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Wideband MRE and static mechanical indentation of human liver specimen: Sensitivity of viscoelastic constants to the alteration of tissue structure in hepatic fibrosis ☆

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ABSTRACT

Despite the success of elastography in grading hepatic fibrosis by stiffness related noninvasive markers the relationship between viscoelastic constants in the liver and tissue structure remains unclear. We therefore studied the mechanical properties of 16 human liver specimens with different degrees of fibrosis, inflammation and steatosis by wideband magnetic resonance elastography (MRE) and static indentation experiments providing the specimens' static Young's modulus (E), dynamic storage modulus (G') and dynamic loss modulus (G''). A frequency-independent shear modulus μ and a powerlaw exponent α were obtained by fitting G' and G'' using the two-parameter sprinpot model. The mechanical parameters were compared to the specimens' histology derived parameters such as degree of Fibrosis (F), inflammation score and fat score, amount of hydroxyproline (HYP) used for quantification of collagen, blood markers and presurgery in vivo function tests.

The frequency averaged parameters G', G'' and μ were significantly correlated with F (G': $R=0.762$, G'': $R=0.830$; μ: $R=0.744$; all $P<0.01$) and HYP (G': $R=0.712$; G'': $R=0.720$; μ: $R=0.731$; all $P<0.01$). The powerlaw exponent α displayed an inverse correlation with F ($R=-0.590$, $P=0.034$) and a trend of inverse correlation with HYP ($R=-0.470$, $P=0.089$). The static Young's modulus E was less correlated with F ($R=0.587$, $P=0.022$) and not sensitive to HYP. Although inflammation was highly correlated with F ($R=0.773$, $P<0.001$), no interaction was discernable between inflammation and mechanical parameters measured in this study. Other histological and blood markers as well as liver function test were correlated with neither F nor the measured mechanical parameters.

In conclusion, viscoelastic constants measured by wideband MRE are highly sensitive to histologically proven fibrosis. Our results suggest that, in addition to the amount of connective tissue, subtle structural changes of the viscoelastic matrix determine the sensitivity of mechanical tissue properties to hepatic fibrosis.

1. Introduction

During the last decade, elastography has been established for clinical assessment of liver fibrosis (Bamber et al., 2013; Cosgrove et al., 2013). Complementary to a variety of ultrasound-based elastographic modalities (Degos et al., 2010; Doherty et al., 2013; Poynard et al., 2013), magnetic resonance elastography (MRE) (Talwalkar et al., 2008; Huwart et al., 2007; Asbach et al., 2010; Glaser et al., 2012) is widely used for imaging the viscoelastic parameters in the liver. In MRE, externally induced time harmonic vibrations are captured by 2D- or 3D motion encoding MRI sequences. These vibrations are analyzed by solving the inverse problem of the time harmonic wave equation to construct the

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