In Vivo MR Elastography of the Liver: Preliminary Results

O. Rouviere[1], M. Yin[1], M. A. Dresner[2], P. J. Rossman[1], L. J. Burgart[3], J. L. Fidler[4], R. L. Ehman[1]

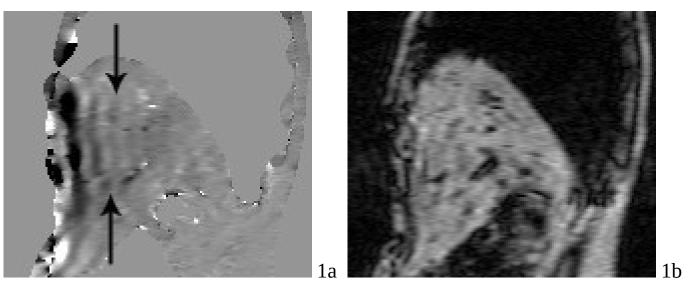
[1]MR Research Laboratory, Mayo Clinic, Rochester, Minnesota, United States, [2]Imaging Sciences Department, Hammersmith Hospital, London, United Kingdom, [3]Anatomic Pathology, Mayo Clinic, Rochester, Minnesota, United States, [4]Radiology, Mayo Clinic, Rochester, Minnesota, United States

Introduction: Regardless of cause, the development of liver fibrosis eventually leads to cirrhosis, which is associated with a 50% 5-year mortality due to severe complications including variceal bleeding, hepatic failure and development of hepatocarcinoma. It is now understood that fibrosis can be reversible when appropriate treatment is given. Thus, the development of non-invasive method to assess liver fibrosis would be significant, not only to appreciate the prognosis of the disease, but also to monitor treatment efficacy [1]. Previous studies have established that fibrosis is associated with increased liver stiffness [2]. MR Elastography (MRE) is a new technique that can quantify tissue stiffness [3], and MRE of the liver has recently been proven to be feasible in humans [4]. The objectives of our study were: 1. To define a reliable imaging protocol by assessing the best way to deliver shear waves into the liver (subcostal versus transcostal approach) and the best imaging planes; 2. To test this protocol in healthy volunteers and in patients with known liver fibrosis.

Material and methods: We used an 8-cm pneumatic driver vibrating during the entire image acquisition (continuous mode) [4]. First, we used a gradient echo (GRE) MRE sequence (TR/TE: 37.5/19.5 ms; flip angle: 30º; FOV: 20 cm; matrix: 256x64; slice thickness: 5 mm; one pair of motion-encoding gradients; 8 phase offsets) to evaluate the shear waves amplitude field generated by an 80-Hz driving frequency on a 15% B-gel phantom, without and with ribs interposition. The mean displacement induced by the waves and the phantom mean stiffness (Direct Inversion algorithm) were calculated on imaging planes orthogonal to the driver's surface (0-50 mm from the driver's center) and on oblique planes (10-50º from the vertical). Second, 12 healthy volunteers underwent a GRE MRE of the liver (TR/TE: 33.3/17.8 ms; flip angle: 30º; FOV: 34-38 cm; matrix: 256x64; slice thickness: 10 mm; one pair of motion-encoding gradients; 4 phase offsets), with a 90-Hz driving frequency successively applied subcostally and transcostally. Imaging planes were orthogonal to the driver's surface (0-30 mm) and oblique (10-30º). For each imaging plane, 2 readers evaluated the visibility of shear waves by using a 5-point subjective quality score. Then, the liver stiffness was evaluated by manual estimation of wavelength on 1D image profiles. Third, the same GRE MRE sequence (transcostal excitation only) was tested in 7 patients with stage I-IV liver fibrosis on liver biopsy. Image analysis methodology was the same as for the volunteer study.

Results: In vitro, the interposition of ribs created a distortion of the wave field and a dramatic decrease in shear wave amplitude. However, for 0-30 mm orthogonal planes and for 10-30º oblique planes, images with interposed ribs still provided an evaluation of the phantom stiffness within $\pm$ 20% of the value obtained on images without ribs. In healthy volunteers, the subjective quality score was, surprisingly, significantly better for transcostal than for subcostal images ($p<0.05$). The liver stiffness estimations did not differ significantly for both techniques (2.10 $\pm$ 0.31 kPa (subcostal) versus 1.94 $\pm$ 0.28 kPa (transcostal)). The different imaging planes were also found to provide similar results. The preliminary clinical trial of MRE in evaluation of patients with biopsy-proven hepatic fibrosis, demonstrated that patients had significantly increased liver shear stiffness (6.58 $\pm$ 6.13 kPa) compared with normal volunteers ($p<0.001$).

Conclusion: MRE of the liver is feasible and appears to provide a promising method to non-invasively diagnose fibrosis in the liver.



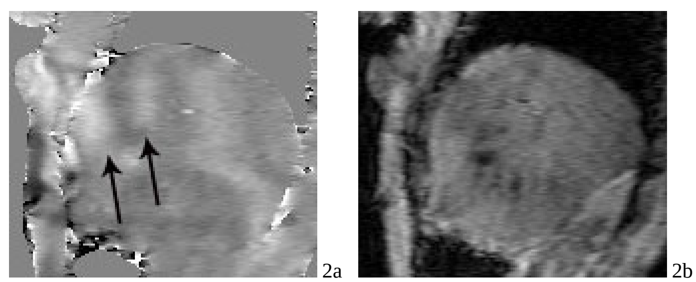


Figure 1a: Phase image showing shear waves(arrows) in the liver of a healthy volunteer (transcostal approach). The estimated liver stiffness is 1.83 kPa. Figure 1b: corresponding magnitude image.

Figure 2a: Phase image showing shear waves with an increased wavelength in the liver of a patient with liver cirrhosis at biopsy (transcostal approach). The estimated liver stiffness is 17.25 kPa. Figure 1b: corresponding magnitude image.

References: 1) Friedman SL, J Hepatol 2003; 38:S38-S53. 2) Yeh WC et al, Ultrasound Med Biol 2002; 28:467-474. 3) Manduca A et al, Med Image Analysis 2001; 5:237-254. 4) Dresner MA et al, ISMRM 2004.