Practical limitations on OCE for accurate evaluation of soft tissue elastic modulus

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Background, Motivation and Objective

The local group velocity of propagating mechanical waves has been widely used in optical coherence elastography (OCE) to characterize soft tissue mechanical properties. In dynamic OCE (Fig.1a), mechanical waves are tracked with a fast scanning OCT beam at different tissue points resulting in 2D or 3D maps of the local wave speed. In most cases, the wave group velocity is considered as equivalent to the shear wave speed and, hence, the shear modulus. However, for bounded or layered media such as the cornea or skin, this equivalence is severely limited. Here we share these limitations with the OCE community to avoid serious mistakes in modulus reconstruction.

Statement of Contribution/Methods

Group velocity measurements can represent tissue properties in bulk media, such as the tissue-like phantom in Fig.1b. In bounded media, however, multiple guided modes (Fig.1c) can greatly complicate the shape of propagating waves. 2-D Fourier transform based dispersion analysis is used for this case. Fitting the experimental dispersion data with analytical functions (Fig.1d) can reconstruct the true shear wave speed and, therefore, the tissue elastic modulus if signals are of sufficient bandwidth to accurately estimate the high frequency asymptotes of individual modes. Acoustic micro-tapping (AμT) with a focused air-coupled ultrasound transducer generated high bandwidth mechanical waves in PVA phantoms and ex vivo porcine corneas, and these waves were tracked with ultrafast, phase-sensitive OCT.

Results/Discussion

For the bulk phantom, Rayleigh wave propagation does not disperse. Hence, the group velocity is equal to the shear wave speed with a multiplier 0.955, and can be used for elastic modulus estimation. For bounded tissue, group velocity maps exhibit structural artifacts often considered as real structure by mistake. With sufficient signal bandwidth and propagation distance, however, dispersion analysis can provide accurate measurement of the shear wave speed.

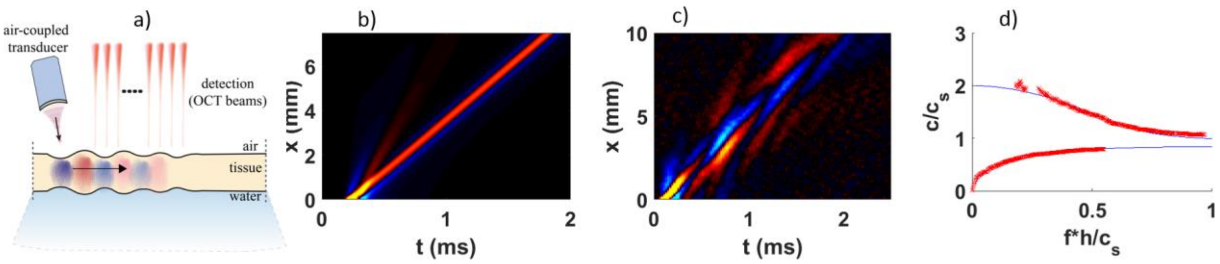

Figure1. a) – Dynamic OCE diagram with an air-coupled transducer for broad bandwidth mechanical wave excitation. b) – Rayleigh wave field (XT plot) on the surface of a bulk phantom - wave does not disperse. c) - XT plot on the surface of a bounded PVA phantom of thickness, h, guided modes are clear. d) – Dispersion curves of the first two modes (red crosses) obtained using the wave field (c), superimposed on the analytical solution (solid lines).