Viscoelastic Characterization of HIFU Ablated Lesion using K-space Analysis and Convolution Theorem

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Background, Motivation and Objective

Measuring the viscoelasticity of HIFU ablated lesion is necessary for therapeutic evaluation. Acoustic radiation force (ARF) shear wave has been studied to estimate the viscoelasticity. In this study, in order to solve the problem arising from limited shear wave data and get better evaluation of the viscoelasticity of HIFU ablated lesion, we propose a method using two-dimension Fourier transform (2DFT) and convolution operation.

Statement of Contribution/Methods

By conducting 2DFT of shear wave signal, the velocity and attenuation can be determined from the shape of signal in k-space (blue curve in Fig.1 (a)). However, significant biases will be caused if the measured data is limited due to the difficulty of measurement (red curve in Fig.1 (a)). According to convolution theorem, the limited data padded with zeros is the convolution of ideal signal and a rectangle window in k-space (green curve in Fig.1 (a)). In this case, mean square error of measured signal and convolution signal is calculated as loss function, and by minimizing it we can get the viscoelasticity.

In our experiments (Fig.1 (b)), laser Doppler vibrometer was used to track shear wave for higher resolution and no interference by HIFU. A HIFU transducer was used for treatment in gel phantoms with bovine serum albumin and ARF shear wave driven by a pulse with duration of 500 μs. The measuring range is 10 mm with step length of 0.5 mm. The viscoelasticity of both HIFU ablated lesion and normal phantom are estimated for comparison.

Results/Discussion

Shear wave signals of HIFU ablated lesion (Fig.1 (c)) and normal phantom (Fig.1 (d)) are given in time and space domain. Figure.1 (e) and Fig.1 (f) show velocity and attenuation of HIFU ablated lesion (red) and normal phantom (blue) at 100-500 Hz. The mean and standard deviation of velocity and attenuation (Fig.1 (g)), and of elasticity and viscosity derived from Voigt's model (Fig.1 (h)) are shown. These figures illustrate that the velocity of HIFU ablated lesion increases with increasing frequency while the velocity of normal phantom scarcely changes. The attenuation increases with increasing frequency in both states. By contrast, the velocity of HIFU ablated lesion is greater than that of normal phantom while the attenuation of HIFU ablated lesion is smaller than that of normal phantom.

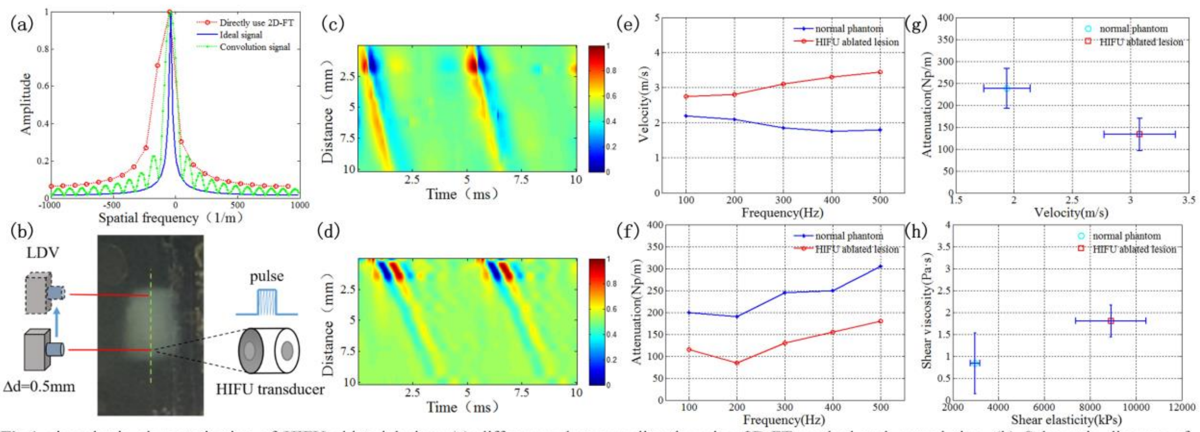

Fig.1 viscoelastic characterization of HIFU ablated lesion: (a) differences between directly using 2D-FT method and convolution. (b) Schematic diagram of experiments. Measured shear wave signal of HIFU ablated lesion (c) and normal phantom (d) in time and space domain. The shear velocity and attenuation of HIFU ablated lesion (e) and normal phantom (f) at 100-500 Hz. (g) The mean and standard deviation of velocity and attenuation. (h) The mean and standard deviation of shear elasticity and viscosity.