In Vivo MR-Elastography of Liver Fibrosis

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Introduction

It is known that liver fibrosis is associated with increased liver stiffness (1). Magnetic Resonance Elastography (MRE) allows the measurement of the mechanical properties of in vivo tissue in a quantitative manner. Therefore, there is hope that MRE can contribute to the assessment of liver fibrosis (2). We have performed a feasibility study on healthy volunteers and patients with different grades of liver fibrosis. The study was performed on the basis of two mechanical parameters: shear stiffness and shear viscosity.

Methods

Low-frequency (65 Hz) longitudinal mechanical waves (rather than directly applying shear waves) were transmitted into the tissue and through mode conversion the desired shear waves were obtained. This method allows sufficient wave amplitude throughout the entire liver because of the reduced attenuation associated with longitudinal waves (3).

The longitudinal waves were coupled into the liver by means of a transducer, placed at the back of the patient (in supine position), against the last rib. Images were obtained on a Philips Gyroscan Intera whole body imager operating at 1.5 T using a four elements synergy body coil. The MRE pulse sequence was a motion sensitized (using sinusoidal displacement encoding gradients) spin echo sequence, phase-locked to the mechanical excitation. Five sagittal slices (SL=4 mm) through the liver were acquired with a leading, gating navigator placed on the diaphragm. The FOV was 250 mm, matrix size 64^2 leading to an isotropic voxel size of $4\times4\times4\,\mathrm{mm}^3$. Four dynamics were measured with TE=61 ms, TR=430 ms and NSA=2, leading to an acquisition time of 3 min 41 s to obtain one component of the displacement. The scan was repeated twice to obtain the other two orthogonal components. Four volunteers and 10 patients (with different grades of liver fibrosis) were scanned after obtaining formal consent. For the patients, a liver biopsy was taken on the same day.

The phase maps were processed according to the method described in ref. 3 to obtain stiffness and viscosity maps. For each case, the largest possible rectangular ROI that fits into the liver was taken to calculate the mean and standard deviation over the ROI for the central slice. The values were compared with the results from the biopsy (using the METAVIR grading from F0 = no fibrosis to F4 = cirrhosis).

Results and discussion

Figure 1 shows a magnitude image (central slice) as obtained with the MRE pulse sequence for a patient. The corresponding stiffness and viscosity maps are shown too. Liver biopsy yielded a F4 grade for this patient. It can be clearly seen that the liver is not homogeneous but local stiffening is present. This is also revealed from Fig.2 where we show the elasticity modulus (mean value over the ROI) versus the METAVIR grade of fibrosis for the 14 cases. Grade –1 corresponds to the healthy volunteers. As expected, the liver becomes stiffer for higher grades of fibrosis. The error bars do not present the error on the mean but the standard deviation over the ROI. The increase of the standard deviation with the METAVIR grade reflects the fact that the liver becomes more heterogeneous with fibrosis. Viscosity data V yielded similar results as elasticity data E. At first sight, there is a strong correlation between elasticity and vicosoity. This can be observed from the (Pearson) correlation coefficients: corr(E,V) = 0.980, corr(Esd,E) = 0.909, corr(Vsd,V) = 0.988 and corr(Esd,Vsd) = 0.913 (where sd stands for standard deviation).

A problem with our method is the long acquisition time, depending on the navigator efficiency: for some patients it was 25 min. An EPI-version of the MRE-sequence can be a solution. Furthermore, only a small part of the liver is covered with MRE. More slices are needed to allow a good comparison with biopsy, certainly if fibrosis leads to heterogeneous livers (biopsy measures locally too). Finally, our simple analysis (mean and standard deviation over a ROI) for a small population of patients is only a first step. Clearly more sophisticated image analysis tools are needed to estimate accurately the grade of fibrosis and more patients are needed to draw definitive conclusions.

Conclusions

MRE can be a feasible method to assess liver fibrosis.

References

(1) Sandrin et al., Ultrasound in Med. & Biol 29 (12), 1715-1713 (2003)

(2) Dressner et et al, ISMRM 2004, p. 502

(3) Sinkus et al. , MRI (2004), in press

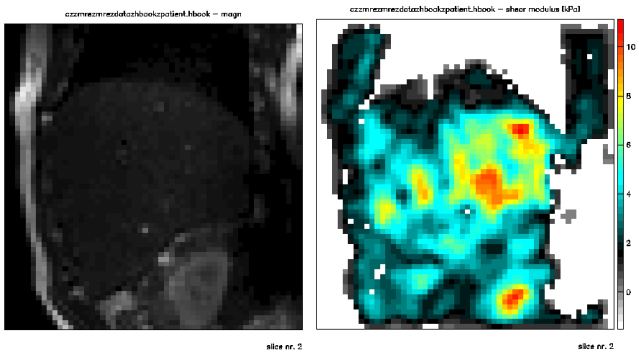

Figure 1: Magnitude image, stiffness and viscosity maps for a patient.

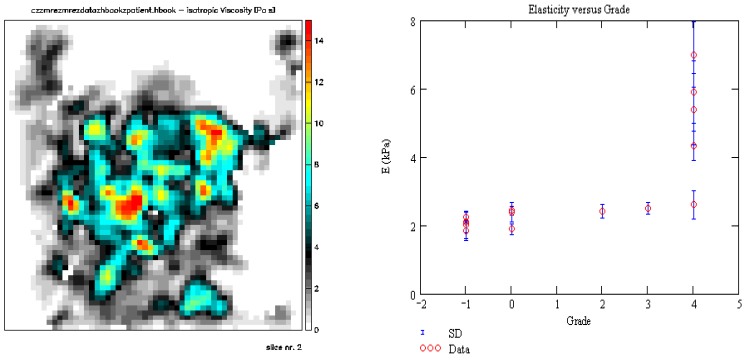

Figure 2: Stiffness versus METAVIR-grade of fibrosis for volunteers and patients