SHEAR WAVE ELASTOGRAPHY OF THE ARTERIAL WALL – WHERE WE ARE TODAY

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1. Introduction

Shear Wave Elastography (SWE) is a recently developed noninvasive method for elastography assessment using ultrasound. The technique consists of sending an acoustic radiation force (pushing sequence) into the tissue that in turn generates an orthogonal low frequency propagating shear wave. The shear wave propagation is measured real time by high speed B-mode imaging. From the B-mode images, the shear wave is tracked via normalized cross-correlation and the speed is calculated, which is used to generate an elasticity map of the tissue's shear modulus. To date, the technique has mostly been used in large homogeneous tissues such as breast and liver where it successfully detects lesions and tumors that are easily missed with normal B-mode ultrasound [1]. SWE could potentially be applied in vascular applications to assess elasticity of the arterial wall to characterize the stiffness as an early indicator of cardiac disease. Furthermore, SWE could aid in the characterization of plaques in the carotid artery, which is critical for the prevention of ischemic stroke.

2. Methods and Results

An initial study was performed using an Aixplorer SWE system (Supersonic Imagine, France) to measure the shear modulus in a polyvinyl alcohol phantom (PVA) vessel with a plaque inclusion (Figure 1). It was possible to distinguish the softer inclusion mean shear wave speed (2.1 m/s) from the arterial wall (3.5 m/s) on the SWE colour-map, but the Young's Modulus calculation of the arterial wall (E=19.8 kPa) did not match the measured Young's Modulus (E=53.1 kPa) from comparative mechanical testing.

We have begun implementing various pushing sequences (single unfocused push, single focused push, line push, comb push) on a programmable ultrasound machine (Verasonics, USA) using a linear transducer (Philips L7-4) in a homogeneous PVA phantom. An algorithm for one dimensional cross-correlation tracking and shear wave speed estimation has been developed and initially tested in an experimental setup.

3. Discussion

According to our initial results, it is possible that SWE could be applied in vascular applications. However, the initial mechanical testing vs. SWE comparison indicated that further development to the post processing is needed before applying it on the carotid artery, which is a heterogeneous tissue with other wave propagation properties than e.g. breast tissue. The carotid artery has a difficult geometry to study for several reasons. The intima-media complex is very thin (< 1mm), and the vessel wall is not stationary. Furthermore, the cylindrical shape of the artery produces complex wave reflections within the arterial wall, which result in a polychromatic propagation of the shear wave. A few studies have applied techniques based on SWE to the arterial wall with promising results and a pilot study demonstrating the feasibility of the technique in-vivo has been published [2]. Still, a considerable effort is needed to validate and optimize the technique for the clinical vascular setting.

References

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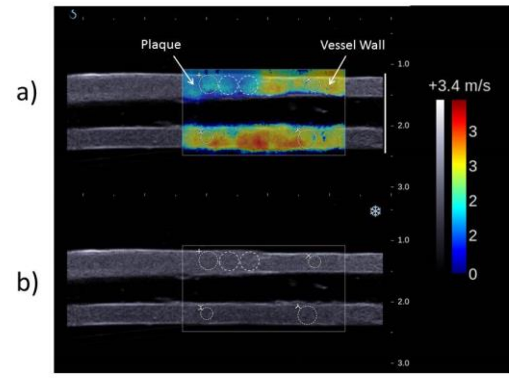

Figure 1a) Shear Wave Elastography of a phantom vessel with plaque inclusion where the shear wave speed is color-coded. **b)** Region of interests on corresponding B-mode image.