MICROSCOPIC MEASUREMENT OF THREE-DIMENSIONAL DISTRIBUTION OF TISSUE VISCOELASTICITY

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Abstract: According to recent development of practical system for tissue elasticity imaging, it is required to elucidate the quantitative relationship between diseases and parameters about tissue elasticity and viscosity to diagnose the stage of disease progression and differentiate malignant from benign precisely. From this viewpoint, we are investigating on development of a three-dimensional tissue viscoelasticity microscope for accumulating quantitative data on mechanical properties of tissues. In this study primary system was constituted and its basic performance was evaluated using tissue phantom.

Key words: Tissue characterization, Ultrasound microscope, Elastic modulus, Viscoelasticity

1. INTRODUCTION

Ultrasonic tissue elasticity imaging has been investigated for the purpose of utilizing mechanical properties of tissues for diagnosis [1,2,3]. Recently, practical equipment for assessing tissue elasticity in the form of strain images has been developed and used for diagnosing diseases such as breast cancer [4,5]. To diagnose the stage of disease progression and differentiate malignant from benign precisely using parameters which represent tissue elasticity and viscosity, it is required to elucidate the quantitative relationship between these parameters and diseases. However, any database to refer such a kind of the relation has hardly been established yet.
For this purpose, some approaches to the microscopic measurement of tissue elasticity have been proposed [6]. These methods are aimed at attaining higher spatial resolution with high frequency ultrasound, consequently, thin slices of tissue must be used to prevent the attenuation of ultrasound. However, such thin slices are two-dimensional (2D) distributions, and the real mechanical properties of tissue are apt to change when the tissue is sliced thinly since the tissue microstructure is destroyed. To evaluate the mechanical properties of tissues under similar conditions to clinical use, it is important to measure the three-dimensional (3D) distribution of mechanical properties by using a relatively thick specimen to preserve the microstructure of tissues.

From the above viewpoint, we are investigating the development of a 3D tissue viscoelasticity microscope for accumulating quantitative data on the mechanical properties of tissues. In this study, the primary system was constructed and its basic performance was evaluated using a tissue phantom.

2. PARAMETERS ON TISSUE VISCOELASTICITY

Among the various approaches for tissue elasticity imaging, the major approach is the static method, which utilizes the deformation of tissues induced by compression and relaxation and displays the strain distribution or percentage of deformation as a preliminary step. Its second step is the estimation of the elastic modulus by solving the constitutive equation from the strain distribution and boundary condition similar to stress distribution on the surface.

The static method has the advantages that the system is simple since no other additional devices than a probe is required, and it is easy to reconstruct elasticity images with high spatial resolution since strain is basically obtained by comparing RF signals of two frames. In addition, the data acquisition time is of the same order as that of conventional ultrasonography, which is suited to three-dimensional measurement. Therefore, a practical system for clinical use, based on static methods, has recently been developed by us in cooperation with medical-equipment makers [4,5]. Considering the process of elasticity imaging for clinical diagnosis, the microscopic measurement proposed in this study is based on static methods.

In terms of the elastic properties of tissues, Young’s modulus is defined as the slope of the stress-strain curve as follows:

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E(\varepsilon) = \frac{\partial \sigma(\varepsilon)}{\partial \varepsilon},
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