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# Tabletop magnetic resonance elastography for the measurement of viscoelastic parameters of small tissue samples

Selcan Ipek-Ugay [a], Toni Drießle [b], Michael Ledwig [b], Jing Guo [a], Sebastian Hirsch [a], Ingolf Sack [a], Jürgen Braun [c,*]

[a] Department of Radiology, Charité – Universitätsmedizin Berlin, Berlin, Germany
[b] Pure Devices GmbH, Würzburg, Germany
[c] Institute of Medical Informatics, Charité - Universitätsmedizin Berlin, Berlin, Germany

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ABSTRACT

We demonstrate the feasibility of low-cost tabletop MR elastography (MRE) for quantifying the complex shear modulus $G^*$ of small soft biological tissue samples as provided by pathologists. The MRE system was developed based on a tabletop MRI scanner equipped with a 0.5 T permanent magnet and a tissue sample holder mounted to a loudspeaker. A spin echo sequence was enhanced with motion-encoding gradients of 250 mT/m amplitude synchronized to acoustic vibration frequencies. Shear wave images suitable for elastography were acquired between vibration frequencies of 0.5 and 1 kHz in agarose, ultrasound gel, porcine liver, porcine skeletal muscle, and bovine heart with a spatial resolution of 234 μm pixel edge length. The measured frequency dependence of $G^*$ agreed well with previous work based on high-field MR systems. The ratio between loss and storage moduli was highest in liver and ultrasound gel, followed by muscle tissue and agarose gel while ultrasound gel and liver showed similarly low storage moduli compared to the other samples. The shear wave to noise ratio is an important imaging criteria for MRE and was about 4.2 times lower for the preliminary setup of the 0.5 T tabletop system compared to a 7 T animal scanner. In the future, the new tabletop MRE system may serve as a low cost device for preclinical research on the correlation of viscoelastic parameters with histopathology of biological samples.



## 1. Introduction

Magnetic resonance elastography (MRE) [1,2] is a non-invasive medical imaging modality that depicts the viscoelastic properties of soft body tissue for diagnostic purposes. Various studies have demonstrated the high sensitivity of MRE to diseases including hepatic fibrosis [3–6], heart diseases [7], neurological disorders [8–12], and tumors [13–18].

Sensitivity of viscoelastic constants to pathological tissue alterations arises from the hierarchical organization of mechanical structures in biological tissue. Specifically, the effective shear modulus of biological soft tissue is determined by architectural properties across a continuum of scales from cellular to macroscopic dimensions [19,20]. It has been shown that wideband MRE combining multiple drive frequencies provides similar shear modulus values as compared to oscillatory rheometry which is an established method for studying the topology of viscoelastic networks [21,22]. Nevertheless, it remains a major goal of elastography to identify the relationship between tissue structure and macroscopic viscoelastic parameters towards the analysis of tissue structures by in vivo imaging. Therefore, effort has been invested in performing MRE of tissue samples and animal disease models in order to facilitate a correlation between MRE and histology [23–28]. For example wideband MRE on human liver samples has revealed that fibrogenesis is associated with the replacement of soft and densely linked viscoelastic networks of healthy liver by sparsely cross-linked rigid fibers [29]. Other mechanical test methods for micro samples of biological tissue or single cells such as atomic force microscopy (AFM) or optical stretcher aim at the mechanics based quantification of tumor malignancy [30–32].

*Abbreviations:* AFM, atomic force microscopy; MEG, motion-encoding gradient; MRE, magnetic resonance elastography; FOV, field of view; ROI, region of interest; SE, spin echo; TE, time to echo; TR, time to repetition.

* Corresponding author at: Charité – Universitätsmedizin Berlin, Institute of Medical Informatics, Hindenburgdamm 30, 12200 Berlin, Germany. Fax: +49 30 450544901.
*E-mail address:* juergen.braun@charite.de (J. Braun).

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