SUPERSONIC SHEAR WAVE IMAGING FOR THE ASSESSMENT OF THE NONLINEAR MECHANICS AND ANISOTROPY OF ARTERIES: PROOF OF PRINCIPLE BASED ON EX VIVO TESTING OF THE HORSE AORTA

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Abstract

Supersonic shear wave imaging (SSI) is potentially applicable for assessment of arterial wall elasticity. However, SSI in human arteries is challenging due to anisotropy and small dimensions. Therefore, feasibility of SSI in thicker equine aorta was studied and results were compared with mechanical data. The ability of SSI to acquire stretch-induced stiffening of arteries and determine collagen fiber orientation was investigated.

Keyword(s): biomechanics – medical imaging

1. INTRODUCTION

Supersonic shear wave imaging (SSI) is an ultrasound (US) tissue elasticity evaluation method, which has been widely applied to bulk tissues (liver, breast). In arteries SSI potentially serves as a technique for early detection of cardiovascular disease. SSI is based on studying the propagation of a shear wave (SW) in the tissue created through the application of an acoustic body force. Whereas SSI in *thin* human arterial walls is challenging due to complex wave propagation phenomena [1], we operated SSI measurements in *thicker* equine aorta and simultaneously performed mechanical testing to serve as reference values.

2. METHODS

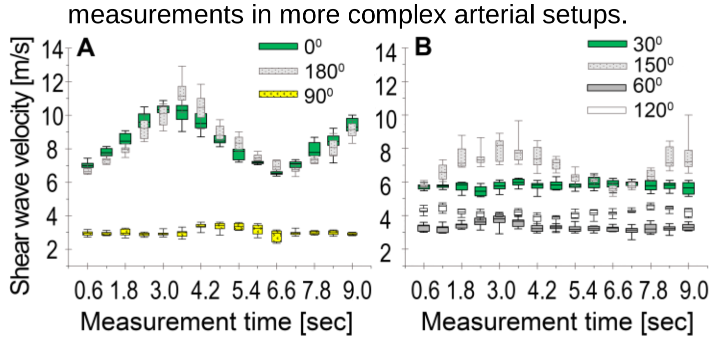
A cylindrical slab was excised from the proximal descending aorta of a 7-month old standardbred mare and cut open axially to obtain a rectangular specimen (≈8.6cm circumferential, ≈7cm axial, 4-4.6cm radial). The specimen was fixed in the uni-axial testing machine and stretched cyclically along its circumferential direction (engineering strain varied from 10% to 35%, stretch rate 7.7%/s). The US probe was fixed above the specimen in the angle position controller and rotated from 0^0 to 180^0 (30^0 step). The SW speed (SWS) results were derived from the tissue velocity data by using a time-of-flight method [2].

3. RESULTS

Non-linear viscoelastic arterial behavior was observed with stretch-induced stiffening by a factor of 2.6 (avg E-modulus 91.6kPa at 10% strain, 235.5kPa at 35% strain). The SSI results along the circumferential direction ($0^0/180^0$ probe position) indicated cyclic SWS changes between ≈6.55m/s and ≈10.7m/s (Fig.1A). The E-modulus was derived from this data [2] and ranged from 137.52 to 366.6kPa (increased by 2.7). The SWS values for the angles of $30^0/150^0$, $60^0/120^0$ and 90^0 degrees were markedly lower (Fig. 1B).

4. DISCUSSION

SWS along the tissue's circumferential direction ($0^0/180^0$) varied cyclically with the same period as imposed by the uni-axial testing, indicating progressive recruitment and stretching of the collagen fibers. Moreover, successive decrease in SWS amplitudes and SWS variation for the probe angles of $30^0/150^0$, $60^0/120^0$ and 90^0 demonstrates (presumed) circumferential orientation of the fibers. This study is a feasibility study to establish the performance of SSI measurements in more complex arterial setups.



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