

A COMPARISON OF SHEAR WAVE ELASTOGRAPHY PUSHING SEQUENCES

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1. Introduction

Changes in stiffness of soft tissue are a sign of abnormalities. Therefore, techniques capable of estimating elasticity of tissue can contribute in the assessment of various diseases. Shear wave elastography (SWE) is an ultrasound-based technique where a pushing beam induces shear waves (SW) characterized by lower wave speed than longitudinal waves and that travel orthogonally to the pushing beam direction. Tissue elasticity can then be estimated from measuring the local SW velocity. There are multiple ways of generating SW using acoustic radiation force impulses. The purpose of this study was therefore to compare the performance of four different pushing sequences with a commercial device and in an experimental setup.

2. Methods

A programmable ultrasound system (Verasonics Inc, Redmond, WA, USA) with a 128-element linear transducer (Philips L7-4) was used to induce SW in a homogeneous PVA phantom (10% PVA, 3% graphite, 2 freeze cycles) and to measure the SW propagation. 180V p-p voltage and 5 MHz centre frequency were used for each transmission. Four pushing sequences were investigated: 1) focused push, focusing at a single point for 96 μ s, 2) unfocused push, where the 12 central elements were excited for 198 μ s to generate an unfocused plane wave, 3) unfocused comb-push [1], where four simultaneous and unfocused pulses, equally spaced in the lateral direction, were emitted, and 4) line-push [2], where three pushes were focused along a line at progressively deeper focal points. The focused pushes were spaced 0.7 mm axially with a 0.2 ms delay between pushes.

SW propagation was imaged with plane wave pulses at a frame rate of 10 kHz and 5 MHz centre frequency. The average of three angled plane waves (-8° , 0° , 8°) was used to construct each frame. Axial particle velocity was estimated at each pixel and frame using Loupas' 2D autocorrelator [3] setting a 5-sample range gate length across 5 frames. The result was directionally filtered to reduce noise and artefacts. By cross-correlating the time-dependent axial velocity of two pixels, 2 mm apart laterally, the local SW speed was estimated (Figure 1). Due to the absence of SW in the pushing region, all implemented sequences, apart from the comb-push, exhibit blind areas, in which SW speed cannot be estimated. The width of this area was also measured. Finally, our implementations were compared with the commercial SW system Aixplorer (Supersonic Imagine, France).

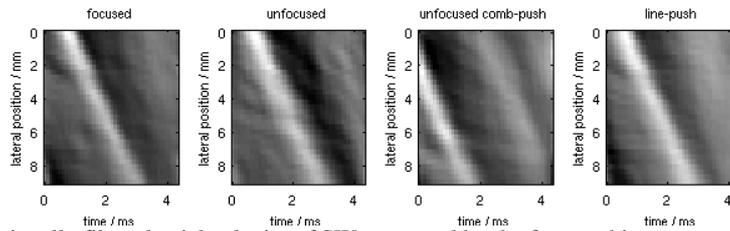


Figure 1: Directionally filtered axial velocity of SW generated by the four pushing sequences, at one depth.

3. Results

Table 1 summarizes the measured SW velocity and blind area width for each implementation. As can be seen, SW velocity mean values are close to each other and to those obtained with the commercial system. The line-push resulted in the widest blind area, while the comb-push had none.

Table 1: Measurement results for different pushing sequences.

	<i>Unfocused</i>	<i>Comb-push</i>	<i>Focused</i>	<i>Line push</i>	<i>Aixplorer</i>
SW velocity	4.39 ± 0.18 m/s	4.40 ± 0.21 m/s	4.65 ± 0.29 m/s	4.57 ± 0.30 m/s	4.5 ± 1.5 m/s
Width of blind area	2.3 mm	0 mm	2.5 mm	3.0 mm	-

4. Conclusions

To summarize, all the pushing sequences implemented in this study performed similarly concerning the SW speed estimation, with values close to the ones obtained with the commercial SW system. The comb-push, however, had the advantage of not leading to any blind areas. Further investigations should include quality measures relevant to specific clinical applications.

References

- [1] Zhao, Heng, Pengfei Song, Matthew W Urban, James F Greenleaf, and Shigao Chen. "Shear Wave Speed Measurement Using an Unfocused Ultrasound Beam." *Ultrasound in Medicine & Biology* 38, no. 9 (September 2012): 1646–1655.
- [2] Bercoff, J., M. Tanter, and M. Fink. "Supersonic Shear Imaging: a New Technique for Soft Tissue Elasticity Mapping." *IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control* 51, no. 4 (April 2004): 396–409.
- [3] Loupas, T., J.T. Powers, and R.W. Gill. "An Axial Velocity Estimator for Ultrasound Blood Flow Imaging, Based on a Full Evaluation of the Doppler Equation by Means of a Two-dimensional Autocorrelation Approach." *IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control* 42, no. 4 (July 1995): 672–688