Noninvasive Assessment of Liver Stiffness with Tagged MRI

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Introduction: Liver disease is an important and growing public health problem, with there frequently being clinically silent progression to the later serious complications of cirrhosis. A pathological hallmark of the progression to cirrhosis is the development of liver fibrosis, so that monitoring the appearance and progression of liver fibrosis can be used to guide therapy. Fibrosis of the liver is known to result in increased mechanical stiffness, so that the assessment of liver stiffness is a key feature of current noninvasive approaches, for example, by detecting the motion of the liver induced by external sources with ultrasound or MRI [1, 2]. In this study, we describe a new MRI liver assessment method by using the pulsations of the heart as an intrinsic motion source and by using magnetization-tagged MRI (tMRI) [3] as a noninvasive method to image the motion of the liver for the assessment of liver stiffness.

Methods: Cardiac tMRI was performed on five healthy volunteers (30.8 ± 4.7 years old; 3T Tim Trio, Siemens) and four patients with liver cirrhosis (56.8 ± 15.2 years old; 1.5T Avanto, Siemens). An electrocardiogram-gated conventional tMRI sequence was performed and images were acquired at end-tidal expiration, both for consistency of positioning and for a relatively relaxed state of the diaphragm. Two different views including both the heart and the adjacent portions of the liver (coronal and short axis in the mid-base) were acquired in each subject. For image analysis, a Gabor filter bank [4] was used to extract the tag position information and then the displacement and strain were calculated within the liver. The motion of the liver can be tracked and analyzed throughout the whole cardiac cycle.

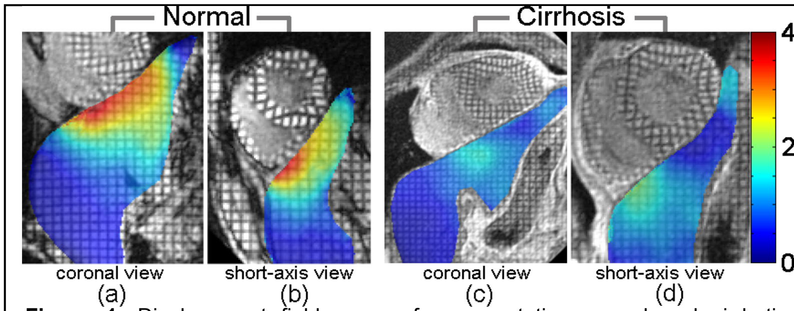

Figure 1. Displacement field maps of representative normal and cirrhotic subjects. Normal subject (a) in coronal and (b) short-axis views. Cirrhotic patient (c) in coronal and (d) short-axis views.

Results: Figure 1 shows representative coronal and short-axis tagged images of the heart and liver at end-systole for normal and cirrhotic subjects, with superimposed (absolute) displacement color-maps (units of millimeter) derived from the analysis of tagged images. In normal, there are relative concentrations of the motion and deformation beneath both the left and right ventricles. However, the overall amount of displacement is appreciably less in cirrhotic patients, and the region of deformation induced by the motion of the adjacent left ventricle extends into a less localized region in the cirrhotic liver, reflecting its greater stiffness and resistance to stretching and shearing deformations. The corresponding short-axis principal strain maps at end-systole (the greatest and least fractional length changes, P1 and P2, respectively) are shown in Fig.2a and 2d. A region-of-interest (ROI) was selected with a size of 10mmx10mm at a region just below the diaphragm (indicated by arrows) for both subjects, and the average strain values were calculated through the cardiac cycle (Fig. 2b and 2e). In Fig. 2c and 2f, the box plots of P1 and P2 strain rates at end-systole for five normal and four cirrhotic patients were generated to compare both groups (P1, P2 strain rates; mean ± standard deviation; 0.0228% ± 0.0054%, -0.0132% ± 0.0008% for normal subjects; 0.0088% ± 0.0046%, -0.0069% ± 0.0032% for cirrhosis patients). Compared with normal subjects, the cirrhotic subjects showed marked decreases of both strain and strain rate, i.e., measures of the local mobility and elasticity.

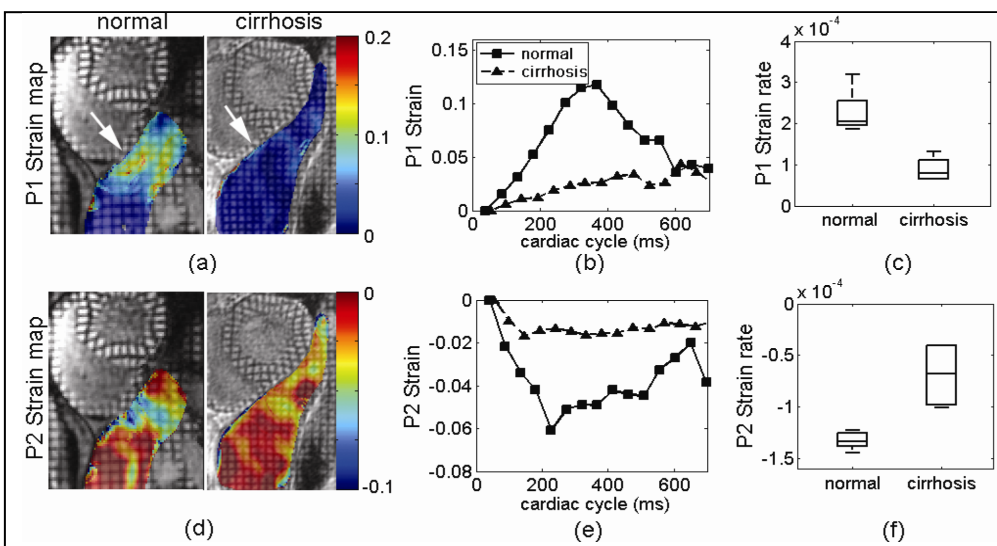

Figure 2. (a) Representative short-axis P1 strain maps of (left) a normal and (right) a cirrhosis patient at end-systole. (b) Average P1 strain values in a ROI through the cardiac cycle. (c) Box plots of P1 strain rate at end-systole for five normal subjects and four cirrhosis patients. (d) The corresponding short-axis P2 strain maps. (e) Average P2 strain values in the same ROI through the cardiac cycle. (f) Box plots of P2 strain rate at end-systole.

Discussion: This study demonstrates a new MRI liver assessment method, measuring cardiac-induced deformation, as a noninvasive means to evaluate liver stiffness, which is expected to provide an early marker for the development of liver fibrosis. The noninvasive nature of this imaging-based stiffness assessment method and its ability to be performed with conventional MRI equipment contribute to create a potential for this method to have a significant beneficial impact on patient care, in a clinically important disease.

References:

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