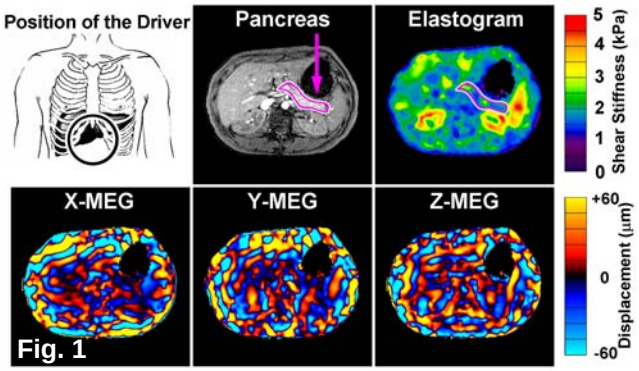
Assessment of the Pancreas with MR Elastography

M. Yin[1], S. K. Venkatesh[2], R. C. Grimm[1], P. J. Rossman[1], A. Manduca[1], and R. L. Ehman[1]

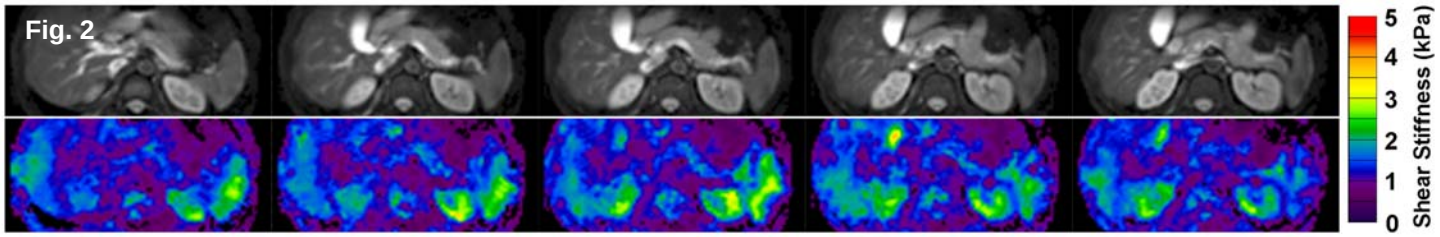
[1]Department of Radiology, Mayo Clinic, Rochester, MN, United States, [2]Diagnostic Radiology, National University of Singapore, Singapore

Introduction: The pancreas is a retroperitoneal organ with both exocrine and endocrine functions. Chronic pancreatitis is a progressive and destructive inflammatory process that results in organ fibrosis, induration, duct obstruction, and atrophy with significant loss of exocrine function and diabetes (1). The key histopathological features of chronic pancreatitis, regardless of etiology, are necrosis and fibrosis. In general, advanced stages of chronic pancreatitis may be diagnosed easily with imaging modalities like ultrasonography, CT, MRI, and MR cholangiopancreatography (MRCP). Endoscopic retrograde Pancreatography (ERCP) and MRCP provide excellent details about duct structure but detection of mild disease is not reliable. Endoscopic ultrasound is a sensitive procedure to detect the disease, but is invasive and mild disease may remain undetected (2). It is therefore challenging to make an early diagnosis of chronic pancreatitis. There is limited knowledge about the mechanical properties of pancreas and how they change with the onset of necrosis and fibrosis in chronic pancreatitis (3). MR Elastography (4) is a modified phase-contrast MRI technique for quantitatively assessing the mechanical properties of biological tissues by visualizing propagating shear waves in soft tissues and has been shown to accurately assess hepatic fibrosis in patients with chronic liver diseases (5-7). Besides liver tissue, many other abdominal organs are readily accessible by MRE (8). The goal of this study was to develop and test an optimized protocol for MR elastography of the pancreas, to evaluate the protocol in a series of normal volunteers, and to compile preliminary normative values for the shear stiffness of the normal pancreas.

Materials and Methods: All experiments were implemented on a 1.5 T whole-body GE imager (Signa, GE Medical System, Milwaukee, WI, USA), using the body coil. After preliminary studies to develop a suitable protocol, ten volunteers were imaged in a supine position, with a 19-cm cylindrical passive pneumatic driver placed against their anterior body wall in the epigastrium (Fig.1). Continuous vibrations at 60 Hz generated shear waves throughout the tissues of the abdomen. A gradient echo based MRE sequence with flow compensation was used to collect one axial wave image through the pancreas, as illustrated in Fig.1. Wave data were collected with a gradient echo MRE sequence along horizontal (X-), vertical (Y-) and through-plane (Z-) directions respectively. The data were processed with a 2D local frequency estimation (LFE) algorithm (9), weighted with shear displacement amplitudes in different directions. The other imaging parameters are: FOV = 32~42 cm, Flip angle = 30°, Slice thickness = 10 mm, TR/TE = 50/32 ms, Matrix = 256×64, 1 pair of trapezoidal motion encoding gradient (MEG), 4 phase offsets. Volumetric wave data were also collected with two-shot, multi-slice spin-echo EPI-based MRE sequence, acquiring 36 axial slices throughout the abdomen with 4-mm thickness. Other imaging parameters were: FOV = 32~42 cm, TR/TE = 1199/55 ms, Matrix = 96×96, 1 pair of MEG with flow compensation, 3 orthogonal motion sensitizing directions, 4 phase offsets. The total acquisition time is about 7 minutes (12 10-second breath holds for GRE-MRE and 20 16-second breath holds for EPI-MRE). After applying twenty evenly spaced 3D directional filters, a 3D LFE inversion algorithm was applied to process the 7D (3D spatial, 3D motion and 1D temporal) wave images into quantitative elastograms.



Results: The epigastric placement of a large passive acoustic driver provided excellent shear wave illumination throughout the pancreas, with wave motion consistently observed in all three orthogonal motion encoding directions (Fig.1). The elastogram shown in Fig.1 was generated using the simple 2D inversion algorithm. The measured shear stiffness of the pancreas in the region of interest has a mean value of 1.9 ± 0.4 kPa. However, analysis of the direction of wave propagation in the multiple slice data sets showed complex patterns in the region of the pancreas, with wave propagation in the SI direction. These results indicate that a simple 2D inversion of data from planar wave images is likely to provide false high stiffness measurements in some areas, due to wave propagation that is not entirely parallel to the plane of section. When the wave image datasets were processed with the full 3D inversion algorithm, the resulting elastograms depicted the pancreas more clearly in multiple sections, compared with the 2D technique. In all volunteers, the shear stiffness of the pancreas was relatively homogeneous and higher than surrounding retroperitoneal fat. The mean shear stiffness value of pancreatic tissue in ten normal volunteers was 2.0 ± 0.4 kPa.



Discussion and Conclusion: The results confirm that the MR Elastography technique can be adapted to provide quantitative images of the shear stiffness of the pancreas. Unlike hepatic MRE, where a 2D acquisition and inversion model provides valid stiffness estimates, the smaller size of the pancreas and the effects of geometric complexity require acquisition and inversion of three dimensional wave field data. Effects of reducing the number of temporal samples of the wavefield (from 4 to 2, for instance) or the number of directions of motion encoding (from 3 to 1, for instance), which have potential to reduce acquisition time by a factor of 6 or more, will need to be explored in ongoing work. The mean shear stiffness of pancreatic tissue in normal volunteers is similar to that of hepatic tissue and approximately twice the stiffness of adipose tissue. We speculate that pancreatic stiffness increases systematically with the degree of fibrosis in patients with chronic pancreatitis. If so, then MRE might be useful for staging and monitoring the treatment of chronic pancreatitis. The results of this study provide a technical and normative basis for testing this hypothesis in further research. The results also provide motivation for exploring MR Elastography as a potential tool for detecting and characterizing focal pancreatic masses. Our preliminary results in the normal volunteers are encouraging and provide motivation for further studies to explore the potential of MRE in assessment of chronic pancreatitis. The MRE technique may also be a promising method to detect, stage, and monitor the treatment for chronic pancreatitis.

References: [1] Dimagno EP. The Pancreas 1993; 665-706. [2] Witt H. Gastroenterology 2007; 132:1557-73. [3] Janssen J. Gastrointest Endosc 2007; 65:971-8 [4] R. Muthupillai, Science 1995, 269: 1854-7. [5] O. Rouviere, 2006, Radiology 240(2): 440-8. [6] L. Huwart, 2006, NMR Biomed 19(2): 173-9. [7] M. Yin, 2007, Clincal Gastroenterology and Hepat 2007;5:1207-13. [8] M. Yin, ISMRM – Flow and Motion Study Group Workshop, July 2006, New York. [9] A. Manduca, Med Image Anal 2001, 5(4): 237-54.