Cross-Validation of Magnetic Resonance Elastography by Continuous Acoustic Vibration and Ultrasound Elastography by Acoustic Radiation Force Impulse: a Phantom Study

Mikio Suga[1,2], Riwa Kishimoto[2], Atsuhisa Koyama[1], Tetsuya Wakayama[3], Takayuki Obata[2], and Hiroshi Tsuji[2]
[1]*Chiba University, Chiba, Chiba, Japan,* [2]*National Institute of Radiological Sciences, Chiba, Chiba, Japan,* [3]*GE Healthcare Japan, Tokyo, Japan*

INTRODUCTION

For noninvasive evaluation of biomedical tissue elasticity, magnetic resonance elastography (MRE) [1], ultrasound elastography (USE) using acoustic radiation force impulse (ARFI) [2] and ultrasound-based transient elastography (UTE) [3] have become common for use in clinical practice. Measured values by UTE were compared with the values by MRE to assess the differences in sensitivity and specificity or advantage and defect [4]. However, USE-ARFI has not yet been compared with MRE. The purpose of this study is to compare the quantitative stiffness values measured by MRE and USE-ARFI using phantoms of known elasticity.

MATERIALS AND METHODS

Five tissue-simulating homogeneous polyacrylamide gel phantoms were made for this study. The phantoms have a rectangular parallelepiped shape of 9 cm in height, 13 cm in width and 13 cm in length. Elasticity of each phantom was physically measured by rheometer (ARES-LS1, TA Instruments). Rheometer parameters included frequency = 100 rad/s, sample size = 25 mm diameter, sample thickness = 1 mm. Results of rheometer measurements: elasticity of the 5 phantoms was 2.1, 5.2, 9.7, 13.3, and 25.0 kPa, respectively. The relation between elasticity μ and shear wave velocity V is given by $\mu = \rho V^2$, where ρ is the material density calculated by the volume and mass of each phantom. Using this equation, shear wave velocity of each phantom was 1.41, 2.23, 3.01, 3.56, and 4.86 m/s, respectively.

USE-ARFI measurements were performed by Virtual Touch Tissue Quantification (VTTQ) on ACUSON S2000 ultrasound system (Siemens Medical Solutions), with 4 MHz convex (4C) and 9 MHz linear (9L) probe. VTTQ specifications of each probe are shown in Table 1. For the measurement, the probe and phantom were mechanically fixed to make stable pressure of 10 ± 0.5 kPa. In each phantom, shear wave velocity was measured by each probe at four positions: depth of 2.0, 4.0, 6.0, and 8.0 cm by 4C, and 1.0, 2.0, 3.0, and 4.0 cm by 9L. Measurement was carried out 10 times at each position and average and standard deviation were calculated.

MRE measurements were performed by Signa HDx 3.0 T (GE Healthcare Japan), with 8-ch head coil and pneumatic driver. Measurement was carried out once in each phantom. Spin-echo EPI (SE-EPI) MRE sequence was used. Imaging parameters were TR = 448 ms, TE = 47.2 ms, FOV = 19.2 x 19.2 cm^2, imaging matrix = 64 x 64, voxel size = 3.0 x 3.0 x 3.0 mm^3, vibration and motion-sensitizing gradient (MSG) frequency = 125 Hz, MSG cycle = 2, phase offset = 4, read-out gradient = R-L. Storage modulus was estimated by three-dimensional integral type reconstruction formula and spatio-temporal directional filtering. Elasticity map was transformed to shear wave velocity map. ROI was 6 x 6 mm^2, nearly VTTQ, and set to 2, 3, 4, 5, and 6 cm depth from pneumatic driver in shear wave velocity map. Average and standard deviation in ROI were calculated.

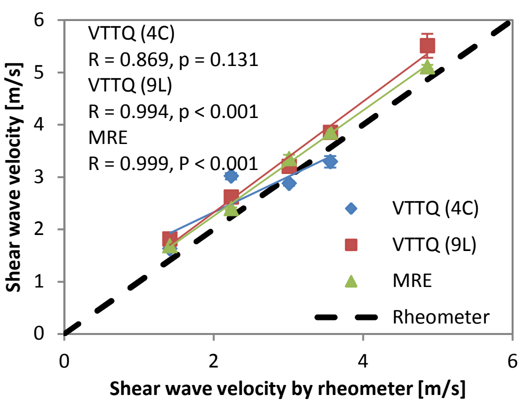

Figure 1. Shear wave velocity of various gel phantoms at depth of 4 cm

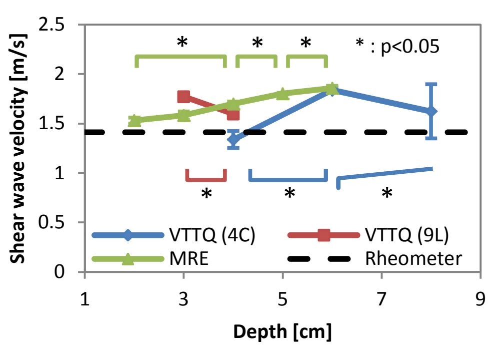

Figure 2. Shear wave velocity of the 2.1 kPa (1.41 m/s) gel phantom at various depths

RESULTS

Figure 1 shows shear wave velocity of the gel phantoms stably measured by MRE and VTTQ (4C and 9L) at depth of 4 cm. There was extremely strong correlation between MRE and rheometer, and VTTQ (9L) and rheometer (correlation coefficient R > 0.99). VTTQ (4C) showed higher standard deviation. The relation between depth and shear wave velocities by each method is shown in Figure 2. Measured value by MRE significantly increased as depth increased. A similar tendency was seen in the other phantoms.

DISCUSSION

VTTQ (4C) showed higher standard deviation than VTTQ (9L), and this agreed with the manual measurement experience. Due to the shape of the 4C probe, this may influence the probe position and angle to the phantom.

CONCLUSION

In this study, the quantitativity of MRE and USE-ARFI (VTTQ) measurement was evaluated by polyacrylamide phantoms. There was strong correlation between MRE and rheometer, and VTTQ and rheometer. VTTQ (4C) showed higher standard deviation, and VTTQ and MRE showed different depth dependency. Therefore, we should consider the properties of each method.

REFERENCES

[1] Muthupillai R., et al., *Science*, 269:1854-1857, 1995.
[2] Tozaki M., et al., Jpn J Radiol, 29:8, pp.598-603, 2011.
[3] Sandrin L., et al., Ultrasound Med Biol., 29:12, pp.1705-1713, 2003.
[4] Oudry J., et al., JMRI, 30:5, pp.1145-1150, 2008.

Table 1. VTTQ specification of each probe

Probe		4 MHz convex (4C)	9 MHz linear (9L)
ROI size	[mm^2]	6 x 10	5 x 5
Depth range	[cm]	0.5 – 8.5	0.5 – 4.0
Velocity range	[m/s]	0.5 – 4.4	0.5 – 8.4