Hepatic MR Elastography by Using Optimized Flexible Drivers

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Target audience includes clinicians and scientists who are interested in MRI technologies for the assessment of hepatic fibrosis.

Introduction: It is well known that liver biopsy is the reference standard for detecting hepatic fibrosis in patients with liver diseases, but liver biopsy is an invasive method and could cause sampling errors, inter-observer variation, patient refusal, pain, bleeding and death [1-3]. As a noninvasive technology for detecting liver fibrosis, MR Elastography (MRE) has shown the highest diagnostic accuracy when compared with other noninvasive methods: Fibroscan® and FIBRO*Spect* II® [4]. MRE uses a mechanical driver to excite mechanical waves in a patient liver, use MRI to measure the wave speed, and calculate liver stiffness maps (elastograms) based on the wave speed. There are different types of drivers, including electromechanical drivers [5, 6], piezoelectric driver (with a rubber mat on patient) [7] and pneumatic drivers [8, 9]. Mechanical drivers are usually small and rigid. Piezoelectric driver uses a rigid rod to connect to the rubber mat, which has to maintain a certain rigidity to convert a point vibration from the tip of rod to its surface vibration. A conventional pneumatic liver driver is rigid too. Since human bodies are soft, large and contoured, the mechanical coupling between rigid drivers and human body is often not optimal. To improve the human-drive mechanical coupling, we have developed a pneumatic flexible driver[10]. <u>The purpose of this study was to improve the efficiency of flexible driver, and to compare it with conventional pneumatic rigid driver in patients with a large range of fibrosis stage. Our hypothesis was that the optimized flexible driver is equivalent to the rigid driver in measuring liver stiffness.</u>

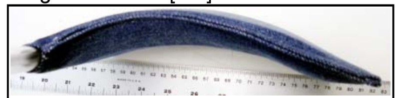

Fig. 1. Flexible driver for liver MRE

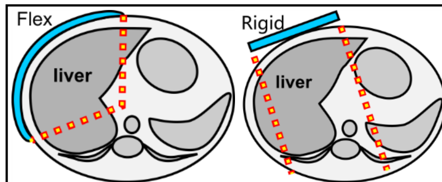

Fig.2. MRE driver positions: Flexible vs. rigid

Methods: ***(1) Subjects:*** Our Institutional Review Board approved the study. A total of 23 patients with biopsy-proven fibrosis stage from F0 to F4. ***(2) Flexible driver :*** Detailed technique information could be found in [10]. In brief, a flexible driver can conform to and cover most of the chest wall (posterior, right and anterior sides) in the vicinity of liver (Fig. 1 and Fig. 2), with a 20 cm width elastic band wrapped around the human body, so that the human-driver mechanical coupling is optimized. For a comparison, a conventional rigid driver position is shown in Fig. 2. The optimized flexible driver has three components: a flexible rectangular bag, a 3-dimensional structure filling material with a energy reflection flexible back plate. ***(3) Haptic MRE:*** Technique details could be found in [8]. In brief, all patients underwent 2D-60Hz liver MRE performed in a 1.5-T MRI scanner (Signa HDx, GE, Wisconsin, USA). Region of interests (ROIs) were drawn in the liver where wave signal-to-noise ratio was higher and larger vessels were absent. Liver stiffness values (mean, standard deviation) were report within the ROIs. <u>MRE was performed twice for each patient, using the optimized flexible driver and conventional rigid driver with comparable acoustic power level.</u> ***(4) Statistic analysis:*** Linear regression was done to investigate the correlation between liver stiffness values measured by the flexible and rigid drivers. Bland-Altman analysis [11] was utilized to evaluate the difference between the two drivers. JMP Pro (SAS, USA) software was used in the analysis.

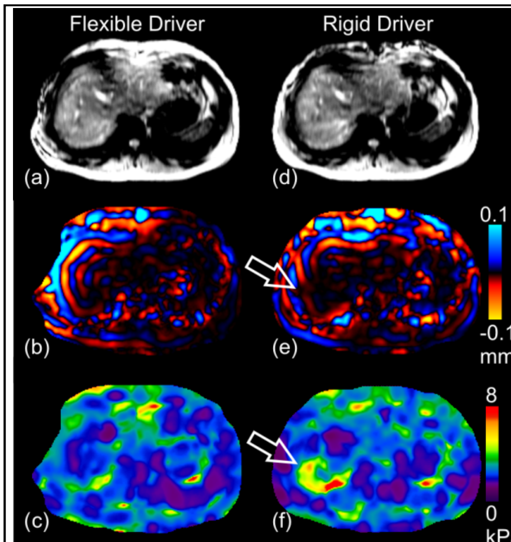

Fig. 3. Examples of liver MRE using flexible driver (a,b,c) vs. rigid driver (d,e,f). Top: magnitude, Middle: wave, Bottom: elastograms. Liver stiffness: 2.13 ± 0.44 kPa (rigid); 2.05 ± 0.36 kPa (flexible). The hot spot (arrow) was exlcuded for liver stiffness measurement due to the sever wave interference. This patient had fibrosis stage of F0.

Results: Linear regression analysis found that the liver stiffness values measured by the flexible driver and rigid driver were highly correlated (R = 0.97, Fig. 4). In the Bland-Altman analysis, <u>the mean difference of the liver stiffness measurements between the rigid and flexible drivers is -0.11kPa</u>, and the [lower, upper] 95% CI of the difference is [-0.31, 0.09] kPa (Fig. 5).

Discussions and Conclusions: Because the flexible driver is soft, all the patients felt more comfortable with the flexible driver than the rigid driver. Fig. 3 shows examples of MRE scans of one patient with both drivers. Both drivers excited comparable wave amplitude in the liver (Fig. 3b, 3e), meaning the optimized flexible driver could be used at the same power level as the rigid driver. Also, the flexible driver excited a more uniform wave filed in the liver than the rigid driver did (Fig. 3b, 3e). In the wave field generated by the rigid driver, a severe wave interference was observed, resulting in an over-estimated stiffness region (hotspot, arrow) in the liver (Fig. 3e, 3f). These findings were popular in this study patient group, and consistent with previous observations [10]. The mean difference (0.11 kPa) between the flexible and rigid driver was larger than the value (0.0061kPa) found in the previous study [10]; a possible reason is that more patients had high stages of fibrosis in this study than the previous study. In practice, a difference of 0.11 kPa is considered within the standard deviation of liver stiffness measured by MRE. <u>Therefore, liver stiffness values measured by the optimized flexible driver are equivalent to those measured by the conventional pneumatic rigid driver.</u>

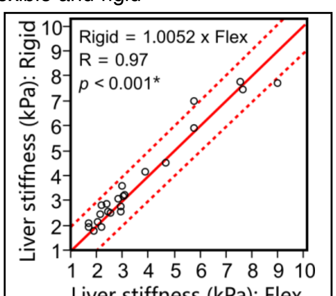

Fig.4. Linear regression: Flexible vs. rigid driver

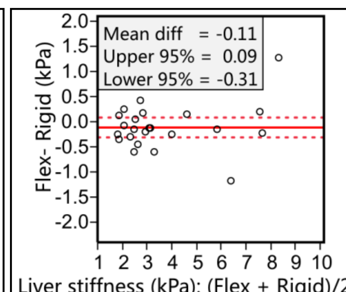

Fig.5. Bland-Altman Plot: Flexible vs. rigid driver.

References:

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