EVALUATION OF 4D ULTRASOUND DATA TO DETERMINE THE RELATIONSHIP BETWEEN 3D AORTIC WALL DISPLACEMENT AND AGE

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Introduction

The cyclic deformation that blood vessels experience can be used to investigate the elastic and biomechanical properties of the vessels *in vivo*. Specifically, axial prestretch of the abdominal aorta is a phenomenon that impacts arterial physiology and pathology. Horny et al has shown that a decrease in axial prestretch is closely linked with age and abdominal aortic aneurysm (AAA) development [1, 2]. However, measuring axial prestretch *in vivo* is not possible, as it requires surgical resection of the aorta. Previous work has suggested that 3D displacement of the aortic wall, which can be measured via 4D ultrasound, could be used to estimate prestretch in living patients [3].

Methods

Ultrasounds were performed on human patients by Wojciech Derwich (MD) at Department of Vascular and Endovascular Surgery of the Goethe University Hospital Frankfurt (Main). All use of anonymized patient data was approved by local ethics committees. A commercial real-time 3D echocardiography system (Artida®, Toshiba Medical Systems, Otawara, Japan) equipped with a 3D transthoracic probe (Toshiba, PST-25SX, 1-4 MHz phased array matrix transducer) was used to acquire 4D ultrasound data.

Ultrasound data was collected from a total of 154 patients (AAA = 81, diseased elderly = 31, young = 32, healthy elderly = 11). The data was segmented and masked using an in-house MATLAB code. The displacements with and without rigid body motion as well as the rigid body motion itself was evaluated in the longitudinal, radial, circumferential, and norm directions. The data was then compared using a Mann-Whitney U statistical test.

Results

Displacements without rigid body motion in the radial direction were found to decrease exponentially with increasing age, both in the evaluations containing AAA patients and excluding AAA patients. A power model

$$y = ax^b \qquad (1)$$

where *y* is displacement and *x* is age, was fit to the data with fits of $a = 64.76$, $b = -1.39$, $R^2 = 0.48$ and $a = 59.67$, $b = -1.36$, $R^2 = 0.46$ for the group including the AAA patients and excluding the AAA patients, respectively.

The rigid body motion in the longitudinal direction was found to increase significantly between patients under age 40 and patients over age 40 in the groups including and excluding AAA patients (Figure 1).

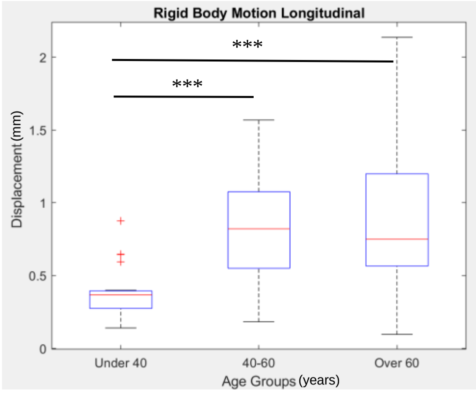

*Figure 1: Rigid body motion in the longitudinal direction among age groups excluding AAA patients. (*** = p < 0.05)*

Additionally, despite the known loss of distensibility with age [3], no change in the size of resulting 3D displacement (norm) was observed as age increased.

Discussion

Radial displacements of the aortic wall excluding rigid body motion – that are closely related to aortic distensibility – have been shown here to decrease exponentially with age, similar to the relationship between age and prestretch demonstrated in Horny et al [1, 2]. In the future, a model relating prestretch and 3D displacement will be investigated.

The finding that rigid body motion in the longitudinal direction increases significantly with age when comparing both AAA patients and elderly patients without AAAs supports previous research and fits with the known negative correlation between prestretch and age and prestretch and AAA development [4].

The consistent norm of the displacements could explain the simultaneous increase in longitudinal rigid body motion and decrease in radial displacement. Further work is needed to confirm this finding.

References

1. Horny et al, JMBBM 4, 8, 2128–2132, 2011
2. Horny et al, BMMB, 16:375-383, 2017
3. Wittek, Book Series of the Engineering Mechanics Group, Siegen, 2022
4. Bulpitt et al, J Am Geriar Soc, 47: 657-663, 1999

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