MR Elastography using SS-SE-EPI with reduced FOV for Kidney: Preliminary Study.

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Introduction: Magnetic Resonance Elastography (MRE) is rapidly developing as a non-invasive imaging technique to assess the mechanical properties of tissue which are dramatically affected by pathological disease processes such as inflammation, cancer and fibrosis. MRE is used for diagnosis of liver diseases (liver fibrosis, fatty liver and so on), and in particular to diagnose and stage hepatic fibrosis [1,2]. Recent reports suggested that kidney MRE could be helpful to assess renal fibrosis which characterizes various conditions of renal diseases [3,4]. In renal MRE, high spatial resolution is needed because pathological evaluation is valid only in the renal cortex [5]. However, the resolution of MRE images is typically limited since it relies on a Single-Shot Spin Echo - Echo Planar Imaging (SS-SE-EPI) sequence, which becomes highly vulnerable to image distortions when the matrix size increases. Alternatively, it has been shown that combining SS-SE-EPI with a spatially selective excitation provides an efficient way of reducing FOV in the phase encoding direction without introducing any image wrapping artifacts [6]. An earlier study of reduced-FOV MRE demonstrated the feasibility of this approach both in phantoms and in the liver [7]. The purpose of this study is to assess the applicability of high spatial resolution MRE to the evaluation of renal parenchyma.

Materials and Methods: In this study, we used a 2D echo-planar RF pulse instead of spatial spectral RF pulse for excitation in the SS-SE-EPI sequence. Fig.1 illustrates the 2D echo-planar RF pulse scheme used in this study. The phase-encode and slice-select gradients traverse the excitation k-space in an echo-planar trajectory, while the RF energy is being deposited. The envelope of this RF pulse defines the slice profile, whereas each sub-lobe of the RF pulse defines the excitation profile in the phase-encode direction. With such an excitation scheme, only the region of interest in the phase FOV direction can be excited without incurring aliasing artifacts, as a result of which fewer phase encodes are required to achieve the desired spatial resolution compared to the traditional method. All examinations were conducted on a clinical MR scanner (Discovery 750w 3.0T, GE Healthcare, Milwaukee, WI) with body AA and PA phased array coil with 32 elements. The parameters for each method were respectively TR/TE = 1000/62.9-71.2 msec (traditional method) and 1000/37.1-41.1 msec (proposed method), number of signal averages (NSA) = 2, motion-sensitizing gradients (MSG) direction = z, and Vibration/MSG frequency = 120 and 150Hz. The proposed method allowed us to achieve 2mm^2 in-plane resolution with 160x80 mm FOV, compared with 4 mm^2 in-plane resolution and FOV =400mm × 400mm with the traditional method. In both cases, all MRE images were acquired axially, with single slice and with 24sec breath-holding. Table 1 shows a comparison of acquisition parameters between the proposed method and the traditional method. This study was approved by the Internal Review Board and performed with informed consent obtained from 3 subjects (3 Men 37.3±9.3 years old). The subjects were imaged in the supine position with a 19 cm cylindrica vibrator at the level of the right kidney on the posterior abdomen wall (Fig.2). Stiffness maps were generated by MRE/Wave (MRI Research Lab, Mayo Clinic) with 2D LFE [8]. ROIs on cortex were traced based on anatomical correlations via axial magnitude images (Fig. 3).

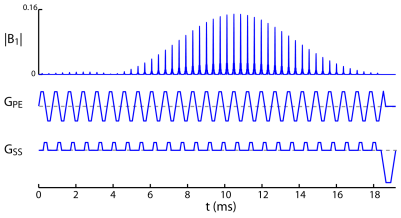

Fig. 1: 2D echo-planar RF pulse scheme

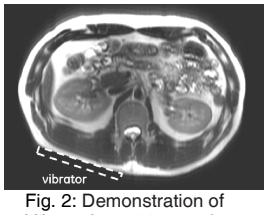

Fig. 2: Demonstration of Vibrator's position on the back.

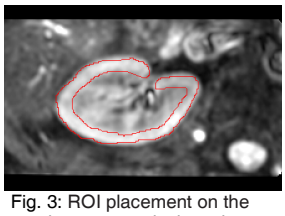

Fig. 3: ROI placement on the renal cortex to calculate shear stiffness.

Table 1 Comparison between spatial resolution of proposed method and the traditional method.

	Traditional method	Proposed method
Spatial resolution [mm^2/pixel]	4	2
FOV [mm]	400 x 400	160 x 80
Slice thickness [mm]	6	4
Matrix size	100 x 100	80 x 40

Table 2 Comparison of mean shear stiffness of renal cortex (kPa) each pulse sequence

	Shear stiffness of renal cortex [kPa]	
	Traditional method	Proposed method
120 Hz	4.5±0.9	3.8±0.3
150 Hz	4.6±0.9	4.2±0.5

Values are presented as means ± SD.

Results: Fig. 4 shows the shear stiffness maps, magnitude images and wave images acquired with each method. This study achieved higher spatial resolution MRE images with considerably reduced image distortion than the traditional method, resulting in a better depiction of the renal cortex and medulla especially in magnitude image as shown in fig [4b and 4e]. Table 2 presents a comparison between of the mean shear stiffness measured with either method. The shear stiffness values were approximately similar for both methods, although proposed approach had consistently lower stiffness levels. Notably, reduced-FOV MRE yielded a lower standard deviation which seems to indicate that it is more robust to partial volume effects.

Discussion: We showed that reduced-FOV MRE is a viable method to examine the stiffness of small anatomical features in the kidney. Since the width of renal cortex is approximately 6.0 to 12.0mm [5], this method could be combined with a higher vibration frequency than what is traditionally used for liver imaging (around 60 Hz) such as 200Hz (e.g. using frequency harmonics by more than 4 phase offsets) to help distinguish between cortex and medulla.

In conclusion, this study demonstrates the potential of SS-SE-EPI with 2D echo-planar RF excitation in obtaining high spatial resolution MRE of the kidney. The renal cortex and medulla could be distinguished using the proposed method in particular using the perfectly registered magnitude images as reference. Further testing on patient population is warranted to understand the potential clinical benefits.

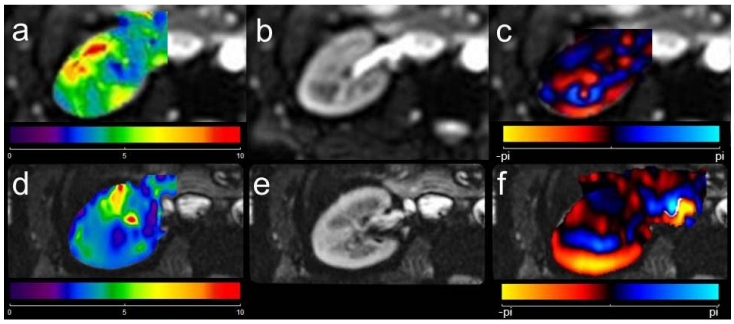

Fig. 4: MR Elastography at 120 Hz of vibration frequency of the kidney in normal subject. Stiffness maps (a,d), magnitude images (b,e), and wave images (c,f) acquired with traditional method (a–c) and proposed method (d–f).

Reference:

1. Venkatesh SK, et al,*AJR Am J Roentgenol.* **190**:1534-1540 (2008)
2. Yin M , et al. *Clin Gastroenterol and Hepatol.***5(10)**:1207-1213 (2007)
3. Venkatesh SK, et al, *Proc ISMRM* **461** (2008)
4. L Warner, et al, *Proc ISMRM* **407** (2009)
5. Lee CU, et al, *Academic radiol* **19(7)**: 834-241 (2012)
6. Emine US, et al, *MRM* ***60:*** 468-473 (2008)
7. *Ken A, et al, JSMRM #41* ***33****: 207 (2013)*
8. Manduca, *Med Image Anal* **5(4)**: 237-254 (2001)