intra individual reproducibility and correlate with the Pfirrmann score. A limitation of our feasibility study in healthy volunteers is the small group variation of Pfirrmann scores imposing the need for further validations in a group of patients.

Conclusion: This study presents the first in vivo measurement of viscoelastic constants of the human intervertebral disc by MRE. Our results show a good reproducibility and correlate with the MRI morphology based Pfirrmann score.

Literature: 1. Pfirrmann et al. *Spine*. 2001;26:1873–8. 2. Hirsch et al. *Magn Reson Med* 2013;doi 10.1002/mrm.24674. 3. Maniadakis et al. *Pain* 2000;84:95–103.