3D multifrequency abdominal MR elastography using a piezoelectric driver, single-shot wave-field acquisition, and multifrequency dual parameter inversion

Jing Guo1, Sebastian Hirsch1, Rolf Reiter3, Thomas Kroencke1, Patrick Asbach2, Juergen Braun1, and Ingolf Sack1

1Department of Radiology, Charité - University Medicine Berlin, Berlin, Berlin, Germany, 2MVZ CBF Radiologie, Charité - University Medicine Berlin, Berlin, Berlin, Germany, 3Department of Medical Informatics, Charité - University Medicine Berlin, Berlin, Berlin, Germany

**Target audience:** Radiologists and MR physicists who are interested and working in the field of MR elastography (MRE).

**Purpose:** To improve the clinical applicability of abdominal MRE [1] and to reduce reconstruction artifacts causing uncertain regions in viscoelasticity maps by introducing a novel 3D multifrequency MRE technique based on a piezoelectric driver, single-shot wave-field acquisition and multifrequency dual parameter inversion. Furthermore, we test the new method on healthy volunteers and patients with ascites regularly challenging the external wave stimulation of the liver.

**Methods:** Abdominal MRE was applied to ten healthy volunteers (3 females, age range from 22 to 51 years) and four patients with portal hypertension (2 females, age range from 58 to 75 years, portosystemic pressure gradients of 32, 18, 27 mmHg, respectively). Experiments: All experiments were conducted on a 1.5-T MRI scanner equipped with a 12-channel phased array surface coil. Single-shot spin-echo EPI with flow-compensated motion-encoding gradient (MEG) was used for rapid 3D motion field acquisition. Vibration frequencies were 30, 40, 50 and 60 Hz. For each drive frequency, MEG-direction and wave dynamic, 10 adjacent transversal image slices of 2.7×2.7×5 mm³ resolution were recorded. Data acquisition was split into 12 breath holds of 15 sec each. Total examination time was 6 to 8 min. Further imaging parameters: TR / TE = 182 ms / 54 ms; field of view (FoV), 350×284 mm²; matrix size 128×104; MEG frequency, 50 Hz; MEG amplitude, 30 mT/m.

**Results:** As seen from Fig.2, liver, vessels, fluid-filled ascites, and aorta are well resolved by $|G|$ and $\alpha$. It is remarkable that areas of larger vessels as inferior vena cava and abdominal aorta are identifiable with low intensity in the $|G|$-map, revealing the low shear modulus of such fluid-filled compartments. Patients have significantly higher $\alpha$-values ($\alpha = 0.511 \pm 0.060$) compared to healthy volunteers ($\alpha = 0.313 \pm 0.041$, P = 1.1×10⁻³), whereas the group-mean shear modulus $|G|$ is not altered between our groups (volunteers: 1.44 ± 0.23 kPa, patients: 1.96 ± 0.99 kPa, P = 0.129). We use the intra-hepatic standard deviations for quantifying heterogeneity. The SD-values are generally lower in healthy volunteers than in patients (SD of $|G| = 0.54 \pm 0.09$ kPa [volunteers], SD of $|G| = 1.07 \pm 0.61$ kPa [patients], P = 0.015; SD of $\alpha = 0.157 \pm 0.026$ [volunteers], SD of $\alpha = 0.217 \pm 0.012$ [patients], P = 0.001). In the group of healthy volunteers, both parameters $|G|$ and $\alpha$ are higher in the spleen than in the liver (P = 0.015 and 6.58*10⁻³, respectively). In the same group, a significant correlation between splenic and hepatic stiffness ($|G|$) exists, as illustrated by Pearson's linear correlation coefficient (R = 0.8488, P = 0.002) which agrees with literature values [6]. However, no such correlation between splenic and hepatic MRE constants was found for $\alpha$ or for both $|G|$ and $\alpha$ in patients.

**Discussion:** It is a stimulating result that we could resolve hepatic and splenic stiffness by the same scan in all subjects including those with ascites. The higher powerlaw exponent $\alpha$ in the spleen suggests that the spleen has a more strongly cross-linked mechanical structure than the liver. Given that nearly 80% of the spleen is made up of red pulp, which consists of fibrils and connective tissue cells, it is not surprising that splenic $\alpha$ is significantly higher. Our study reproduces the correlation of splenic and hepatic stiffness reported in [6,7]. However, the lack of correlation between splenic and hepatic $\alpha$ suggests that $|G|$ in both organs is sensitive to mechanisms which do not alter the inherent tissue architecture such as changing vascular pressure, interstitial fluid accumulation, or strengthening of connective tissue.