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Theoretical and phantom based investigation of the impact of sound speed and backscatter variations on attenuation slope estimation

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Abstract

Quantitative ultrasound features such as the attenuation slope, sound speed and scatterer size, have been utilized to evaluate pathological variations in soft tissues such as the liver and breast. However, the impact of variations in the sound speed and backscatter due to underlying fat content or fibrotic changes, on the attenuation slope has not been addressed. Both numerical and acoustically uniform tissue-mimicking experimental phantoms are used to demonstrate the impact of sound speed variations on attenuation slope using clinical real-time ultrasound scanners equipped with linear array transducers. Radiofrequency data at center frequencies of 4 and 5 MHz are acquired for the experimental and numerical phantoms respectively. Numerical phantom sound speeds between 1480 and 1600 m/s in increments of 20 m/s for attenuation coefficients of 0.3, 0.4, 0.5, 0.6, and 0.7 dB/cm/MHz are simulated. Variations in the attenuation slope when the backscatter intensity of the sample is equal, 3 dB higher, and 3 dB lower than the reference is also evaluated. The sound speed for the experimental tissue-mimicking phantoms were 1500, 1540, 1560 and 1580 m/s respectively, with an attenuation coefficient of 0.5 dB/cm/MHz. Radiofrequency data is processed using three different attenuation estimation algorithms, i.e. the reference phantom, centroid downshift, and a hybrid method. In both numerical and experimental phantoms our results indicate a bias in attenuation slope estimates when the reference phantom sound speed is higher (overestimation) or lower (underestimation) than that of the sample. This bias is introduced via a small spectral shift in the normalized power spectra of the reference and sample with different sound speeds. The hybrid method provides the best estimation performance, especially for sample attenuation coefficient values lower than that of the reference phantom. The performance of all the methods deteriorates when the attenuation coefficient of the reference phantom is lower than that of the sample. In addition, the hybrid method is the least sensitive to sample backscatter intensity variations.

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Figures

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Figure 3 Estimated attenuation slope for the...

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