Validity study of Spin Echo EPI based hepatic MR Elastography at 3.0T

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Introduction: Magnetic Resonance Elastography (MRE), a noninvasive technique for quantitatively assessing the mechanical properties of soft tissues (1), is very promising for diagnosing hepatic fibrosis by detecting elevated hepatic shear stiffness (2-4). Typically MRE is performed on 1.5T MR systems as these are commonly available in the clinical practice. MR imaging at higher field strengths, specifically 3.0T, continues to be of significant interest because of the anticipated boost in intrinsic SNR at these field strengths. However, other effects like increased T1 and susceptibility can result in significant signal loss in GRE MRE that may affect the stiffness measurements. An alternative approach that may be more robust for performing MRE at higher field strengths is to use spin-echo EPI (SE-EPI) MRE, since the spin-echo properties of the signal may protect it against some of the susceptibility effects that affect GRE MRE. The purpose of this study was to evaluate a SE-EPI MRE protocol and compare it to a standard GRE MRE protocol at both 1.5T and 3.0T in healthy volunteers with no known liver disease to determine if the signal variations characteristic of the different imaging sequences and field strengths cause a significant change in the SNR of the data or adversely affect the estimates of tissue stiffness.

Materials and Methods: 11 volunteers with no known liver disease were imaged consecutively on a 1.5T and a 3.0T whole-body MR scanner (HDx, GE Medical System, Milwaukee, WI, USA), using the 8-channel torso coil in accordance with our institutional review board procedures. Volunteers were imaged in the supine position with a 19-cm cylindrical passive pneumatic driver placed against their anterior body wall. Continuous vibrations at 60 Hz supplied by an active driver system generated shear waves throughout the tissues of the abdomen as described in [4]. On each system, a GRE MRE sequence with flow compensation and ASSET (R=2) was used to collect axial wave images with the following parameters: FOV = 32-42 cm; flip angle = 30º; slice thickness/skip = 10 mm/0 mm; TR/TE = 50/20 ms; matrix = 256×64; 1 pair of 16.7-ms, 1.84 G/cm flow-compensated trapezoidal motion-encoding gradients; SI spatial saturation bands; and 4 phase offsets. Acquisition time was 56 seconds, split into 4 periods of 14-second suspended respiration. Similarly, SE-EPI MRE with flow compensated imaging gradients and ASSET (R=3) was used to collect the same axial wave images with the following parameters: FOV = 32-42 cm (matched to GRE MRE); slice thickness/skip = 7 mm/3 mm; TR/TE = 1000/52 ms; matrix = 96×96, 1 pair of 6.45-ms, 3.2 G/cm non-flow-compensated trapezoidal motion-encoding gradients on each side of the refocusing pulse; SI spatial saturation bands; and 4 phase offsets. Acquisition time was 16 seconds performed in suspended respiration. The amplitude of the active driver system was the same for the GRE and SE-EPI MRE acquisitions, and the properties of the motion-encoding gradients for the SE-EPI acquisition were tailored to match the sensitivity of the GRE acquisition (about 9.6 µm/rad). Four slices were obtained in each volunteer (sequentially in separate breath holds for GRE MRE). Anatomic landmarks such as the portal vein and hepatic veins were chosen to obtain matched axial imaging planes in each individual on each system wherever possible. The acquired MRE wave images were then processed with a 2-D multi-scale direct inversion (MSDI) algorithm. The mean liver stiffness was recorded for each volunteer for each imaging technique and each field strength and intraclass correlation (ICC) and Bland-Altman analyses were performed to determine if there were significant variations in the measured stiffness. For SNR calculations, 3x3(x4 offsets) sliding windows within which the ratio of the mean and SD of the MR magnitude data was used as an estimate of the magnitude SNR (MSNR). The inverse of the MSNR is a measure of the error in the phase data, so the phase-difference SNR can be calculated as the product of the wave amplitude from the phase data and the MSNR. The median MSNR from the whole liver for each subject and each imaging condition was used for 2-sided paired t-tests (α=0.05) to detect any significant differences in the different techniques.

Fig. 1 Comparison of Hepatic MR Elastography (1.5T vs 3.0T, GRE vs EPI)

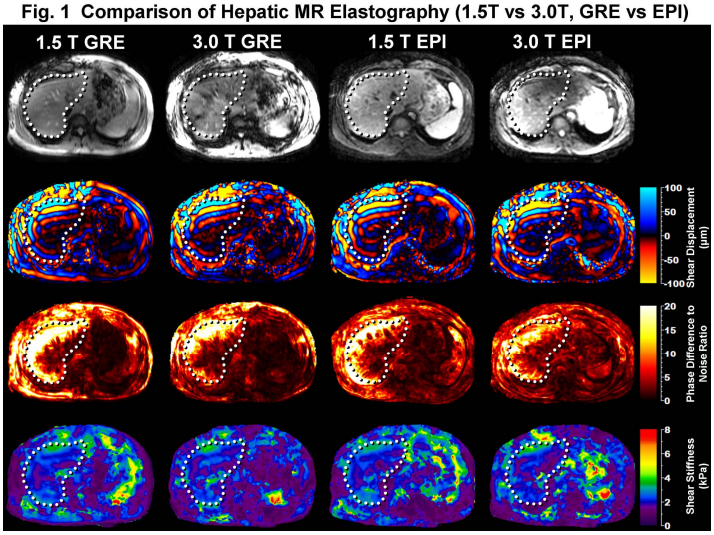
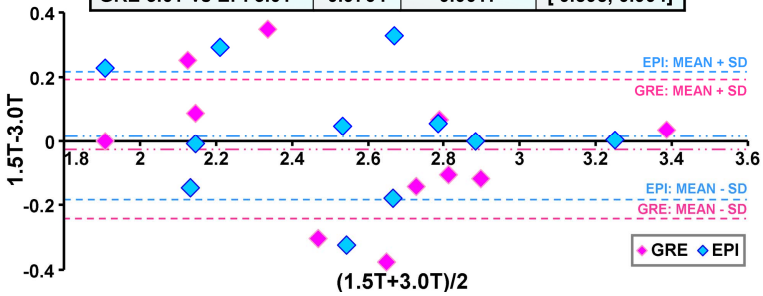


Fig. 2 Intra-Class Correlation and Bland-Altman Analysis

(ICC_0 < 0.80)	ICC	p-value	95% CI
GRE 1.5T vs GRE 3.0T	0.9391	0.0372	[0.774, 0.984]
EPI 1.5T vs EPI 3.0T	0.9394	0.0361	[0.776, 0.984]
GRE 1.5T vs EPI 1.5T	0.9672	0.0039	[0.880, 0.991]
GRE 3.0T vs EPI 3.0T	0.9764	0.0017	[0.898, 0.994]



Results: Fig.1 shows an example of MRE data from one of the normal volunteers with the MR magnitude images in the top row, phase/wave data in the second row, phase difference SNR in the third row, and elastograms in the bottom row. The wave data and the elastograms do not show any substantial differences in the liver using the various imaging methods and field strengths. Fig. 2 shows a Bland-Altman analysis comparing the hepatic stiffness at 1.5T and 3.0T for each imaging sequence (red: GRE; blue: SE-EPI). The mean difference for each case is nearly zero, which indicates no bias in the reported hepatic stiffness at the two field strengths. A significant correlation using the ICC analysis (ICC_0 < 0.80, p-value < 0.05) was found between the imaging sequences and field strengths in the series of 11 volunteers, as shown in the table in Fig.2. The results of the SNR t-tests, shown in Fig. 3, indicate that the 1.5T GRE and 1.5T SE-EPI SNRs and the 3.0T GRE and 3.0T SE-EPI SNRs are not significantly different (p>0.1; gray boxes in Fig. 3). The other tests indicate differences in the SNR, specifically that the 1.5T data had higher SNRs than the corresponding 3.0T data.

Fig. 3 P-Values for Paired 2-Sided T-Tests

	GRE (3.0T)	EPI (1.5T)	EPI (3.0T)
GRE (1.5T)	P < 0.01	P > 0.1	P < 0.01
GRE (3.0T)		P < 0.01	P > 0.1
EPI (1.5T)			P < 0.01

Discussion and Conclusion: The results demonstrate a strong agreement in the measured stiffness for both SE-EPI and GRE MRE at 1.5T and 3.0T. The SE-EPI acquisition has the benefit that it can be performed in a single breath hold.

References: [1] R. Muthupillai, Science 1995, 269: 1854-7. [2] O. Rouviere, M. Yin, et al. 2006, Radiology 240(2): 440-8. [3] L. Huwart, 2006, NMR Biomed 19(2): 173-9. [4] M. Yin, et al. 2007, Clincal Gastroenterology and Hepat 2007;5:1207-1213.