Fluid Suppressed $T1_\rho$ Mapping of Human Liver on Clinical Scanners

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INTRODUCTION

Extracellular matrix (ECM) is the main component of liver tissue and macromolecules like collagen, proteoglycan, elastin etc are major constituents of ECM. Currently, invasive biopsy of the liver tissue is the gold standard for staging liver fibrosis. While the use of MRI based techniques such as MR elastography as a non-invasive means to diagnose and grade hepatic fibrosis has been shown they require additional device for shear wave generation. T1ρ-weighted (T1ρ-W) MRI (1) is an emerging technique for exploring the biochemical changes in different pathologies (2-6). In spite of significant potential of T1ρ technique to quantify early macromolecule changes related to disease, it hasn't been explored *in-vivo* liver tissue due to experimental challenges such as respiratory motion, specific absorption rate (SAR), and B_0 and B_1 field in-homogeneities. In the current study, our objective was to develop and implement a novel T1ρ imaging technique capable of T1ρ mapping of liver in a single breath- hold without exceeding SAR limits on 1.5T and 3T clinical scanners.

MATERIALS AND METHODS

Following informed consent, five healthy volunteers (27-33 Y) underwent the T1ρ MRI on 1.5T and 3T clinical scanners (Siemens). The study protocol was approved by the Institutional Review Board (IRB) of the University of Pennsylvania. ***Fluid Suppressed T1ρ Pulse Sequence Design*:** Fluid suppressed T1ρ pulse sequence consists of three parts, a non-selective inversion and delay (TI) to suppress fluid signals, a B_1 and B_0 compensated T1ρ pulse cluster 90^o(+x)-SL(+y)-180^o(+y)-SL(-y)- 90^o(-x) (6,7) and a segmented turbo flash readout and spoiler for each shot. The flash readout sequence uses 1 or 2 shots and centric encoding to preserve the maximum T1ρ weighting. Imaging was performed at several spin-lock (SL) pulse amplitudes (B_1) and SL durations (TSL) to generate T1ρ maps. ***Imaging parameters*:** T1ρ imaging was performed with TSL =0, 10, 20, 30ms, spin lock pulse amplitude B_1 =400Hz, Flash readout TR/TE =5.1/2.4ms, flip angle =10^o, FOV=300*300mm^2, matrix size =128*128, slice thickness =5mm, number of shots =2 and a shot TR of 2s for non-fluid suppressed T1ρ and number of shots = 1 and shot TR=4s with TI =1700/3500 for 1.5T/3T for fluid suppressed T1ρ imaging. The data corresponding to four TSL's was acquired during breath-hold period (scan time =16s). T1ρ imaging was also performed at other spin lock amplitudes (B_1 =300 and 500Hz). ***Image Processing and Data Analysis***: The T1ρ-W data corresponding to spin-lock pulse duration, TSL =0, 10, 20, 30ms was fitted voxel-wise to mono-exponential decay expression S(TSL) = S(0)*exp(-TSL/T1ρ) for computing T1ρ values.

RESULTS AND DISCUSSIONS

The T1ρ pulse sequence was successfully implemented and T1ρ-W data corresponding to four TSL (0, 10, 20, 30ms) durations were collected in a single breath-hold for each volunteer. In all experiments SAR deposition was under the FDA limits. T1ρ-W data with different TSL's fitted well to mono-exponential decay curve. Figure 1 shows T1ρ data acquired from healthy human liver at 1.5T scanner. Fluid suppressed T1ρ-W image corresponding to TSL=0 is shown in Fig 1A. T1ρ values show an increase of ~5% with increase in B_1 =300 to 500Hz (Fig 1B). T1ρ maps without and with fluid suppression are shown in Fig.1C and 1D respectively. High values (>60ms) in healthy liver sections correspond to the liver vasculature. The fluid suppression pulse sequence suppressed signal as well as T1ρ values from blood vessels. In blood vessel voxels, changes in T1ρ values are mostly due to incomplete recovery of blood signal at the null point of fluid. T1ρ values in normal tissue (without visible vessels) were also decreased by around 5%. Average T1ρ values with fluid suppression in segmented liver tissues for B_1 =400Hz were 46.2±3.2 ms. T1ρ values in liver tissues were quite homogeneous after fluid suppression. T1ρ data was reproducible, and range of T1ρ values in all healthy volunteers were similar (around 46ms). The T1ρ values on 3T were lower by ~10% compared to values on 1.5T. As expected T1ρ values went down with increasing field strength. A decrease of T1ρ values with increasing field strength provides an advantage in the implementation of T1ρ technique at high field strength within SAR limits as small SL durations (same amplitude) pulse are required for T1ρ mapping. Along with sequence optimization, further work is in progress to investigate T1ρ sensitivity and specificity in detecting liver fibrosis both *in-vivo* and *ex-vivo* tissues. In summary, fluid attenuated single breath hold T1ρ mapping of liver can be achieved without exceeding SAR limits on clinical scanners and potentially may be used to study liver fibrosis..

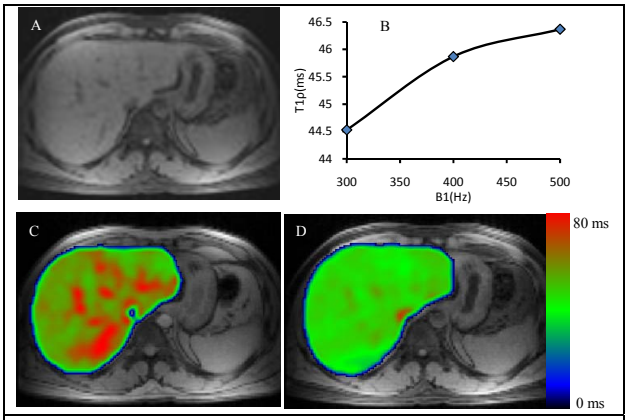

Figure1. T1ρ-W image (A) corresponding to TSL =0 ms, and T1ρ dispersion curve (B). T1ρ color maps, without (C) and with (D) fluid suppression respectively, of segmented liver section overlaid over base image (TSL=0). Color bar represents absolute T1ρ values. B_1 =400Hz, TSL =0, 10, 20, and 30ms.

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