Objective: Ascending aortic tissue experiences both longitudinal and circumferential forces affecting mechanical behavior. We compared the independent effects of age, diameter, tissue thickness, and aortic length on biaxial physiologic mechanical parameters, in both aneurysmal and non-aneurysmal tissues, and uniaxial failure metrics in aneurysmal tissue.

Methods: From 5/2018–10/2022, 424 aortic tissue samples were obtained from 120 adults undergoing elective ascending aortic surgery, 104 (87%) with aneurysms and 16 (13%) transplant recipient/donor controls (mean age: 54±15 aneurysms, 58±5 controls). Biaxial mechanical testing (268 samples, 63%) simulated equiaxial stress-strain curves. Uniaxial testing (154 samples [72 longitudinal,72 circumferential], 37%) assessed tissue failure in longitudinal (Ezz) and circumferential (E??) directions. Machine learning multivariate boosting strategies were implemented to determine the independent effects of age, diameter, tissue thickness, and aortic length on mechanical metrics.

Results: On biaxial testing aneurysmal tissue was more deformable, transitioning from the low to higher stiffness at larger strains, than control tissue in both the longitudinal (Ezz: 0.30 vs. 0.18, P<.001) and circumferential (E??:0.30 vs. 0.25, P=.009) directions (Figure 1A). Comparing longitudinal transition stiffness (Ezz) along the aorta, root specimens were stiffer than those cut from the proximal, middle, and distal ascending aorta (P<.001); no observed difference in circumferential transition stiffness (E??). Age and region were the most influential predictors of longitudinal transition stiffness under physiologic deformations by multivariate boosting. On uniaxial testing, tissue failure, failure stress was lower in the longitudinal versus circumferential direction (1.0 vs. 1.9 MPa, P<0.001). Failure stress decreased with increasing age, indicating earlier failure (Figure 1B). Failure stress was most strongly associated with patient age and tissue orientation (circumferential>longitudinal, Figure 1C).

Conclusions: Age is the most prominent predictor of biomechanical behavior, outperforming diameter, tissue thickness, and aortic length. Differences in the mechanics of aneurysmal tissue relative to control tissue may differ from previous hypotheses. Differences in longitudinal and circumferential directional capacitance may contribute to aortic failure and partially explain circumferential tears in ascending dissection.

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