Liver MR T1rho measurement in liver cirrhosis patients: a preliminary study with a 2D fast field echo sequence at 3T

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Introduction: Liver fibrosis, a common feature of almost all causes of chronic liver disease, involves the accumulation of collagen, proteoglycans, and other macromolecules within the extracellular matrix. The accumulation of proteins in the extracellular matrix promotes the formation of scars that bridge together adjacent portal triads and central veins. Ultimately, progressive hepatic fibrosis leads to cirrhosis, in which fibrous bands carve the liver parenchyma into nodules of regenerating hepatocytes, a characteristic feature of almost all end-stage liver disease. Liver biopsy is the standard of reference for diagnosis and staging of liver fibrosis. However, it is an invasive procedure with possible side complications. Histologic assessment of fibrosis is also an inherently subjective process, and subject to sampling variability. With a biliary duct ligation induced liver fibrosis rat model, it has been hown that MR T1rho imaging is able to detect liver fibrosis, and the degree of fibrosis is correlated with the degree of elevation of the T1rho measurements (1). Liver T1rho MR imaging in healthy volunteers has been recently presented (2). The intra-class correlation coefficient (ICC) for scan-rescan reproducibility in healthy volunteers was 0.764 (2). In this study, we carried out liver T1rho MR imaging on 10 patients with confirmed liver cirrhosis.

Materials and Methods: The study was approved by the Institutional Ethics Committee, with all subjects providing informed signed consent. 10 patients with established liver cirrhosis were recruited from the liver clinic of our hospital. The cause of 9 patients was hepatitis B, while the remaining one patient' cause remains to be confirmed. MRI data acquisition was performed on a 3T clinical scanner (Achieva, Philips Healthcare). An 8 channel cardiac coil was used as the signal receiver to cover the liver, and the in-built body coil was used as the signal transmitter. Subjects were examined supine. Liver anatomical imaging covering the whole liver was carried out using a standard axial breath hold T2-weighted SPAIR (Spectral Adiabatic Inversion Recovery) sequence. Using axial T2-weighted image as reference, three representative axial slices were selected to cut through the upper, middle and lower liver for T1 rho imaging. For T1rho measurement, a rotary echo spin-lock pulse was implemented in a single-shot 2D fast field echo (FFE) sequence with centric phase-encoding acquisition. Spin-lock frequency was set as 500 Hz and the spin-lock times of 1 ms, 20 ms, and 50 ms were used for T1rho mapping. TE and TR for FFE acquisition were 1.16 ms and 2.3 ms respectively. The voxel size was $1.50 \times 1.50 \times 7.00$ mm^3. The flip angle was 40 degrees and the number of signal averages (NSA) was 3. A sensitivity-encoding (SENSE) factor of 1.5 was applied for parallel imaging to reduce the phase encoding steps and hence the acquisition time. The whole body specific absorption rate (SAR) was < 0.4W/kg for this sequence. The images were acquired with a breath-hold technique. Study subjects were trained to breath hold during shallow breathing, and maintain breath-holding at a similar breathing depth. The actual data acquisition time which needed breath-holding was 8 seconds per spin lock time point. T1rho maps were computed on a pixel-by-pixel basis using a mono-exponential decay model of with a home-made Matlab program (Mathworks, Natick, MA, USA): $M(TSL)=M_0*exp(-TSL/T1rho)$ Where M_0 and $M(TSL)$ denote the equilibrium magnetization and T1rho-prepared magnetization with the spin lock time of TSL, respectively. This mono-exponential equation was linearized by logarithm and T1rho maps were generated by fitting all pixel intensity data as a function of TSL time using linear regression. T1rho was calculated as -1/slope of the straight-line fit. To quantify liver T1rho value, three to five regions-of-interest (ROIs) of approximately 100-200 mm^2 were manually placed on the liver right robe parenchyma region on the T1rho maps for each slice, excluding observable artifacts and blood vessels. The mean value of these ROIs was regarded as the liver T1rho value for the subject.

Results: One patient with substantial ascites did not successfully complete the required MR scan due to the difficulty in holding his breath. Nine patients completed the study. T1rho value inhomogeneity was noted in the liver of the patients, with T1rho value from right robe tended to be higher than the T1rho value from left robe. With T1rho value measured from the right liver lobes, the mean value (± SD) was 51.1±8.1 millisecond, significantly higher than the mean value of 43.0±2.2 millisecond in healthy volunteers reported in our previous study (Ref 2, p<0.01).
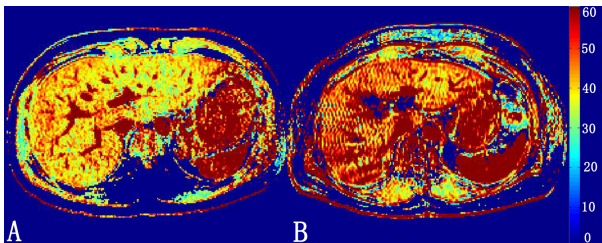

Fig 1, A: Liver T1rho map of a healthy volunteer from one our previous study (2); B: A: Liver T1rho map of a patient with liver fibrosis in this current study.

Discussion: This study demonstrated it was feasible to obtain liver T1rho measurement for patients with liver cirrhosis at 3T, and liver T1rho relaxation value was higher in these patients compared with the liver T1rho relaxation value in normal subjects. It is known that hepatic fibrosis and hepatic cirrhosis may not be homogeneously distributed across the liver (3). We measured the T1rho value of the right lobe instead of both right and left lobes, because it is common that right lobe undergo more severe cirrhotic changes while the left lobe regenerate and become hypertrophied. In the current study, we used 3 spin-lock time points instead of 6 spin-lock time points as we used in volunteers, as our patients were less likely to have a good breath-hold than the volunteers. Our analysis showed when satisfactory MRI data were acquired, the T1rho measurements from 3 spin-lock time points and 6 spin-lock time points demonstrated similar value. Our results represent the first 'proof-of-concept' in vivo study in patients that liver cirrhosis is associated with an increase liver T1rho value. We are recruiting more patients for this study, and are looking for better meanings to address the liver cirrhosis distribution inhomogeneity. Further technical optimizations for MR data acquisition are also underway in our laboratories.

References: 1). Wang YX, et al. Radiology 2011 ; 259:712 - 719   2). Wang YX, et al. Korean Congress of Radiology annual meeting 2011 Seoul Oct 27-29 abstract SS 30 AB-08   3) Romero-Gomez M, et al. Hepatology 2008;47:810-816