Feasibility of Local Phase Velocity Based Imaging (LPVI) used for Shear Wave Elastography of Renal Transplants

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Background, Motivation and Objective

Shear wave elastography (SWE) is used in many clinical applications to measure the mechanical properties of soft tissues. Among the various methods used for SWE, most techniques are based on measuring the time-of-flight of the shear wave (SW) in the time-domain. Recently, we proposed a method called the Local Phase Velocity Imaging (LPVI) to construct images of phase velocities. The motivation of this work is to evaluate feasibility of the LPVI method for measurement of the viscoelastic properties of renal transplants in patients undergoing protocol biopsies.

Statement of Contribution/Methods

SW motion data are acquired using a General Electric Logiq E9 in renal transplants in 23 patients undergoing protocol biopsies. The local SW phase velocity (PV) is then recovered in the frequency domain for multiple frequencies using LPVI. LPVI involves the SW mode isolation of the particle motion and using directional and bandpass filters in a two-dimensional (2D) wavenumber domain. Then, various steps of Fourier-based operations are applied to obtain localized maps of PV over selected bandwidths. Images at different frequencies are reconstructed over an independently selected frequency range for each human subject. For selected regions-of-interest (ROIs), representing cortex of the kidney, mean PV is calculated for selected frequency bands (from multiple 2D LPVI maps). The resulting dispersion data are fit to Kelvin-Voigt (KV) and Kelvin-Voigt Fractional Derivative (KVFD) models. The model parameters are used to study human subjects with renal interstitial fibrosis and tubular atrophy (IFTA) 0 (none) and 1 (mild to moderate).

Results, Discussion and Conclusions

Using the LPVI approach 2D SW PV maps were reconstructed for 23 human subjects undergoing protocol biopsies [Fig. 1b]. Then KV and KVFD models were fit to the resulting mean phase velocities for selected ROIs [Fig. 1c] and μ_1, μ_2 parameters of the KV and μ_1, μ_2 and α parameters of the KVFD models were estimated. Using the Wilcoxon rank sum test we evaluated the differences for each parameter for patients with IFTA = 0 and 1 ($p = 0.036$ and 0.042 for μ_1 and μ_2 for the KV model, and $p = 0.675$, 0.349 and < 0.001 for μ_1, μ_2 and α, for the KVDF model, respectively) [Figs. 1d-h]. In conclusion, LPVI is feasible in analysis of renal transplant data and provided useful information about viscoelastic parameters in those allografts.

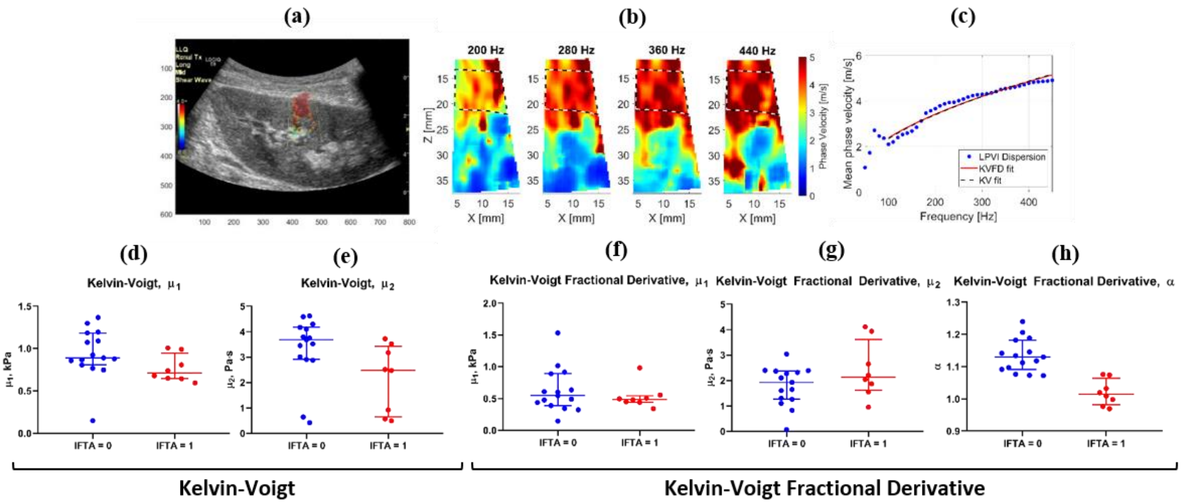

Figure 1. (a) B-mode image for a renal transplant. (b) Two-dimensional shear wave phase velocity maps for a selected frequencies, for the kidney from (a). (c) A mean phase velocity within selected ROI calculated from (b) with fit to KV and KVFD models. (d)-(h) Summary of estimated coefficients for KV and KVFD models for 23 human subjects as median and interquartile range as whiskers (Wilcoxon rank sum test, $p = 0.036$ and 0.042 for μ_1 and μ_2 for the KV model, and $p = 0.675$, 0.349 and <0.001 for μ_1, μ_2 and α, for the KVFD model, respectively) .