MR-Elastography: A unique tool to non-invasively measure the complex shearmodulus of tissue - application to breast, liver, Alzheimer's disease and rheology

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Abstract

Palpation has ever since been most important to screen for pathological abnormalities, especially in the area of breast cancer detection. MR-Elastography offers a unique technique to assess non-invasively the complex shear modulus of biological tissue. The basic concept is to illuminate the region of interest with mono-chromatic low-frequency mechanical waves and image the propagation of those waves via phase-locked motion-sensitized MR-sequences. The advantage over ultrasound-based approaches is that MR allows to measure the 3D displacement vector of the wave field within a volume. Thus, reconstruction of the complex shear modulus G* can be done in an unbiased way: remnants of the compressional wave field are eliminiated via application of the curl operator to the complex-valued displacement field yielding a Helmholz type of equation. Inversion is done locally using third-order derivatives of the 3D displacement field. Results are presented for breast cancer and a 20increase in specificity is demonstrated when adding viscoelastic information to classical data provided by the established MR-mammography. The application to liver shows that the degree of fibrosis can be staged via the complex shear modulus having an enormous impact on the treatment of hepatitis C. Initial results

for Alzheimers disease in mice show that the anisotropic mechanical properties decrease in the corpus callossum (white matter) due to the presence of the disease. This finding correlates to findings done with diffusion tensor MRI imaging the mobility of water molecules. Finally, we investigated the dispersion properties of the complex shear modulus in tissue. A power-law behavior for G^* as a function of frequency is found. A possible explanation is the underlying fractal vascular system representing an enormous mismatch in acoustic impedance for the mechanical wave.