Two-Point Method for Shear Wave Attenuation Measurement in Tissue-Mimicking Materials

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Background, Motivation and Objective

Shear wave (SW) elastography is used in several clinical applications for assessment of soft tissue viscoelastic properties. We present a two-point shear wave attenuation coefficient, α_0, measurement method that is insensitive to geometrical spreading of the wave energy. The motivation of this work is to quantitatively assess soft tissue shear wave attenuation using SW propagation measured at two lateral locations.

Statement of Contribution/Methods

A focused acoustic radiation force push beam was used to produce a broadband propagating SW. A local attenuation is then recovered from two lateral locations along the propagation path. First, a one-dimensional Fourier transform is performed for waveforms at two positions, x_1 and x_2. A Gamma distribution function is fit to the resulting power spectra in order to calculate the symmetry indexes, n_1 and n_2, and the bandwidth factors, $f_{\beta 1}$ and $f_{\beta 2}$. The symmetry indexes, n_1 and n_2, are averaged and then the bandwidth factors are recalculated. Using a linear relation between the n_1 and n_2 and $f_{\beta 1}$ and $f_{\beta 2}$ a loss tangent factor is computed. Finally, by using an estimate of the real wavenumber and loss tangent, α_0 can be calculated. The method was tested on simulated SW data sets from numerical viscoelastic phantoms with a constant SW speed of 1.8 m/s and varying viscosity of 0.25, 0.5, 1 and 2 Pa·s for Phantoms I, II, III and IV, respectively, and two commercial viscoelastic elastography phantoms (Phantoms A and B).

Results, Discussion and Conclusions

Using the proposed method, attenuation coefficients α_0 were estimated. We plotted attenuation values based on the choice of first signal position versus the distance between the two measurement signals in Figs. 1a-d for four numerical phantoms. The box plots for each case were evaluated for selected regions-of-interest (ROIs) and compared with the analytical responses in Fig. 1e. Median values of α_0 for models I, II, III and IV are 0.295, 0.451, 0.634 and 0.849 Np/m/Hz, respectively. Analytical values for the same phantoms were 0.281, 0.445, 0.642 and 0.860 Np/m/Hz. We also estimated mean and standard deviation of α_0 from 10 different acquisitions at different locations in the commercial phantoms where $\alpha_0 = 0.704 \pm 0.042$ and 0.653 ± 0.049 Np/m/Hz for Phantoms A and B, respectively. The proposed method is feasible to provide robust attenuation estimates based on two measurement points in tissue-mimicking materials.

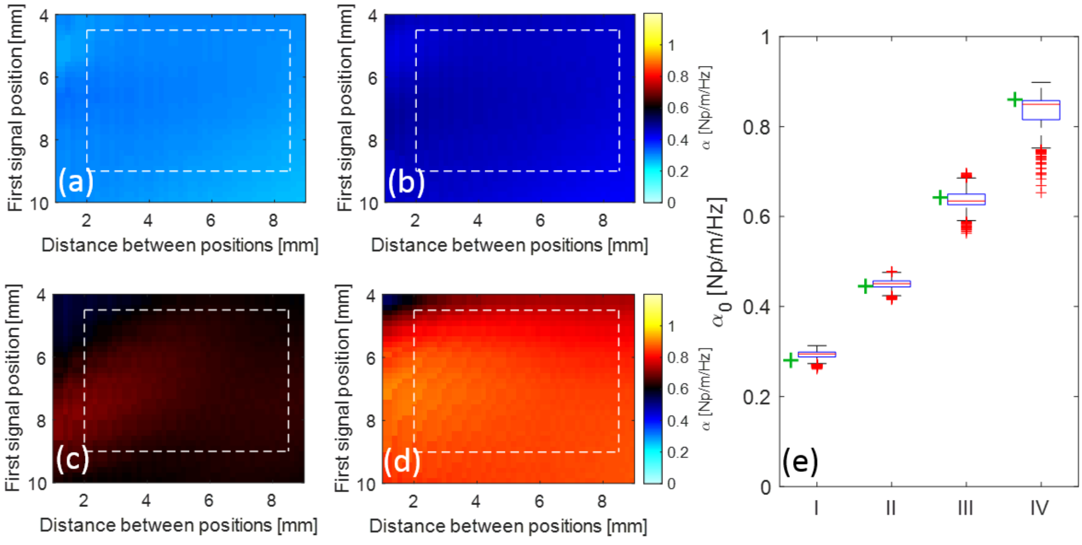

Figure 1. The attenuation coefficient, α_0, calculated for numerical, homogeneous viscoelastic phantoms with assumed shear wave speed of 1.8 m/s and viscosity of (a) I, 0.25 Pa·s; (b) II, 0.5 Pa·s; (c) III, 1 Pa·s; and (d) IV, 2 Pa·s. Results are presented for first signal position versus the distance between two measurement signals. The estimated interquartile ranges (IQR) with the maximum whisker lengths specified as 1 times the IQR for each phantom, for selected ROI, are presented in (e). Green crosses present analytical estimates.