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Fractal network dimension and viscoelastic powerlaw behavior: II. An experimental study of structure-mimicking phantoms by magnetic resonance elastography

Jing Guo[1], **Oleg Posnansky**[1], **Sebastian Hirsch**[1], **Michael Scheel**[1], **Matthias Taupitz**[1], **Juergen Braun**[2] **and Ingolf Sack**[1,3]

[1] Department of Radiology, Charité-Universitätsmedizin Berlin, Germany
[2] Institute of Medical Informatics, Charité-Universitätsmedizin Berlin, Germany

E-mail: ingolf.sack@charite.de

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Abstract

The dynamics of the complex shear modulus, G^*, of soft biological tissue is governed by the rigidity and topology of multiscale mechanical networks. Multifrequency elastography can measure the frequency dependence of G^* in soft biological tissue, providing information about the structure of tissue networks at multiple scales. In this study, the viscoelastic properties of structure-mimicking phantoms containing tangled paper stripes embedded in agarose gel are investigated by multifrequency magnetic resonance elastography within the dynamic range of 40–120 Hz. The effective media viscoelastic properties are analyzed in terms of the storage modulus (the real part of G^*), the loss modulus (the imaginary part of G^*) and the viscoelastic powerlaw given by the two-parameter springpot model. Furthermore, diffusion tensor imaging is used for investigating the effect of network structures on water mobility. The following observations were made: the random paper networks with fractal dimensions between 2.481 and 2.755 had no or minor effects on the storage modulus, whereas the loss modulus was significantly increased about 2.2 kPa per fractal dimension unit ($R = 0.962$, $P < 0.01$). This structural sensitivity of the loss modulus was significantly correlated with the springpot powerlaw exponent (0.965, $P < 0.01$), while for the springpot elasticity modulus, a trend was discernable (0.895, $P < 0.05$). No effect of the paper network on water diffusion was observed. The gel phantoms with embedded paper stripes presented here are a feasible way for experimentally studying the effect of network topology on soft-tissue viscoelastic parameters. In the dynamic range of *in vivo* elastography, the fractal network dimension primarily correlates to the loss behavior of soft tissue as can be seen from the loss modulus or

[3] Author to whom any correspondence should be addressed.

