Magnetic resonance elastography (MRE) of the kidney in healthy volunteers

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Background: Interstitial fibrosis is a pathological process associated with renal failure. Staging fibrosis is currently performed by biopsies. This process is prone to sampling errors and to eventual complications. We hypothesize that fibrosis stiffens the renal cortex, making it detectable and quantifiable by MR elastography (MRE) [1].

Aims: The aim of this preliminary study was to assess the feasibility of the technique, its reproducibility, and to provide initial stiffness values in the normal kidney.

Methods: Ten healthy volunteers were enrolled in the study. MRE was performed on a 1.5T scanner (GE Healthcare Signa Excite) with a system similar to that used for liver [2]. A passive driver was placed against the posterior abdominal wall. A continuous vibration was applied using a loudspeaker. All three components of the displacements field were acquired in three contiguous imaging planes, with eight frames per vibration cycle. The curl operator was applied to the displacement field to remove the contribution of the longitudinal wave [3]. The resulting images were processed by directional filtering and local frequency estimator [4] to estimate the shear velocity. This process provided three images (one for each component of the curl vector) in each imaging plane. MRE was successively performed at two frequencies (45 and 76 Hz) to investigate the role of viscoelasticity. The total acquisition time was approximately 1 hour.

Results: Renal MRE was feasible in all volunteers. The amplitude of the vibration in the kidney was 15-30 µm at 45 Hz (median value), and 7-15 µm at 76 Hz. The shear velocity in the kidney was 2.3 ± 0.3 m/s at 45 Hz (mean ± standard deviation), and 3.1 ± 0.3 m/s at 76 Hz. Individual results are reported in figure 2. Assuming a Kelvin-Voigt model ($G^* = \mu + i\omega\eta$), the velocity measurements correspond to a storage modulus $\mu = 1.7$ kPa and a viscosity $\eta = 12$ Pa.s.

Conclusions: The study showed that MRE of the kidney was feasible. It also provided initial shear velocity values for the normal kidney, and evidence of viscoelastic behavior in vivo. Further work will be conducted to assess the correlation between the viscoelastic properties and fibrosis.

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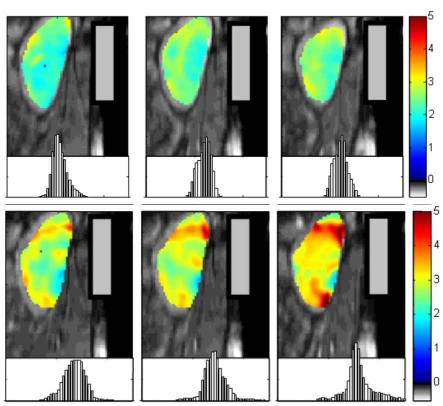

Fig.1: Shear velocity images with corresponding histograms at 45 Hz (top) and 76 Hz (bottom) in 3 contiguous imaging planes (volunteer #6).

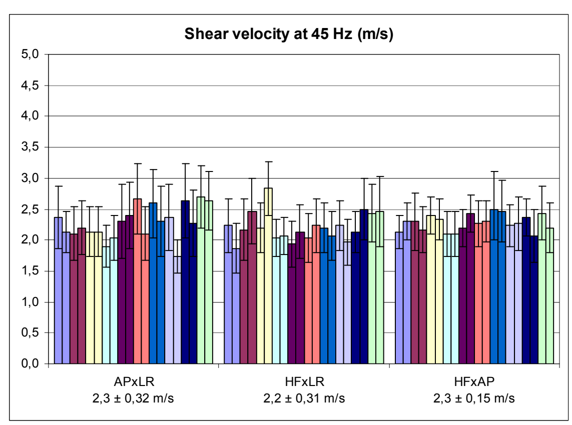

Fig.2: Summary of shear velocity measurements at 45 Hz. Each color represents a single volunteer.