Elasticity Measurement of Soft Tissue using Magnetic Resonance Microscope

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Introduction

Information on tissue elasticity is an important parameter, because there are several disease states which result in alteration of tissue stiffness. For example, it is known that malignant tumors tend to be much harder than normal tissues and most benign tumors. Magnetic resonance elastography (MRE) is a method that can visualize the propagating acoustic strain waves in materials being measured [1]. The local quantitative values of shear modulus are calculated from distribution of the acoustic strain waves in the MRE image. In order to observe tissues such as the early stage of tumors in detail, spatial resolution of the MRE image is not enough because of hardware limitation of the conventional MRI system. Therefore we developed an elasticity measurement system using an MR microscope.

Methods

Experiments were performed on the 1 T magnetic resonance microscope (MRmicro, MRTechnology). Developed external vibration system is made of multi-layer piezoelectric element (AE1010D16, NEC-TOKIN) and bamboo rod as shown in figure 1. The resonant frequency of bamboo rod is about 300 Hz. The amplitude of external vibration is about 10 microns around 200 Hz. The actuator was driven by a waveform generator. And the waveform generator was synchronized with an MR controller by trigger pulse. A modified phase-sensitive spin-echo sequence was used for data acquisition. Oscillating gradients (motion-sensitizing gradients, MSG) were synchronized with a mechanical excitation of 200 Hz for encoding of the acoustic strain waves. The strain wave images with multiple initial phase offsets can be generated with increasing delays between MSG and mechanical excitation [2]. Typical parameters are the followings; field of view 25x25 mm^2, image matrix 128x128 $pixel^2$, slice thickness 1 mm, repetition times 1500 ms and echo time 62.9 ms. To acquire shear modulus map, we adapted the two-dimensional Helmholtz equation to the strain wave images with eight phase offsets [3]. The first objects were homogeneous agarose gel phantoms. The second object was an excised bovine liver supported by 0.6% agarose gel.

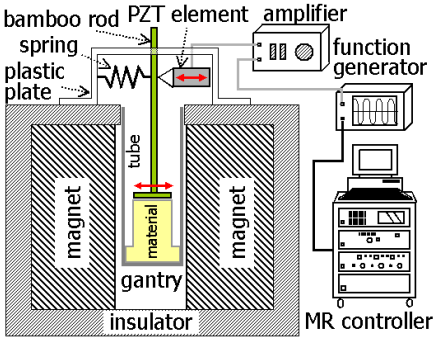

Figure 1. MR elastic microscope system

Results and Discussion

The shear modulus of 0.5%, 0.7% and 0.9% homogeneous agarose gel phantoms were 1.6 (SD: 0.17) kPa, 4.7 (SD: 0.96) kPa, and 7.6 (SD: 1.2) kPa, respectively. The shear moduli that were measured from the developed system almost correspond to the shear moduli measured by the viscoelastic analyzer (Rheogel-E4000, UBM) as shown in figure 2. The shear modulus of *in-vitro* bovine liver was 1.77 (SD: 0.18) kPa (average of the dotted square domain in figure 3d). These results suggest the developed MR elastic microscope system makes it possible to measure the shear modulus with high resolution.

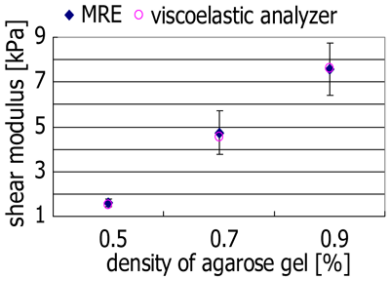

Figure 2. Shear modulus of agarose gel

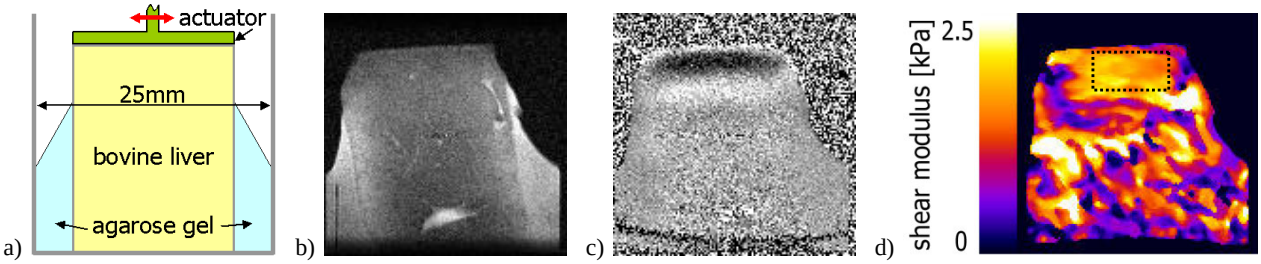

Figure 3. a) A schematic showing the bovine liver sample, b) MRI, c) strain wave image, d) shear modulus map

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