Assessment of Chronic Pancreatitis with MR Elastography

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Introduction: Chronic pancreatitis is a continuing inflammatory disease of the pancreas that often results in irreversible morphological changes, severe pain and/or loss of function [1]. A significant problem is that the diagnosis of this disease typically occurs after the disease has progressed into an irreversible fibrosis state resulting in a low prognosis for improvement. Therefore, it is generally appreciated that there is a need for methods that can diagnose the disease at an earlier stage. Magnetic resonance elastography (MRE) is a phase-contrast MRI elasticity imaging technique that can quantitate the shear stiffness of soft tissues [2]. MRE is now being used clinically for the diagnosis of liver fibrosis and is being investigated for a number of other organ systems. We hypothesize that the mechanical properties of the pancreas vary with chronic pancreatitis and that MRE-derived shear stiffness values can be used to diagnose the disease, potentially much earlier than the current diagnostic strategies. The purpose of this work was to develop an MRE technique to be applied to the pancreas and to obtain preliminary data comparing the stiffness of healthy and diseased pancreatic tissue.

Methods: All experiments were conducted according to our institutional review board guidelines with all subjects providing written informed consent. 4 healthy volunteers and 8 patients from a population suspected for pancreatic diseases who were undergoing clinically indicated MR exams were recruited for this study. A 1.5-T whole-body scanner (Signa EXCITE, GE Healthcare, Milwaukee, WI) and an 8-channel torso coil array was used for all acquisitions. To create the necessary shear wave motion within the pancreas for MRE, continuous vibrations at 40 Hz were applied with a pressure-activated passive drum driver placed on the anterior chest wall of the subjects, as indicated in figure 1a. The passive drum driver was connected to an active driver engine that created the required vibrations. Due to the complicated anatomy of the pancreas, wave propagation in all three orthogonal directions was imaged [3] using an echo planar imaging based spin echo MRE sequence (SE_EPI), shown in figure 1b. The sequence included two 7.1-ms motion-encoding gradient (MEG) lobes present on either side of the 180° pulse. Other imaging parameters included: imaging plane = axial, FOV = 38.4 cm, acquisition matrix = 96 X 96 X 28, reconstruction matrix = 128 X 128 X 28; frequency-encoding direction = RL, TR/TE = 1050/39.4 ms, slice thickness = 3 mm, and 3 phase offsets. The acquisition was performed using three breath holds of 17 sec each. A 3D local frequency estimation algorithm with spatio-temporal directional filters was used for the calculation of shear stiffness maps (elastograms) from the shear wave data [4]. The stiffness values obtained were compared to the clinical data; ANOVA was used to find the statistical difference in the stiffness of the healthy and diseased pancreas with an α value of 0.05.

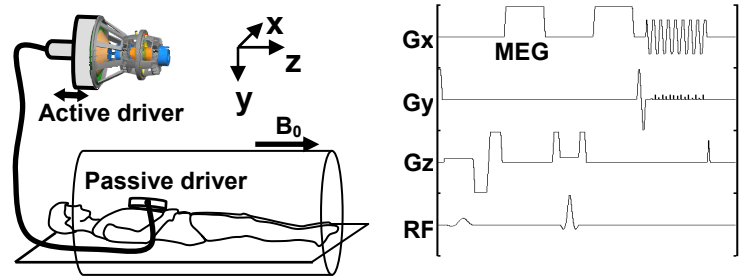

Figure 1: (a) Experimental setup. (b) SE_EPI MRE pulse sequence.

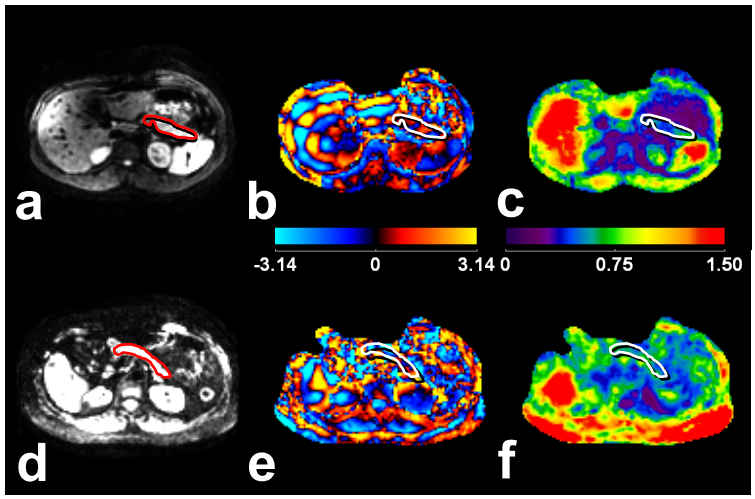

Figure 2: MRE results. Magnitude image, through-plane displacement image and shear stiffness map from a healthy volunteer (a-c) and a patient (d-f). The boundaries of the pancreas are indicated.

Results: Figure 2 shows typical results obtained from the MRE experiments. The top and the bottom rows show data obtained from a healthy subject and a patient respectively. Figures 2a-c show a magnitude image, a through-plane wave displacement image and the corresponding stiffness map respectively; the boundaries of the pancreas are marked. The corresponding images from the patient data are shown in figures 2d-f. The presence of shear waves within the pancreas is visible from the wave displacement images. The stiffness maps indicate the difference in the stiffness between the normal and diseased pancreas. Based on the clinical review of the patients, four subjects had chronic pancreatitis and the likelihood of the disease in the remaining four subjects was indeterminate. Figure 3 shows all of the data obtained from the subjects in this study, plotted against the clinical disease state. The mean stiffness values of the healthy and pancreatitis groups are 0.48 and 0.65 respectively and they were statistically significant with a P value of 0.016. The mean stiffness value of the pancreatitis group was also significantly higher than the indeterminate group with a P value of 0.011.

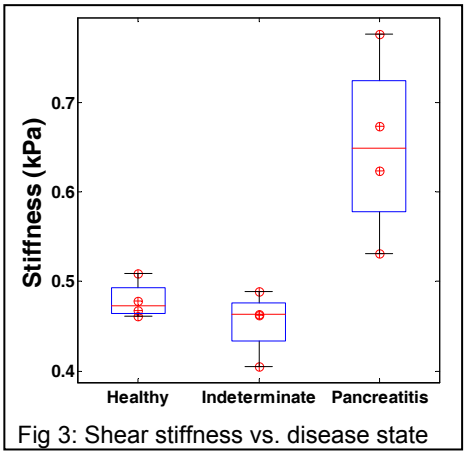

Fig 3: Shear stiffness vs. disease state

Conclusion: Based on these preliminary data we conclude that shear stiffness of the pancreas is higher in patients with chronic pancreatitis than normal volunteers and therefore MRE could potentially be used to noninvasively assist in making the diagnosis of chronic pancreatitis, potentially at an earlier stage of disease than current techniques permit. This provides motivation to further develop this technique and investigate its potential to diagnose chronic pancreatitis in an earlier and more treatable stage.

Acknowledgements: This work was supported by NIH EB 001981

References: (1) Etemad et al., Gastroenterology 120:682-707, 2001. (2) Muthupillai et al., *Science* 269: 1854-1857, 1995. (3) Yin et al., 16th ISMRM, 2008. (4) Manduca A et al., *Med Imag Anal*. 5: 237-254, 2001.