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● *Original Contribution*

MULTIFREQUENCY TIME-HARMONIC ELASTOGRAPHY FOR THE MEASUREMENT OF LIVER VISCOELASTICITY IN LARGE TISSUE WINDOWS

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Abstract—Elastography of the liver for the non-invasive diagnosis of hepatic fibrosis is an established method. However, investigations of obese patients or patients with ascites are often limited by small and superficial elastographic windows. Therefore, multifrequency time-harmonic elastography (THE) based on time-resolved A-line ultrasound has recently been developed for measuring liver viscoelasticity in wide soft tissue windows and at greater depths. In this study, THE was integrated into a clinical B-mode scanner connected to a dedicated actuator bed driven by superimposed vibrations of 30- to 60-Hz frequencies. The resulting shear waves in the liver were captured along multiple profiles 7 to 14 cm in width and automatically processed for reconstruction of mean efficient shear wave speed and shear wave dispersion slope. This new modality was tested in healthy volunteers and 22 patients with clinically proven cirrhosis. Patients could be separated from controls by higher shear wave speeds (3.11 ± 0.64 m/s, 2.14–4.81 m/s, vs. 1.74 ± 0.10 m/s, 1.60–1.91 m/s) without significant degradation of data by high body mass index or ascites. Furthermore, the wave speed dispersion slope was significantly (p = 0.0025) lower in controls (5.2 ± 1.8 m/s/kHz) than in patients (39.1 ± 32.2 m/s/kHz). In conclusion, THE is useful for the diagnosis of cirrhosis in large tissue windows. (E-mail: ingolf.sack@charite.de) © 2014 World Federation for Ultrasound in Medicine & Biology.

Key Words: **Liver cirrhosis, Time-harmonic elastography, Multifrequency vibrations, Shear wave speed dispersion, Obesity, Ascites.**

INTRODUCTION

Elastography of the liver is a viable method for the non-invasive diagnosis of hepatic fibrosis (Cui et al. 2013). The method is based on external induction of controlled shear deformations inside the liver through the application of static shear strain or strain waves inside the liver. Parameters such as shear modulus, shear wave speed and amount of shear strain can be reconstructed from deformation fields to predict hepatic fibrosis.

In recent years, both static and dynamic elastography methods have been investigated for grading liver fibrosis (Bamber et al. 2013; Sarvazyan et al. 2013). Dynamic methods in ultrasound-based elastography use either transient waves induced by external actuators or acoustic radiation force impulses (ARFIs) to stimulate shear vibrations (Bavu et al. 2011; Boursier et al. 2010; Chen et al. 2013; Muller et al. 2009; Palmeri et al. 2008; Sandrin et al. 2003; Ziol et al. 2005). An early method of shear wave excitation uses external time-harmonic waves produced by loudspeakers (Krouskop et al. 1987; Lerner et al. 1990; Parker et al. 1990; Yamakoshi et al. 1990). This method was adopted for magnetic resonance elastography (MRE), which relies on repetitive excitation and imaging readout cycles to automatically cause steady-state time-harmonic tissue oscillations (Muthupillai and Ehman 1996; Plewes et al. 1995). MRE can potentially serve as a gold standard method for dynamic elastography of the liver because it is able to acquire wave fields in three dimensions without acoustic shading (Bonekamp et al. 2009).

The principle underlying time-harmonic elastography (THE) in ultrasound was recently employed for investigations of the human heart and the liver by

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Conflicts of interest: M.N.T. and M.S. are employees of GAMPT mbH, Merseburg, Germany.