Predictors of Ascending Aortic Biomechanics Using Epiaortic Ultrasound: The Role of Aortopathy

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Background

- In-vivo mechanical predictors of aortic tissue behavior are needed to better inform optimal timing for prophylactic ascending aortic aneurysm repair

- Transesophageal echocardiography and epiaortic ultrasound allow for detailed in-vivo assessment of the entire ascending aorta

Research Aims

Aim 1: Determine the clinical predictors of in-vivo biomechanics in aneurysmal and non-aneurysmal ascending aortas.

- Mechanical outcomes of interest:
  - Distensibility
  - Global Circumferential Strain (GCS)
  - Stiffness Index (SI)

Aim 2: Identify the impact of aneurysmal pathology on aortic biomechanics.

- We hypothesize that the presence of an ascending aortic aneurysm will be a significant predictor of in-vivo mechanical outcomes.

Study Design

7/2021-11/2023
95 adults underwent ascending aneurysm replacement

369 intraoperative aortic images acquired

Images excluded:
Incomplete cardiac cycle (N=1)
Image incompatibility (N=2)
Epiaortic ultrasound not completed (N=8)

7/2023-11/2023
39 adults underwent coronary artery bypass grafting (CABG)

129 intraoperative aortic images acquired

Images excluded:
Incomplete cardiac cycle (N=3)

Epiaortic Ultrasound not completed (N=24)

Image Assessment
N=498

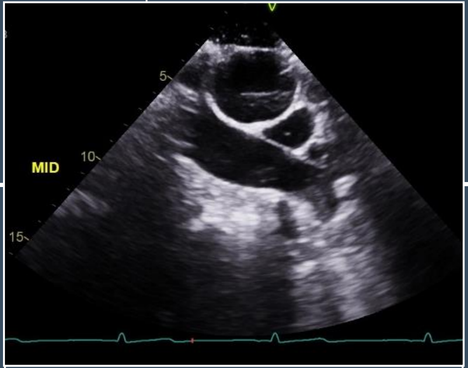
Root

94 aneurysm
36 CABG

Prox

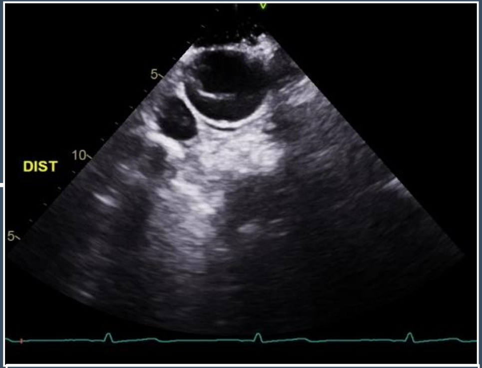
91 aneurysm
31 CABG

Mid

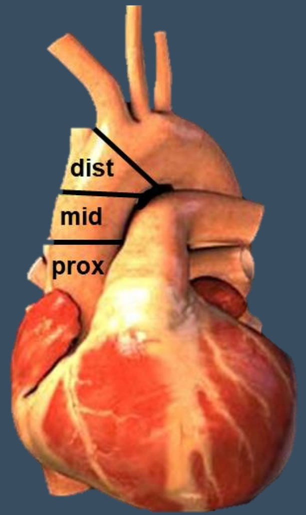


92 aneurysm
31 CABG

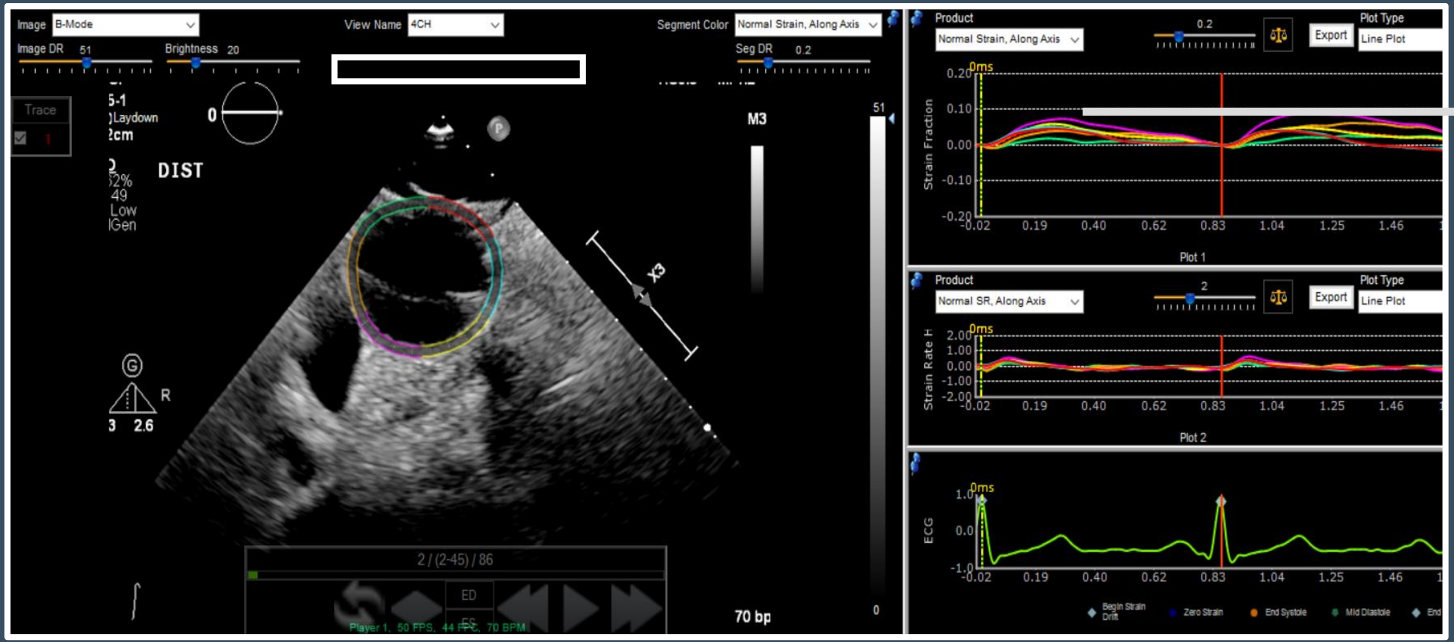
Dist



92 aneurysm
31 CABG



In-Vivo Mechanical Outcomes



Global Circumferential Strain (GCS)

Change in the circumference of the aorta during one cardiac cycle

Stiffness Index (SI)

Resistance of the aorta to deformation indexed to arterial blood pressure

$$\frac{Ln\left({}^{SBP}/{}_{DBP}\right)}{Strain}$$

Distensibility

The ability of the aorta to expand in response to changes in blood pressure

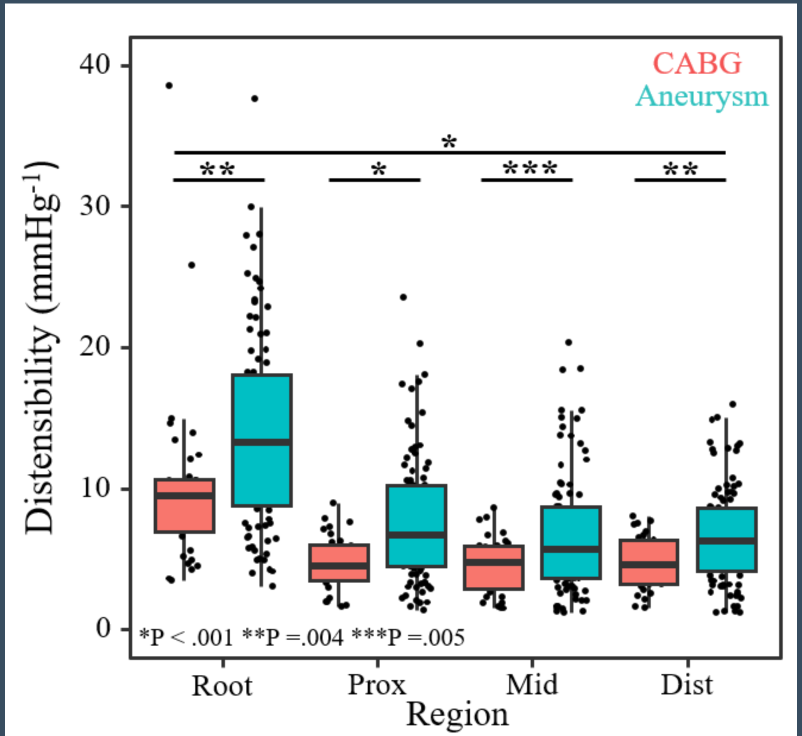
$$\frac{2 * (A_{sys} - A_{dia})}{A_{dia} * (SBP - DBP)}$$

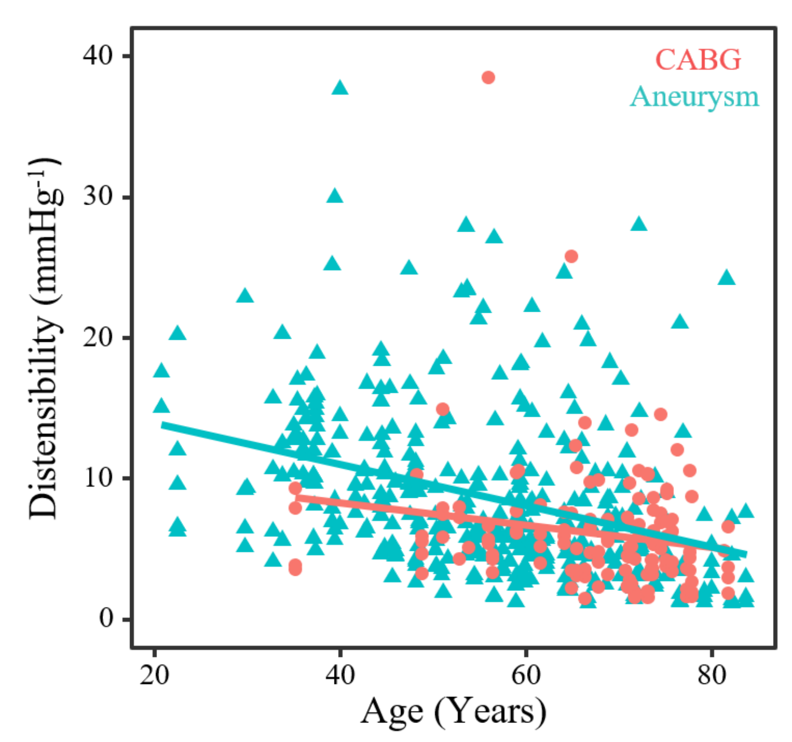
Study Population Characteristics

Variable	Aneurysm (N = 95)		CABG (N = 39)		P-Value
	N	Count (%), Mean±SD	N	Count (%), Mean±SD	
Age (years)	95	55.20 ± 14.74	39	66.73 ± 10.40	<0.001
Sex (male)	95	73 (76.8%)	39	30 (76.9%)	1.000
Race	93		39		0.500
Black		5 (5.3%)		1 (2.6%)	
White		83 (87.4%)		35 (89.7%)	
Other	95	5 (5.3%)	39	3 (7.7%)	
HTN	95	57 (60%)	39	39 (100%)	<0.001
Aortic Valve Phenotype, Tricuspid		42 (44.2%)	39	39 (100%)	<0.001
Aortic Insufficiency	95		39		
None		28 (29.5)		39 (100%)	<0.001
Mild		24 (25.3)		0 (0%)	
Moderate		19 (20.0)		0 (0%)	
Severe		24 (25.3)		0 (0%)	
Maximum Aortic Diameter (cm)	93	5.20 ± 0.60	36	3.65 ± 0.23	<0.001
Centerline Ascending Aortic Length (mm)	91	110.76 ± 16.15	36	88.76 ± 11.17	<0.001

In-Vivo Mechanical Outcomes

Variable	Aneurysm (N = 369)		CABG (N = 129)		P-Value
	N	Mean ± SD	N	Mean ± SD	
Global Circumferential Strain (%)	369	6.4 ± 4.5	129	4.4 ± 2.3	<.001
Stiffness Index	369	13.1 ± 9.3	129	18.1 ± 9.7	<.001
Distensibility ($mmHg^{-1}$)	369	9.1 ± 6.9	129	6.2 ± 4.5	<.001



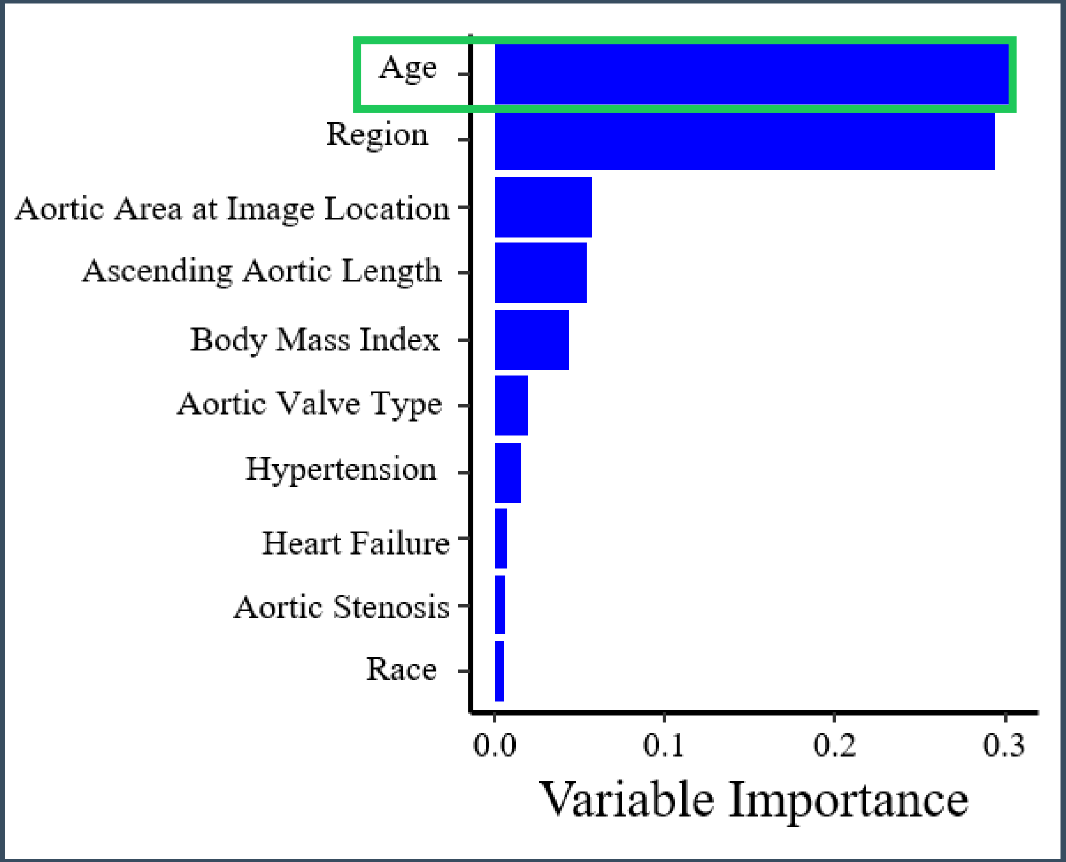


Mixed-Effects Modeling on Distensibility

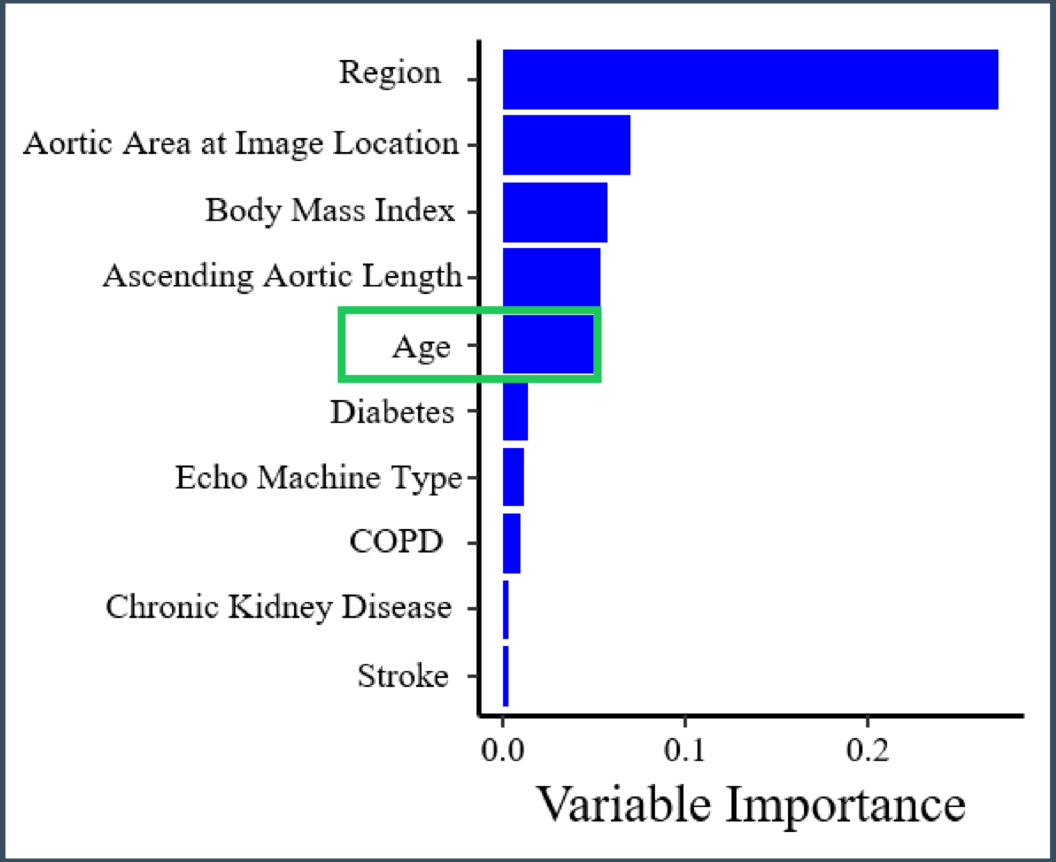
Variable	Aneurysm (N = 369)				CABG (N = 129)			
	Univariable		Multivariable		Univariable		Multivariable	
	Beta Coeff.	P-value	Beta Coeff.	P-value	Beta Coeff.	P-value	Beta Coeff.	P-value
Age	-.17	<.001	-.19	<.001	-.08	<.001		
Region		<.001		<.001		<.001		<.001
Root	8.4		8.4		5.6		5.5	
Prox	1.2		.9		.02		.13	
Mid	.19		.02		-.18		-.09	
HTN								
Ascending Aorta Length	.02	.40			.01	.78		
Aortic Area at Image Location	-.07	.29			-.66	.001		

Variables of Importance on Distensibility

Aneurysm Cohort

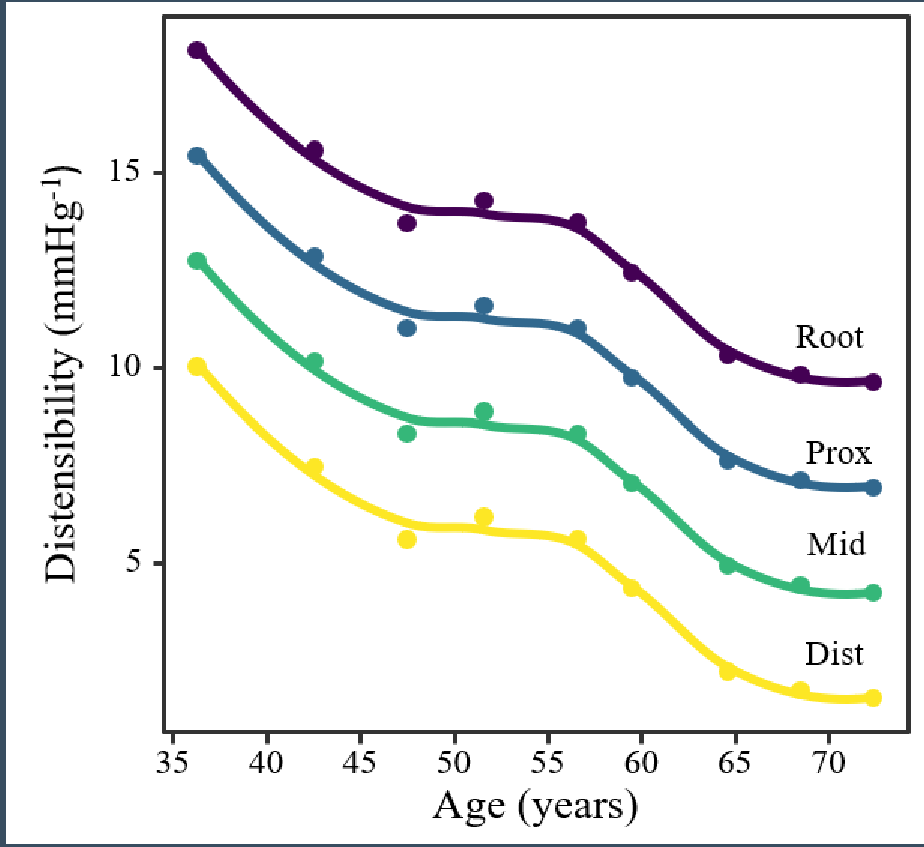


CABG Cohort

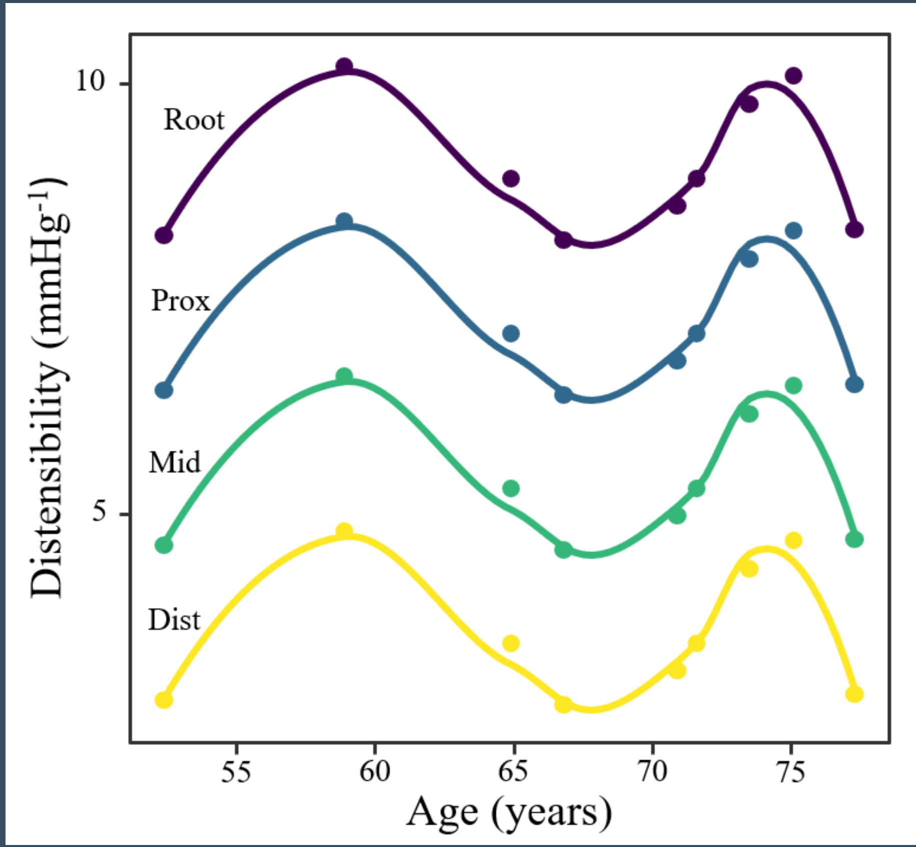


The Relationship Between Age and Region on Distensibility

Aneurysm Cohort



CABG Cohort



Multivariable Mixed-Effects of Combined Cohorts

Variable	Combined Aneurysm and CABG Patients	
	Multivariable Model	
	Beta Coeff.	P-value
Age	-.08	.15
Region		<.001
Root	7.54	
Prox	.67	
Mid	-.04	
HTN	.76	.25
Ascending Aorta Length	.05	.01
Aortic Area at Image Location	.4	.03
Aortic Area at Image Location * Age	-.006	.05

- The mixed effect model demonstrates a negatively associated interaction term between age and the aortic area at the image location, suggesting a trade off between these two covariates.
- Given gradient boosting models have demonstrated a large effect of age, the correlated effect of area is minimized.

Clinical Relevance

- Lengthwise regional variation along the ascending aorta consistently emerges as a significant predictor of in-vivo biomechanical outcomes.

- Age had a more pronounced impact in the aneurysm cohort, suggesting that the presence of an ascending aneurysm may exacerbate age related aortic tissue dysfunction.

- Clinical judgement is necessary to determine the optimal surgical timing balancing age and ascending aortic area.

Conclusions

- Region and age are the most influential predictors of in-vivo ascending aneurysmal aortic mechanics
  - The importance of age differs between aneurysmal and non-aneurysmal aortas

- The interaction between aortic aneurysm and age is complex, and additional imaging modalities should be employed to further assess in-vivo biomechanics.