Evaluation of 4D Ultrasound Data to Determine the Relationship Between 3D Aortic Wall Displacement and Age

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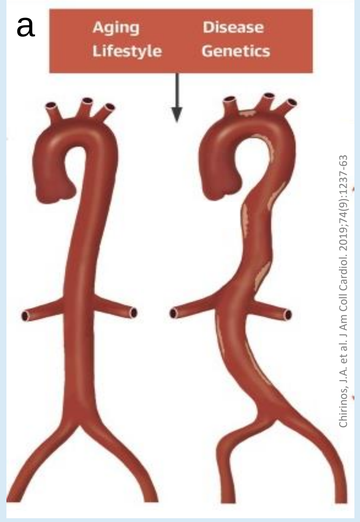
Background



a) Representative image showing healthy (left) and aged (right) artery

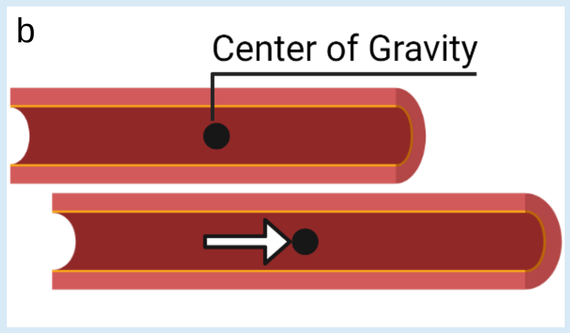
- Vessels deform cyclically, which gives insight into their biomechanical properties *in vivo*
- Aging has been previously shown to fatigue and deform arteries
- Leads to loss of elasticity and prestretch as well as arterial stiffening
- Cardiovascular continuum
- Biomechanical models require surgical resection of the aorta for prestretch values
- Using age as a commonality, a comparison between prestretch and displacement could allow for non-invasive measurements of prestretch

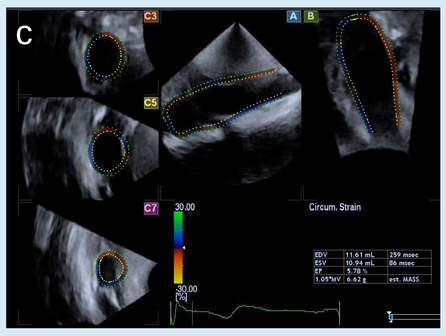
➡ More insight into biomechanical behavior of the aorta could improve patient outcomes

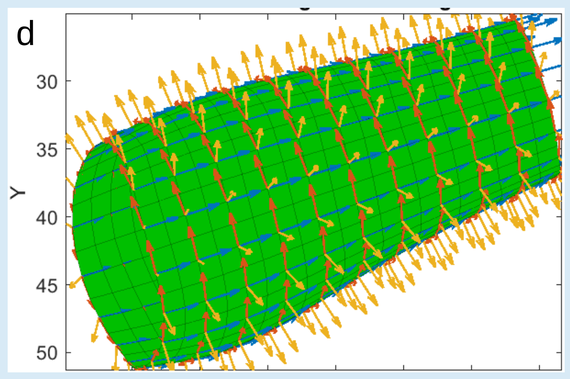
Goals

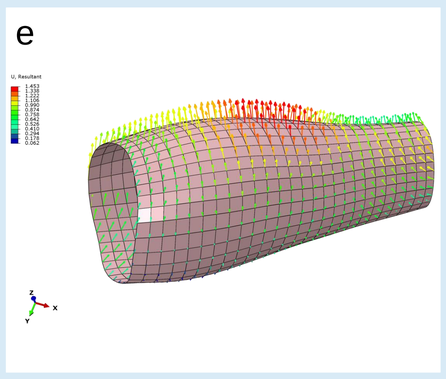
- Short Term: Create a model comparing biomechanical parameters that can be collected using 4D ultrasound to prestretch values
- Long Term: Validate model through creation of a Finite Element Model and Computational Fluid Dynamics

Segmentation of Data







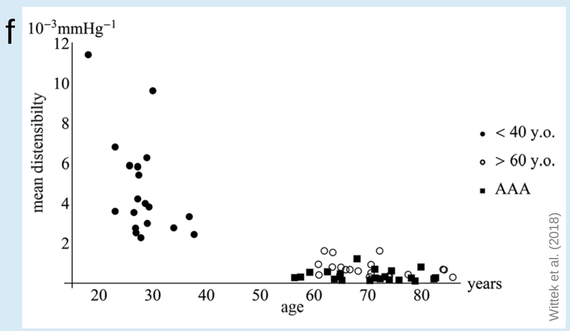


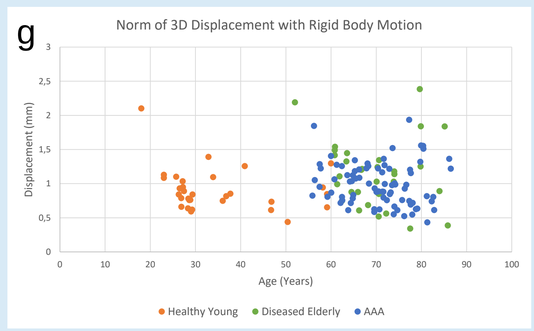
b) Representative figure showing the change in the center of gravity between systole and diastole c.) Ultrasound image demonstrating data collection d.) Representative diagram showing the directions in which the displacement was measured – longitudinal, circumferential, and radial e.) Resulting strain vector plot

- Biomechanical parameters from 4D-ultrasound images
- Analyzed using in-house MATLAB software

➡ Patient-specific model using image sets from different patient groups

Results: Displacement and Age

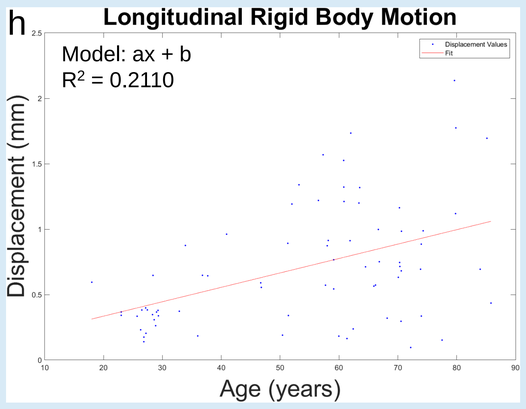


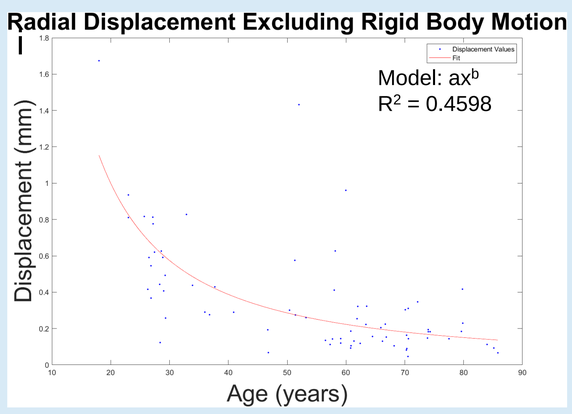


f.) Mean distensibility vs. age g.) No change in overall 3D displacement (the norm vector) is seen as age changes, despite a decrease in distensibility

- Despite a decrease in mean distensibility, overall displacement remains constant with age
- Suggests a balance in individual components of displacement

Results: Displacement and Age

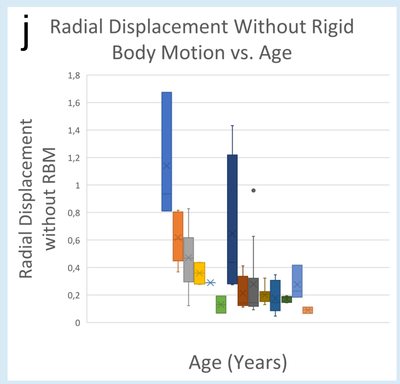


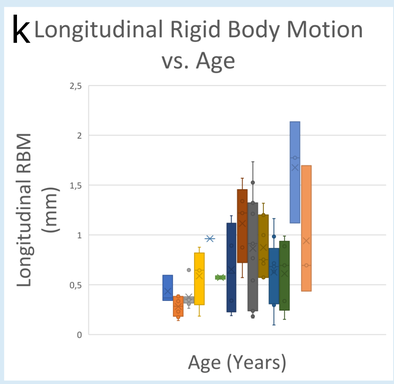


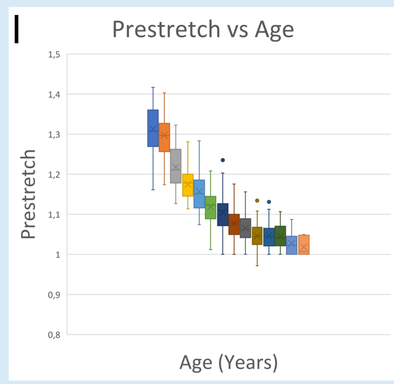
h.) Plot of longitudinal rigid body motion values fit with a linear model i.) Plot of radial displacement excluding rigid body motion fit with a power law model

- Radial displacement without rigid body motion and longitudinal rigid body motion contributed the most to overall displacement
- These parameters were plotted against age to look at the correlations and determine if displacement can be paired to prestretch

Results: Displacement as a Model for Prestretch







j., k., & l.) Plots depicting results for age groups of 5 years each of the three data sets. Ages ranged from 20 to 80 years old.

- Two types of displacement were compared with prestretch to examine the relationship between prestretch and displacement
- Data were paired randomly and rho and p values were measured 10,000 times using a Spearman rank correlation
- Median p values were 2.74E-04 for longitudinal RBM and 1.21E-07 for radial displacement, indicating a significant correlation with prestretch.

Discussion and Future Directions

- A correlation between prestretch and displacement would be useful for better understanding mechanical properties of the vasculature
- We found a significant correlation between displacement and prestretch by pairing age values and no correlation when performing the same analysis on data not paired by age
- In the future, we would like to create a FEA model to validate our findings as well as perform further analysis to confirm our results

Acknowledgments

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