Minimizing Bias and Variance in Clinical Liver Shear Wave Elastography

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Background, Motivation and Objective

Although Shear Wave Elastography (SWE) is widely used for diagnosis of diffuse liver disease[1], the clinical acceptance has been limited by the overall variability and the bias of the measurements between systems or transducers. To further the clinical acceptance of SWE, it is necessary to minimize the variability of SWE and ensure that there is no known bias between different transducers or systems.

In this work, signal processing algorithms, transducer geometry formats, and acquisition strategies were evaluated to minimize the bias and variance of estimated shear wave speeds clinically.

Statement of Contribution/Methods

SWE data were acquired on 61 volunteers *in vivo* and 4 uniform elasticity phantoms. The 61 volunteers had no known history of liver disease and the scan protocol followed the method described by the Society of Radiologists in Ultrasound[2] under an IRB approved protocol. The phantoms were QIBA calibrated[3] with a shear wave speed (SWS) ranging from 1 to 5 m/s. All data were acquired with the 4V1, 5C1, and DAX on the Siemens ACUSON Sequoia and the 4C1 on the Siemens ACUSON S3000.

Both point-SWE and 2D-SWE acquisition strategies were evaluated, which track the shear wave in unidirectional and bidirectional configurations, respectively. Raw IQ data were processed with a range of signal processing algorithms and optimization parameters including shear wave propagation distances, displacement bandpass filter cutoff frequencies, arrival time estimate regression algorithms, and data quality inclusion thresholds.

Analysis of measurement bias was performed using paired t-tests of the median SWS value for a given volunteer. The variance was computed as the standard deviation of the SWS on each patient.

Results, Discussion and Conclusions

For both point-SWE and 2D-SWE, the total shear wave propagation distance and bandpass filter cutoffs significantly biased the estimated SWS in the volunteer population. However, this bias was not seen in phantoms and suggests that phantom calibration alone cannot eliminate clinical biases. Tuning of these parameters eliminated the statistical differences on the volunteer population for all comparisons between systems, transducers and acquisition strategies ($p>0.25$). Further reductions in measurement variability were achieved using the Thiel-Sen[4] regression algorithm and tuning of cutoff thresholds for correlation coefficients and regression quality.

Using the above methods, the average volunteer standard deviation was reduced by up to 83% (0.11 m/s to 0.06 m/s). Together these acquisition and data processing strategies help to reduce measurement bias and improve clinical acceptance.

[1] Bota S, et al. Liver Int 2013; 33(8): 1138-1147

[2] Barr RG, et al. Rad 2015; 276(3): 845-61

[3] Deng et al. *IEEE TUFFC*.2017(1): 164-176

[4] Gilbert. Statistical methods for environmental pollution monitoring 1987