Navigator-Gated In-Vivo 3D Liver MR-Elastography

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Synopsis

Dynamic steady-state 3D MR-Elastography with respiratory motion compensation utilizing MR-navigators has been applied to the measurement of the viscoelastic properties of various stages of liver diseases. With the patient in supine position, sinusoidal longitudinal motion excitation is performed from posterior providing very efficient wave illumination of the entire liver at 65Hz. An increase of the shear modulus and the shear viscosity as a function of the grade of fibrosis is observed.

Introduction

Liver fibrosis and cirrhosis represent an increasing health problem due to the increasing worldwide incidence of hepatitis C infections. Currently, the diagnosis and grading of liver fibrosis and cirrhosis can only be made with histo-pathological analysis of biopsy samples. New treatments to prevent (antiviral therapy) or treat (antifibrotic therapy) fibrosis and cirrhosis are developed. To assess the efficacy of these treatments without repeating invasive liver biopsies, new, non-invasive diagnostic methods should be developed. Here, Elastography as a non-invasive imaging technique represents a promising candidate, because the relationship between the grade of liver fibrosis and the stiffness of the liver has already been established [1]. Compared to transient Ultrasound-Elastography, dynamic MR-Elastography has the benefit to assess the entire organ [2] and to provide full 3D information to enable a correct reconstruction of the viscoelastic parameters.

Methods

The patient is in supine position with the mechanical transducer placed on the back pushing upwards in A-P direction at 65Hz (Fig.1). MR-signal reception is performed via a four-element surface coil utilizing the SENSE technology (factor 1) to provide amplitude and phase information of the MR-image. Respiratory motion is compensated by an interleaved MR-navigator (NAV), which measures the position of the diaphragm and enables acceptance/rejection of “wrong” respiratory motion states in real-time. Typically, respiratory gating leads to a reduction of the scan efficiency of 30-50%. Slice orientation is sagitally with a FOV of 250mm, 64^2 pixels resolution and a slice-thickness of 4mm. Five adjacent slices are measured utilizing a motion-sensitized multi-slice spin-echo sequence (SE) with TE/TR=61/430ms. Thus, the MR-sequence is consisting of [NAV – (5 x SE)] – [NAV – (5 x SE)] – etc. with continuous sinusoidal mechanical excitation. Total scan time for all three spatial motion directions is currently about 20min. Reconstruction of shear modulus and shear viscosity is done utilizing the technique described in [3].

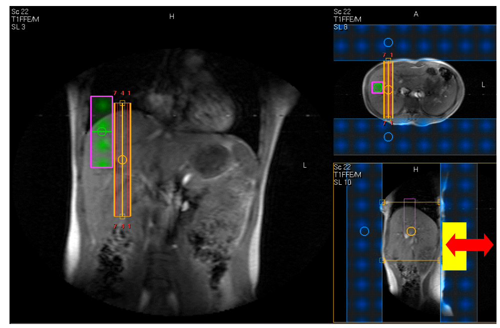
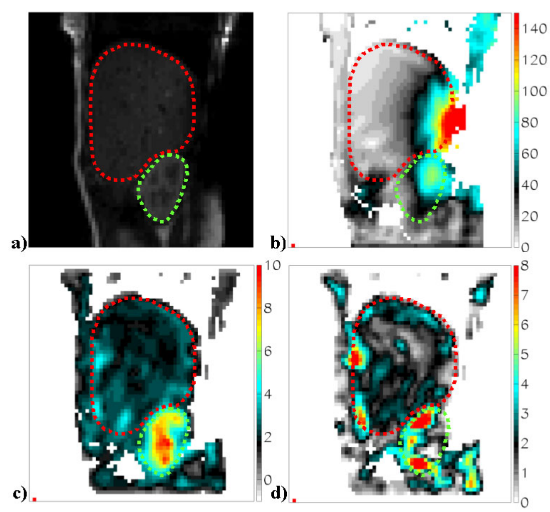


Fig.1: Plan-scan of the MRE-sequence. The stack of 5 adjacent slices is orientated sagitally. The NAV (green area) is located next to the image stack. The mechanical transducer is located at the back of the patient pushing in A-P direction (yellow rectangle).

Results

Very good penetration of the mechanical waves throughout the entire liver is observed (Fig.2a,b). Mode-conversion of the longitudinal wave at interfaces leads to shear waves generated everywhere inside the organ. Cine-movies of the mechanical waves (measured at 4 time-steps during one oscillatory cycle) indicate very good phase coherence of the measured wave fields. The kidney can be well differentiated from the liver in the shear modulus map (Fig.2c). The healthy liver appears rather homogeneous in both the shear modulus as well as the shear viscosity (Fig. 2d). An Increase of shear modulus and shear viscosity as a function of fibrosis grade is observed (not shown).



Discussion

This work demonstrates the technical feasibility of free-breathing in-vivo 3D liver MRE, which opens the way for abdominal applications. Motion compensation via navigator gating seems feasible without distraction of the coherence of the acoustic wave-pattern. This is crucial, because boundary conditions are changing during the respiratory cycle and thus influence the otherwise steady-state wave-field. However, the steady-state is recuperated within a very short time interval due to the longitudinal mode of excitation and the subsequent instantaneous generation of shear waves everywhere. Additionally, the longitudinal mode of excitation allows assessment of patients with acitis. Scan-time reduction can be achieved by for instance EPI-readout methods. Clinical validation of patients with fibrosis/cirrhosis is currently pursued.

References

[1] Sandrin et. al, Ultrasound in Med. & Bio 29 (12), 1705-1713 (2003)

[2] Dresner et. al, ISMRM 2004, p.502 [3] Sinkus et. al, MRI 2004 (in press)

Fig.2 : a) Sagital MR-magnitude image of the liver from a healthy volunteer (red line=liver, green line=kidney). b) Total amplitude as measured by MRE [µm].
c) Reconstructed shear modulus. The kidney is well visible as an object of elevated shear modulus (as expected from normal anatomy).
d) Reconstructed shear viscosity. Again, liver and kidney can be well separated.