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# Tissue Viscoelasticity Imaging using Ultrasound Coupler Gel

## 超音波カプラを用いた組織粘弾性イメージング

Makoto Yamakawa[1†], Tsuyoshi Shiina[2] ([1]Advanced Biomedical Engineering Research Unit, Kyoto Univ.; [2]Graduate School of Medicine, Kyoto Univ.)
山川　誠[1†], 椎名　毅[2] ([1]京都大学 先端医工学研究ユニット, [2]京都大学 医学研究科)

## 1. Introduction

Tissue diagnosis requires evaluating both elastic properties and viscoelastic properties. To evaluate tissue viscoelastic properties, it has been proposed to measure the time constant of the strain saturation curve when step-like stress is applied to tissue [1, 2]. In practice, however, it is difficult to apply ideal step-like stress to tissue. Therefore, we propose a method for evaluating tissue viscoelastic properties by applying vibration that is usually performed in elastography and using an ultrasound coupler gel whose viscoelasticity is known.

## 2. Viscoelasticity Imaging Method

A 5mm-thick coupler gel is inserted between a 7.5MHz linear-array probe and a tissue sample. We vibrate the tissue with a pulse motor and acquire the echo data with an ultrasound scanner. We then estimate the strain distribution of tissue with the extended combined autocorrelation (ECA) method we developed previously [3]. We also estimate the strain distribution of the coupler by detecting the boundary between the coupler and the tissue and tracking its boundary based on the ECA method. Assuming the cascade Kelvin-Voigt model, we propose two methods for evaluating tissue viscoelastic properties: the phase difference between the coupler strain and tissue strain, and the normalized hysteresis loop area of the coupler strain and tissue strain. The phase difference between the coupler strain and tissue strain is estimated using a correlation function. The normalized hysteresis loop area is calculated by dividing the hysteresis loop internal area by integrated area within the upper part of hysteresis loop. These proposed parameters are expressed as a function of a parameter ($\tau=\eta/E$) defined as the viscosity coefficient ($\eta$) divided by Young's modulus ($E$). Parameter $\tau$ is estimated from the phase delay or the normalized hysteresis loop area using Young's modulus and the viscosity coefficient of the coupler gel.

After parameter $\tau$ is estimated, Young's modulus ($E$) can be estimated from the tissue strain and coupler strain. The viscosity coefficient of tissue can then be separately estimated ($\eta=E\tau$).

## 3. Phantom Experiment Results

We used a 1% agar phantom containing a 9mm-diameter pillar inclusion (5% agar) and vibrated this phantom at 1.7Hz. Mechanical measurements indicated that the $\tau$ of the coupler gel was the greatest and the $\tau$ of 5% agar was the smallest. Therefore, the phase of the coupler strain was observed behind the phase of strain inside the phantom (Fig. 1). The hysteresis loop moved counterclockwise (Fig. 2). We were able to acquire images of the phase delay and normalized hysteresis loop area (Fig. 3). Figure 3 shows that the contrast of the phase delay image is better than that of the normalized hysteresis loop area image.

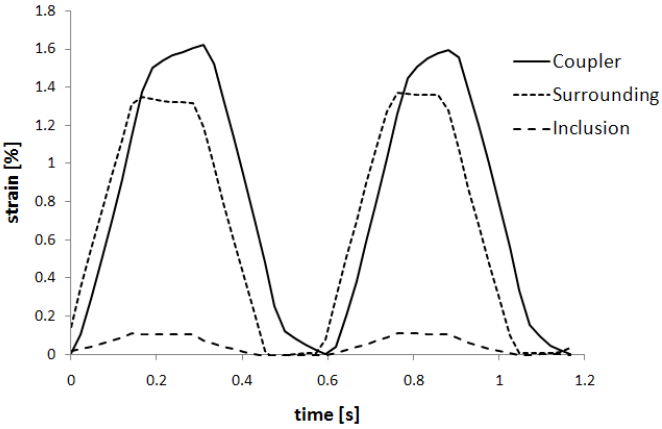



Fig. 1 Strain waveform

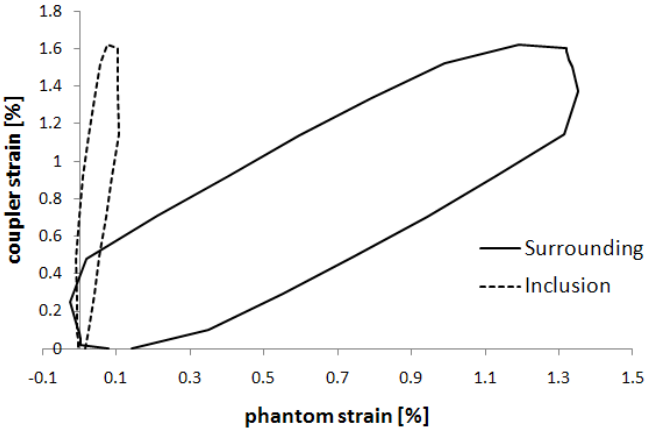
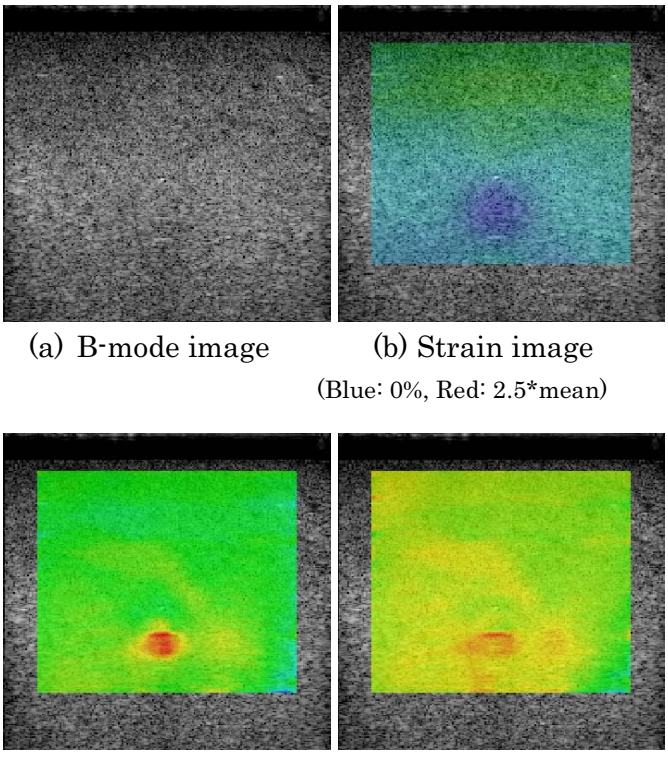



Fig. 2 Hysteresis loop



(a) B-mode image (b) Strain image (Blue: 0%, Red: 2.5*mean)

(c) Phase delay image (Blue: -0.32rad, Red: -0.64rad) (d) Hysteresis image (Blue: 0.4, Red: 0.7)

Fig. 3 Phantom experiment results

The results of phantom experiment in which the frequency of vibration was varied from 0.8Hz to 2.6Hz demonstrate that the phase-delay image was more robust to strain estimation error than the normalized hysteresis loop area image.

## 4. Conclusion

We proposed a method for evaluating tissue viscoelastic properties using coupler gel and vibration. In an agar phantom experiment, we could measure a 0.08 rad phase difference and a 0.06 normalized hysteresis loop area difference between the inclusion and the surrounding material. Since the phase-delay image is more robust to strain estimation error than a normalized hysteresis loop area image, the phase-delay image could be used to evaluate the tissue viscoelastic properties with sufficient accuracy.

In future work, we will measure the viscosity coefficient and Young's modulus of the coupler gel and then estimate the viscosity coefficient distribution and the Young's modulus distribution of tissue.

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