Rapid EPI-based MR Elastography of the Liver

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Introduction MR Elastography (MRE) (1) is a modified phase-contrast MRI technique for quantitatively assessing the mechanical properties of soft tissues by visualizing the propagating shear waves in soft tissues. It is well known that hepatic fibrosis is associated with increased liver stiffness. Therefore, a potential application of MRE might be to detect and quantitatively assess hepatic fibrosis in patients with chronic liver disease. Previous investigations demonstrated that a Gradient-Echo based MRE pulse sequence with several sequential breath holds (2) or a spin-echo based MRE pulse sequence with respiratory navigator gating (3) show promise for this application. However, one problem with those methods is relatively long acquisition time. Thus, the aim of this study was to implement and evaluate echo-planar imaging (EPI) version of the MRE sequence for liver MRE, with potential to allow the entire acquisition to be accomplished in less than one minute.

Materials and Methods All the MRE data were acquired with a 1.5 T GE Signa scanner (GE Medical Systems, Milwaukee, WI) by using the body coil. Volunteers were asked to lie prone with a 14-cm cylindrical pneumatic longitudinal driver placed against their anterior chest wall as shown in the far left of Fig.1. The GRE-MRE and the spin echo EPI-MRE sequences with continuous wave mode were used respectively in two healthy volunteers. Optimum imaging planes, governed by diffraction principles, were obtained (4). The other general imaging parameters are listed in Fig.1 besides the pulse sequence plots. Thus, a single slice MR Elastography acquisition along one motion sensitizing direction was 115 seconds for the GRE-MRE sequence (10 seconds breath holding for each phase offset acquisition and 5 seconds break between every two phase offsets), and only 5 seconds for the EPI-MRE sequence. Mean shear stiffness of the hepatic tissues was obtained by analyzing the acquired MRE data with our inversion software (5).

Fig. 1

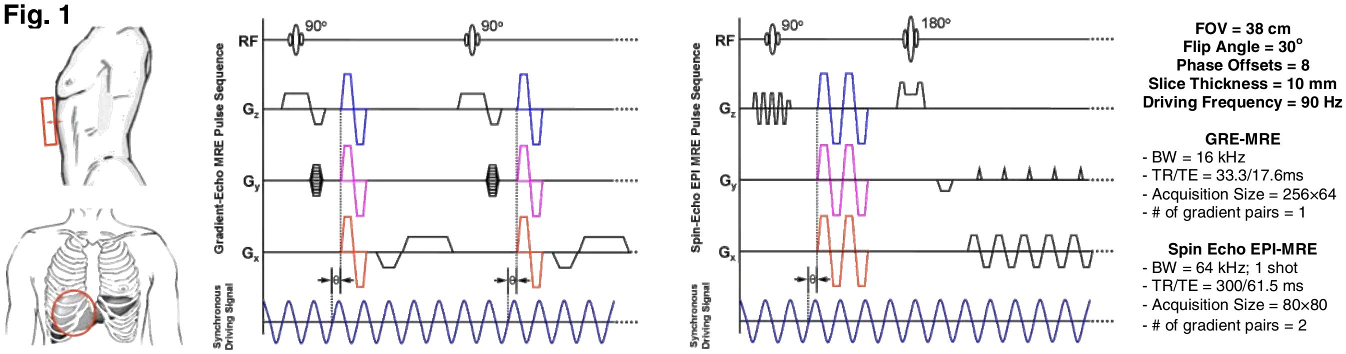
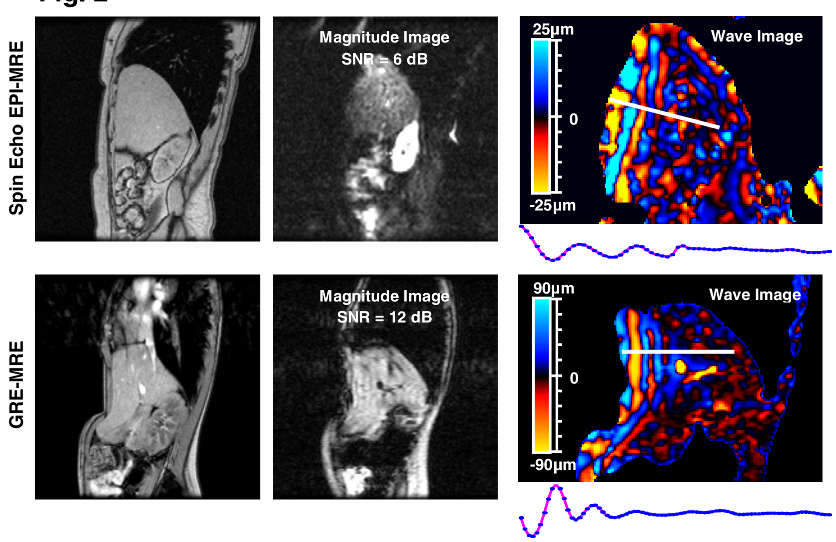


Fig. 2



Results The results of hepatic EPI-MRE acquisition are demonstrated in the first row of Fig.2, which are compared with the GRE-MRE data illustrated in the second row. The far left images are collected with a spoiled GRE sequence without any vibration to display the anatomy and show the relative position of the pneumatic driver against the chest wall. Then, the magnitude and phase difference images acquired from the EPI-MRE and GRE-MRE sequences were illustrated respectively. Comparison of the two MRE magnitude images demonstrated that the SNR of the EPI-MRE image is 6-dB lower than that of the GRE-MRE image. The far right images are enlarged wave images centered on the liver tissues. Planar shear wave fronts are well visualized. At the bottom of each wave image, a displacement profile (magenta line with blue sampling dots) clearly depicts a propagating shear wave corresponding to the marked white line. From the EPI-MRE data, the estimated shear stiffness is 1.8 kPa, which is statistically comparable to the mean value (2.0 ± 0.2 kPa) that we measured in previous studies of the healthy volunteers (2).

Discussion With identical MRE parameters (e.g. phase offsets number, acoustic intensity), the spin-echo EPI-MRE sequence is 23 times faster than that of the GRE-MRE sequence, with a modest reduction of SNR by 6-dB. Furthermore, the GRE-MRE sequence has only one sensitizing gradient pair in order to shorten the acquisition time to an acceptable breath holding time. EPI-MRE sequences have no such strict limitations. Embedded with more motion sensitizing gradient pairs, the EPI-MRE sequences will have a greater sensitivity than that of the GRE-MRE sequence. The results indicate that the EPI-MRE sequence provides shear stiffness measurements that are equivalent to those obtained with the GRE-MRE sequence. In addition, the EPI-MRE can be used in a multi-slice 2-D acquisition with three motion sensitizing directions in a single short breath hold. For example, it is possible to acquire multi-slice (3~5) MRE images with 4 phase offsets and 3 orthogonal motion sensitizing directions in 21~36 seconds. This makes it feasible to consider a clinical protocol that would evaluate the entire liver with MRE, within a few breatholds, thereby minimizing potential sampling errors associated with evaluation of only a single region.

Conclusion The spin-echo EPI-MRE sequence is a promising fast image acquisition method to assess the shear stiffness of the liver tissues in vivo. Compared with the GRE-MRE sequence, the spin-echo EPI-MRE sequence has equivalent accuracy and improved sensitivity for shear wave imaging. This ultra-fast approach may an important role in the 7-D (3-D spatial resolution, 3-D motion directions, 1-D temperal resolution) MR Elastography development.

Reference [1] R. Muthupillai, Science 1995, 269: 1789-1936. [2] O Rouviere, ISMRM 2005, 340. [3] R Sinkus, ISMRM 2005 624. [4] M Yin, ISMRM 2005, 2560. [5] A. Manduca, Med Image Anal 5(4): 237-254, 2001.