Comparing 2D and 3D Magnetic Resonance Elastography Techniques in a Clinical Setting: Initial Experiences

Mikael F. Forsgren[1,2], Bengt Norén[3,4], Johan Kihlberg[2,3], Olof Dahlqvist Leinhard[2,3], Stergios Kechagias[5], and Peter Lundberg[3,6]

[1]Wolfram MathCore AB, Linköping, Sweden, and Center for Medical Image Science and Visualization(CMIV), Linköping University, Linköping, Sweden, [2]Dept. of Medical and Health Sciences, Linköping University, Dept. of Radiation Physics, UHL County Council of Östergötland, Linköping, Sweden, [3]Center for Medical Image Science and Visualization (CMIV), Linköping University, Linköping, Sweden, [4]Dept. of Medical and Health Sciences, Linköping University, Linköping, Sweden, [5]Dept. of Medical and Health Sciences, Linköping University, Dept. of Gastroenterology and Hepatology, UHL County Council of Östergötland, Linköping, Sweden, [6]Dept. of Medical and Health Sciences, Linköping University, Depts. of Radiation Physics and Radiology, UHL County Council of Östergötland, Linköping, Sweden

Target audience: This work benefits both researchers working on implementing magnetic resonance elastography (MRE) in clinical practice as well as MRE methodology developers.

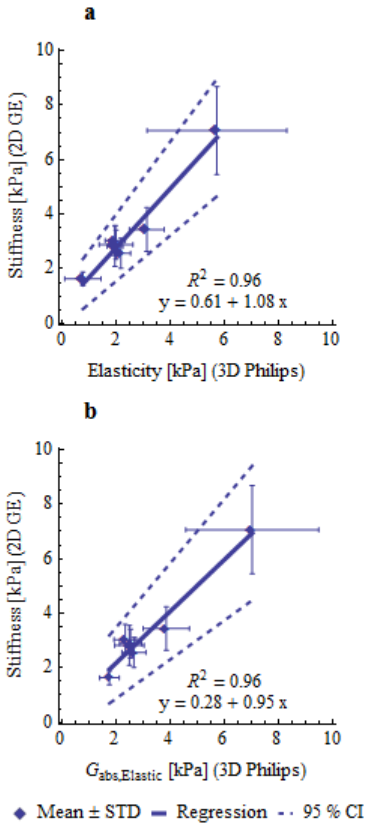

Fig. 1 *Correlation analysis. In both panels the data is shown as the mean of the ROIs for both MRE techniques, the errors bars correspond to one standard deviation and the dashed lines correspond to the 95% confidence interval (CI) of linear regression.* ***Panel (a)*** *shows a scatter plot for the elasticity (x-axis, 3D Philips) and the stiffness (y-axis, 2D GE).* ***Panel (b)*** *shows a scatter plot for the $G_{abs,\ Elastic}$ (x-axis, 3D Philips) and stiffness (y-axis, 2D GE).*

Table 1 *Measured elasticity and stiffness for each patient. Values retrieved from the elastograms for both techniques, reported for each patient as mean and standard deviation. Fibrosis stage based on histopathological exam.*

		3D (Philips)		2D (GE)
Patient	**Fibrosis stage**	**Elasticity [kPa]**	**$G_{abs,Elastic}$ [kPa]**	**Stiffness [kPa]**
1	2	1.96 (±0.37)	2.34 (±0.41)	3.03 (±0.55)
2	3	0.77 (±0.67)	1.76 (±0.36)	1.63 (±0.25)
3	4	5.72 (±2.58)	7.03 (±2.45)	7.06 (±1.62)
4	3	2.18 (±0.29)	2.50 (±0.44)	2.56 (±0.55)
5	2	1.96 (±0.02)	2.49 (±0.54)	3.19 (±0.62)
6	2	1.99 (±0.26)	2.54 (±0.41)	2.88 (±0.54)
7	1	3.13 (±0.64)	3.86 (±0.869	3.44 (±0.80)

Purpose: It has been shown that liver fibrosis, and even cirrhosis, may be reversible in humans. For this reason there is a great need for the imminent introduction of non-invasive and clinically useful methods in order to monitor fibrosis in patients [1, 2]. A body of evidence points to the fact that MRE is a highly useful candidate towards this end [3]. However, before using such techniques more widely, it is important to verify that comparable physical measures are provided by alternative and clinically relevant MRE approaches. The aim of this pilot study was to compare 2D and 3D MRE, also known as MR Rheology, using a commercially available 2D system, with an acoustic transducer, and 3D MRE research system, with an electromagnetic transducer, with respect to liver stiffness and elasticity in patients with diffuse or suspected diffuse liver disease.

Materials and Methods: Seven patients, referred to our hospital for evaluation of elevated serum alanine aminotransferase (ALT) and/or alkaline phosphatase (ALP) levels but without signs of cirrhosis on physical examination, were recruited from a previous study [4], and examined in the course of one day. Fibrosis staging from prior biopsy were gained from [4], see Table 1.

The 3D MRE method included an active electromagnetic transducer generating waves at 56 Hz, and a 1.5 T Philips Achieva MR-scanner, with a phased array body coil (Sense TorsoXL, all 16 coil elements), GRE sequence parameters include; FOV = 320x256 mm^2, matrix = 80x38, slice thickness = 4 mm, # slices = 9, FA = 15°, TR = 112 ms, TE = 9.21 ms, SENSE = 2. The 2D MRE method included a passive acoustic transducer generating waves at 60 Hz, and a 1.5 T GE 450W MR-scanner, with a phased array body coil (HD8 Torso, all 8 coil elements), GRE sequence parameters include; FOV = 440x440 mm^2, matrix = 256x64, slice thickness = 10 mm, # slices = 4, FA = 30°, TR = 50 ms, TE = 21.7 ms, ASSET = 2. The transducers were on both systems placed on the anterior chest wall to the right of xiphoid process (patient in a supine position), the time between each MRE acquisition was dependent on how long it took to transfer the patient between the two MR systems in the hospital (<10 min)

A region of interest (ROI) was placed in an appropriate single 10 mm slice acquired using the GE MR-scanner. A corresponding ROI for the Philips system, covering the same anatomical region, was placed over three slices (4 mm thickness each). This yielded a total cranio-caudal coverage of the ROIs equal to 10 mm (on the GE data) and 12 mm (on the Philips data). The mean and standard deviations of the stiffness (GE), elasticity (Philips) and $G_{abs,Elastic}$ (Philips) were calculated. $G_{abs,Elastic}$ is the absolute value of the shear modulus, which in principle is equivalent to the viscoelastic property, shear stiffness. In the 3D method the shear waves were obtained by applying the curl operator and using the Voigt rheological model to obtain shear elasticity maps [5, 6]. In the 2D method the GE system provided the stiffness maps.

Statistics was performed using Mathematica 9. ROI drawing and quantification of the data from the GE system was performed using Sectra PACS IDS7, and ROI drawing and quantification of the data from the Philips system was performed using a custom software package implemented in ROOT, generously provided by R. Sinkus (Kings College, London, UK).

Results: The measured values are presented in Table 1. Both elasticity and $G_{abs,Elastic}$ correlates well with the stiffness measurement carried out in the GE system (Fig. 1), as was shown by the elasticity and stiffness correlation R^2 = 0.96 ($P < 0.001$) slope = 1.08 ($P < 0.001$), intercept = 0.61 kPa ($P = 0.08$), $G_{abs,Elastic}$ and stiffness correlation R^2 = 0.96 ($P < 0.001$), slope = 0.95 ($P< 0.001$) intercept = 0.28 kPa ($P = 0.43$).

Discussion and Conclusions: The main finding was a very good correlation between the elastograms obtained from the two different MRE techniques, one using a passive acoustic transducer and 2D (GE) and one using an active electromagnetic transducer and 3D (Philips) acquisition; in both comparisons the linear factors in the regressions was close to one. If this observation hold true in larger studies, the existence of robust and reliable absolute quantification tools producing directly comparable data is encouraging, both from a patient as well as research perspective.

References: [1] Rockey, D.C., Clinics in Liver Disease 2008;12:939-62. [2] Cohen-Naftaly M., Friedman, S.L. Ther Adv Gastroenterol 2011;4:391-417. [3] Wang, Q.B. *et al* Hepatology 2012;56:239-47. [4] Norén, B *et al* Eur Radiol 2013;23:174-81. [5] Huwart, L., *et al* NMR Biomed 2006;19;173-9. [6] Sinkus, R., *et al* Magn Reson Imaging 2005;23:159-65