

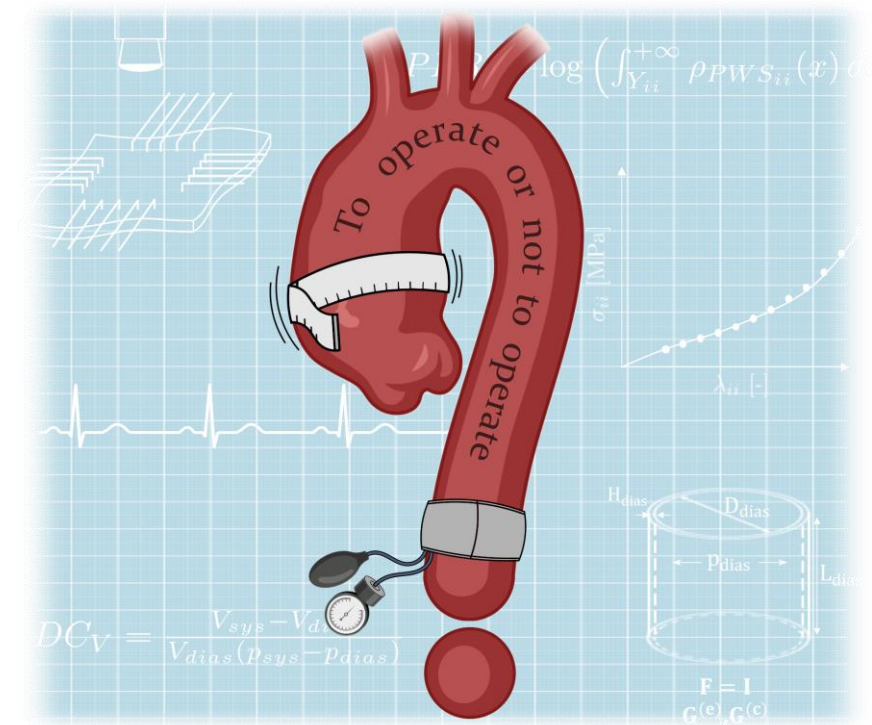
Shift to the Mechanics: Distensibility as a Predictor for Ascending Thoracic Aortic Aneurysm Failure

Nele Famaey¹, Klaas Vander Linden¹, Amber Hendrickx², Emma Vanderveken², Lucas Van Hoof², Steven Dymarkowski³, Filip Rega², Peter Verbrugge², Bart Meuris²

1. Division of Biomechanics, KU Leuven, Belgium

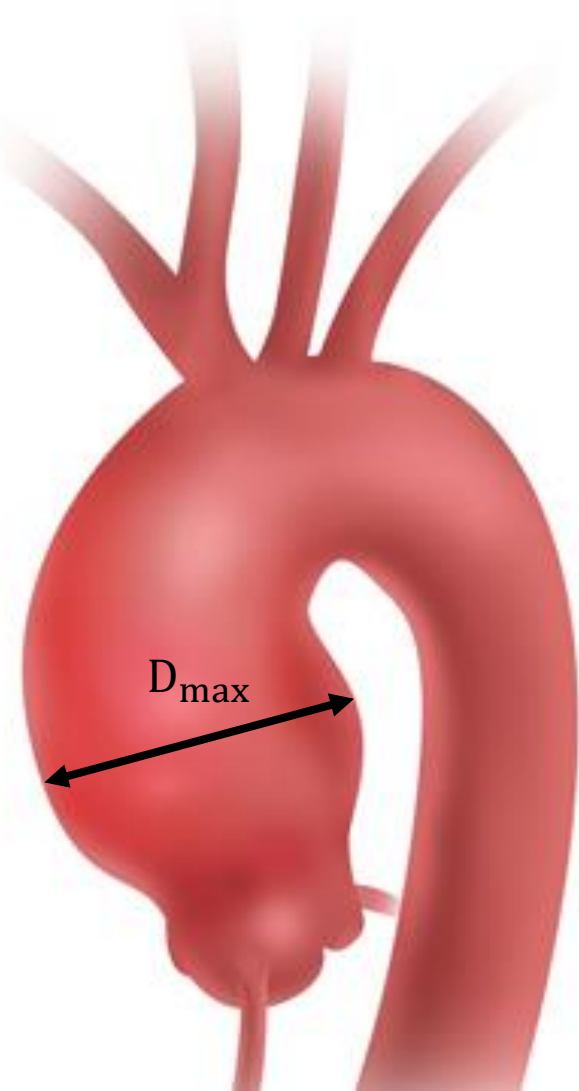
2. Cardiac Surgery, KU Leuven, Belgium

3. Department of Imaging & Pathology, UZ Leuven, Belgium



Shift to the mechanics:

Distensibility as a predictor for ascending thoracic aortic aneurysm failure



$$\text{Failure risk} = \frac{\text{Peak wall stress}}{\text{Wall strength}}$$



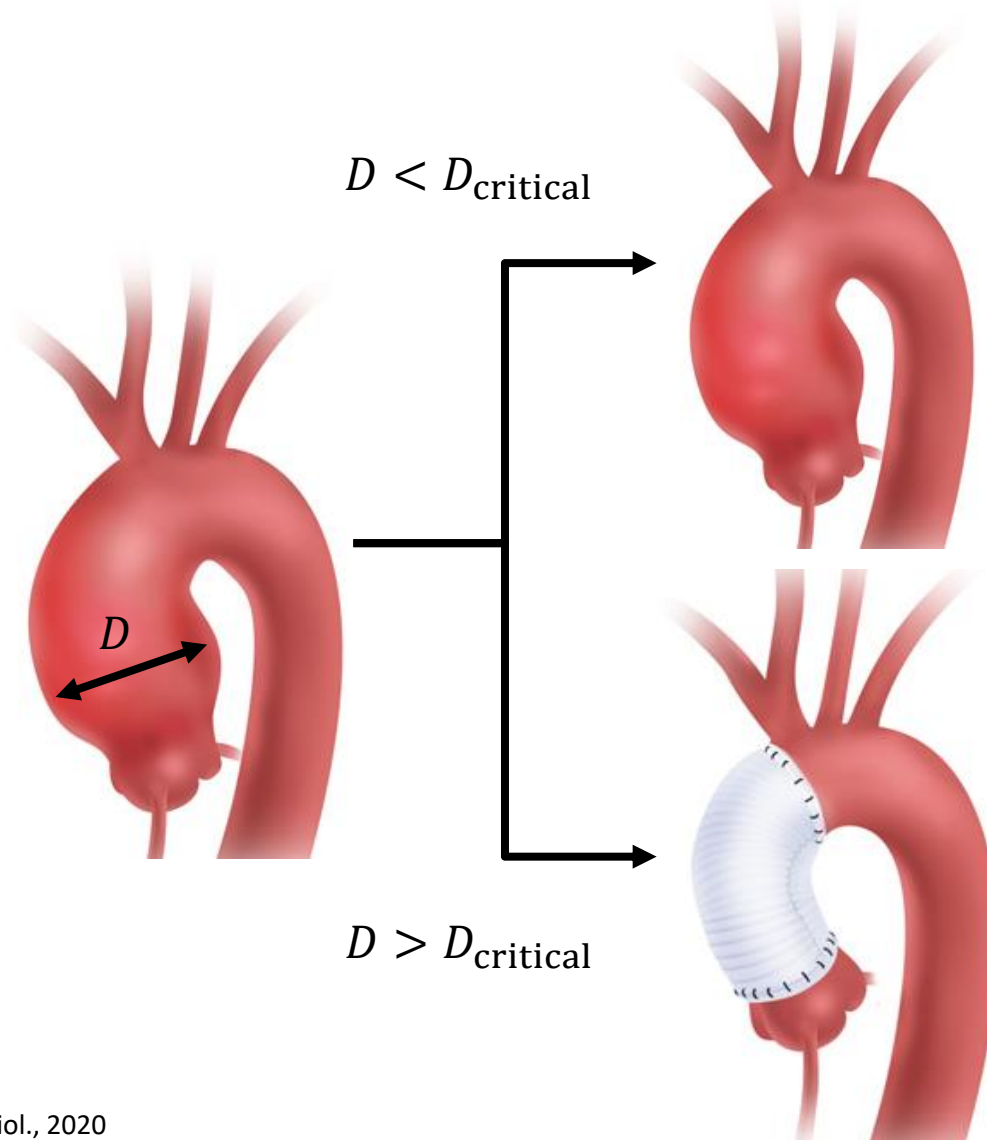
There are no direct biomarkers for stress and strength!



The maximum diameter is currently used as a predictor

Problem statement:

The diameter criterion is insufficient to reliably predict ATAA failure



Early aortic failure?

60% occur at $D < D_{critical}$



Shift critical threshold to the left?



Unnecessary open surgery?

Perioperative mortality: 3-7%

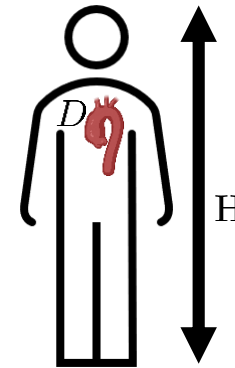
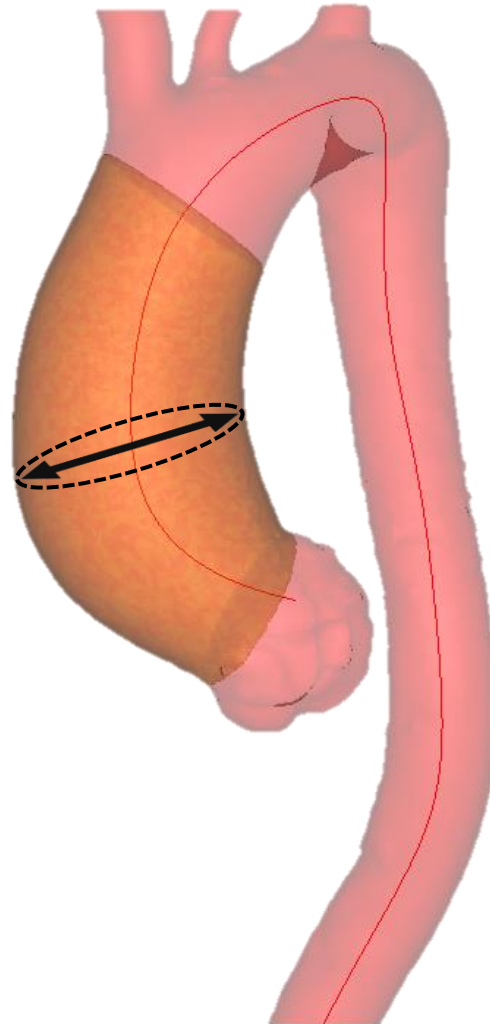
Cost: \pm €30 000

Study objective:

Evaluate various possible clinical predictors in terms of their correlation to the actual failure risk

Predictors from a non-triggered CT-scan:

Diameter: D

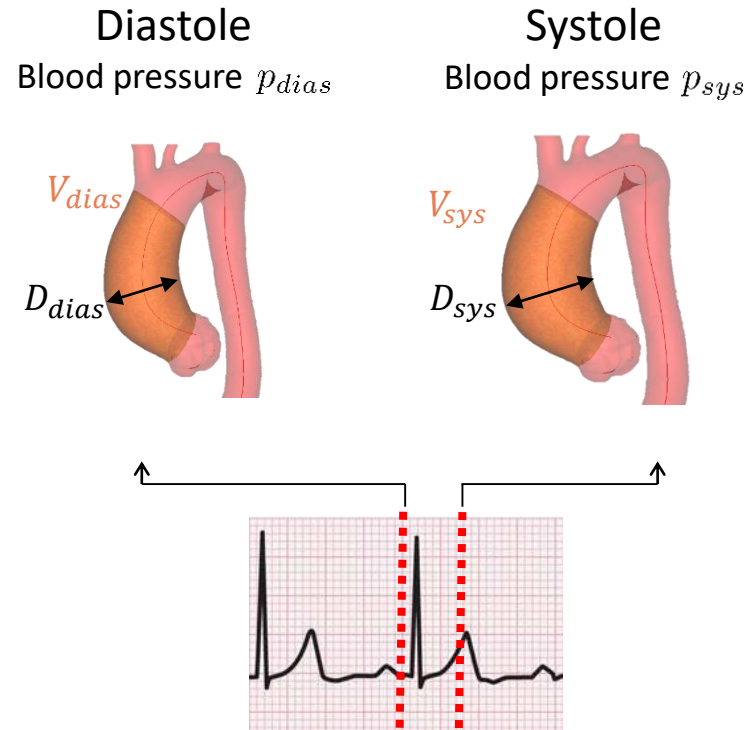


Aortic Height Index: $AHI = \frac{D}{H}$

Study objective:

Evaluate various possible clinical predictors in terms of their correlation to the actual failure risk

Predictors from a triggered CT-scan:



Area-based distensibility:

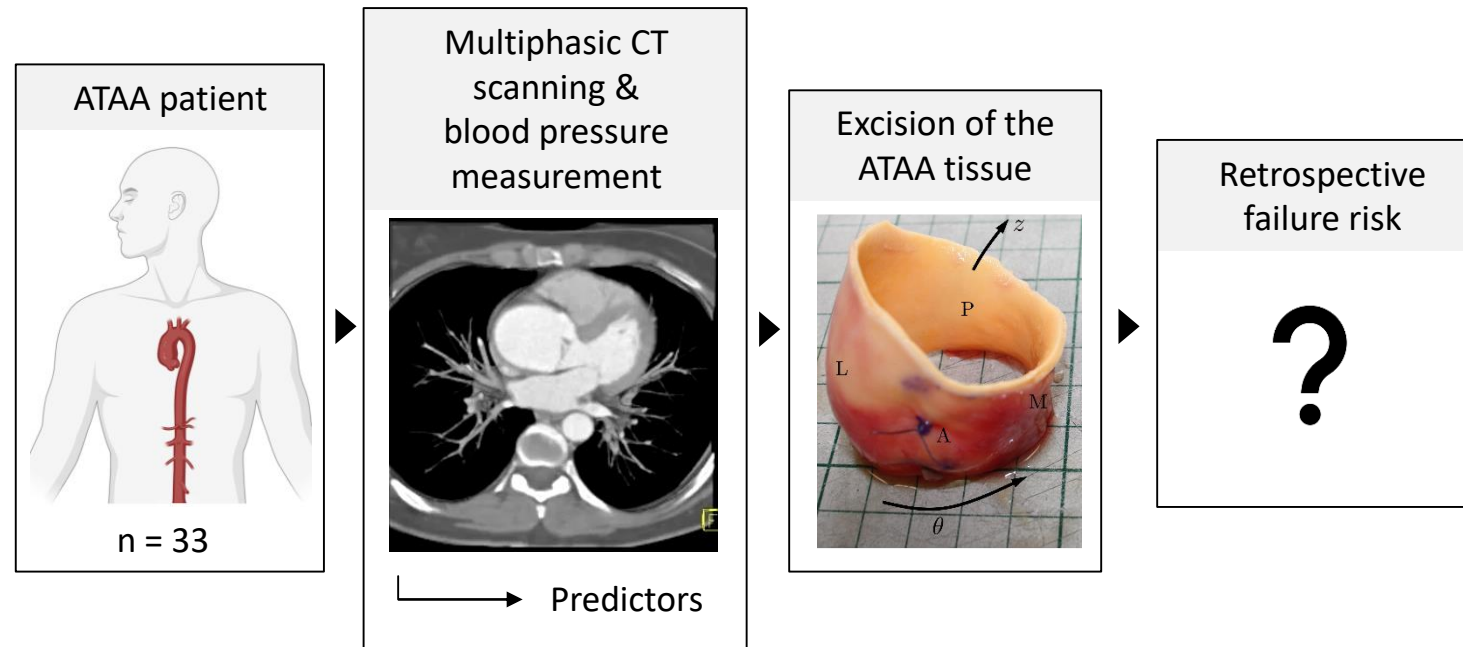
$$DC_A = \frac{D_{sys}^2 - D_{dias}^2}{D_{dias}^2 (p_{sys} - p_{dias})}$$

Volumetric distensibility:

$$DC_V = \frac{V_{sys} - V_{dias}}{V_{dias} (p_{sys} - p_{dias})}$$

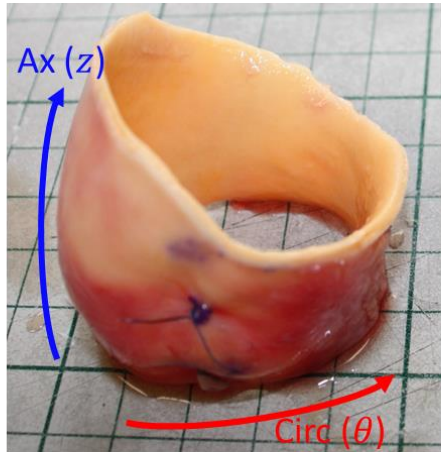
Materials & methods:

Retrospective analysis of failure risk through mechanical testing and computation

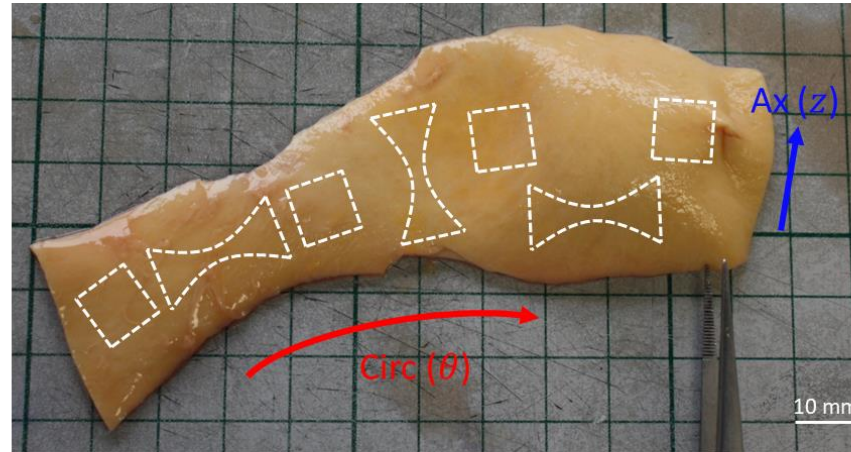


Materials & methods:

Performing tensile tests on aneurysm tissue

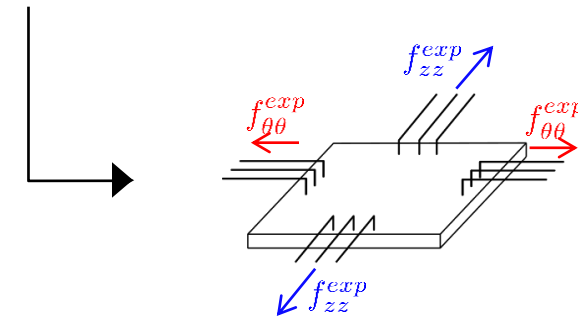


Load-free



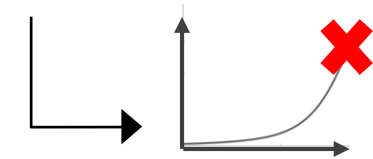
Stress-free

Squared samples for planar biaxial testing:



Material properties

Hourglass samples for uniaxial testing:



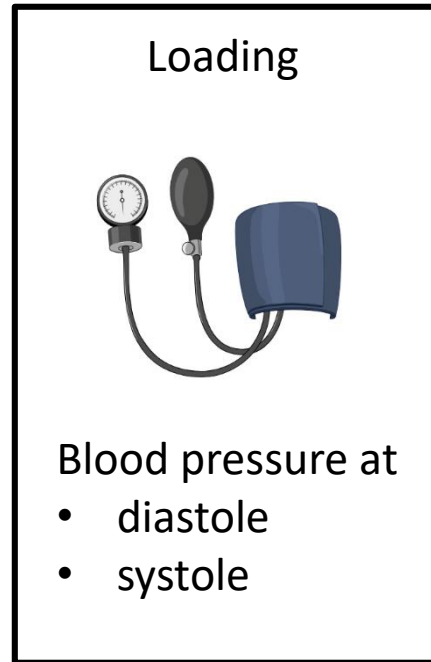
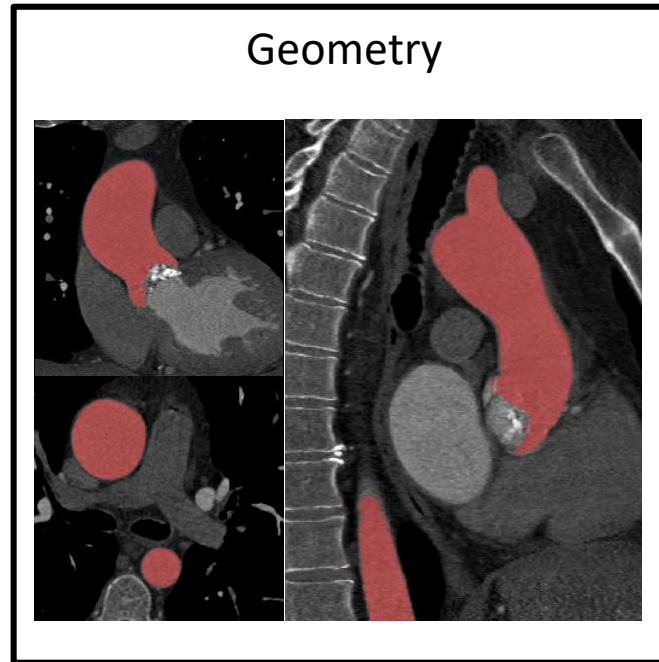
Wall strength



At KU Leuven Core Facility for Biomechanical Experimentation

Materials & methods:

Calculating the peak wall stress



Material properties

$$\Psi_{elastin} = C_{10}(I_1 - 3)$$

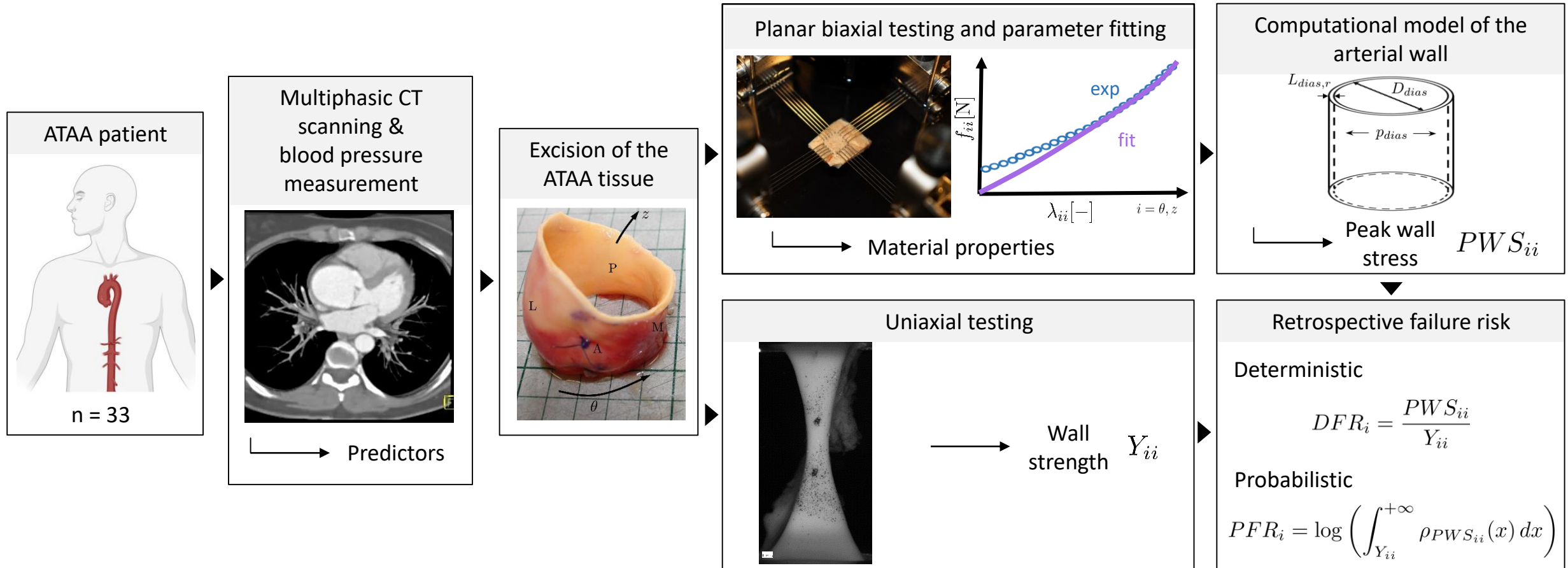
$$\Psi_{collagen} = \frac{k_1}{2k_2}(\exp(k_2(E_i - 1)^2) - 1)$$

Computational model

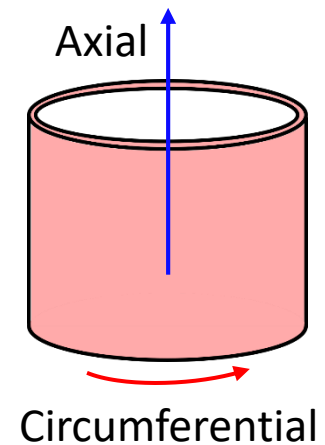
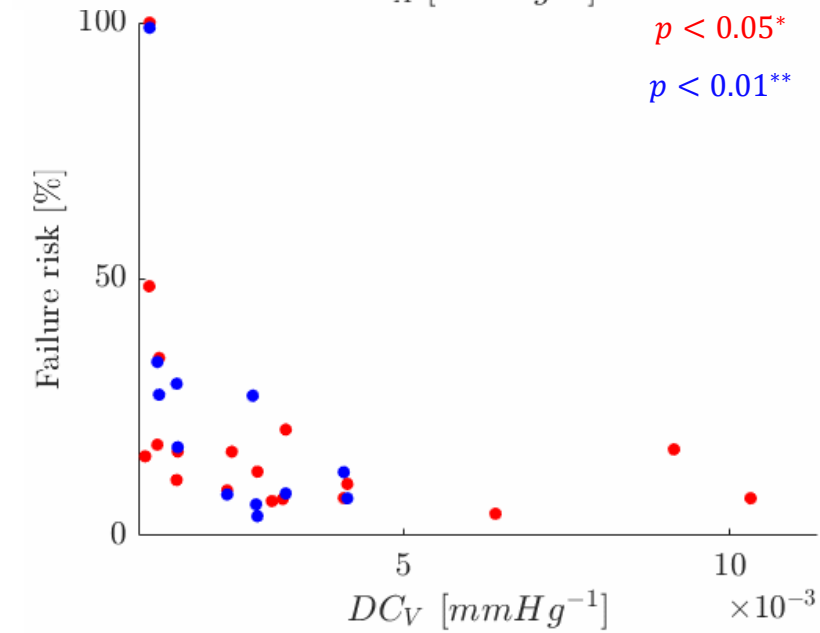
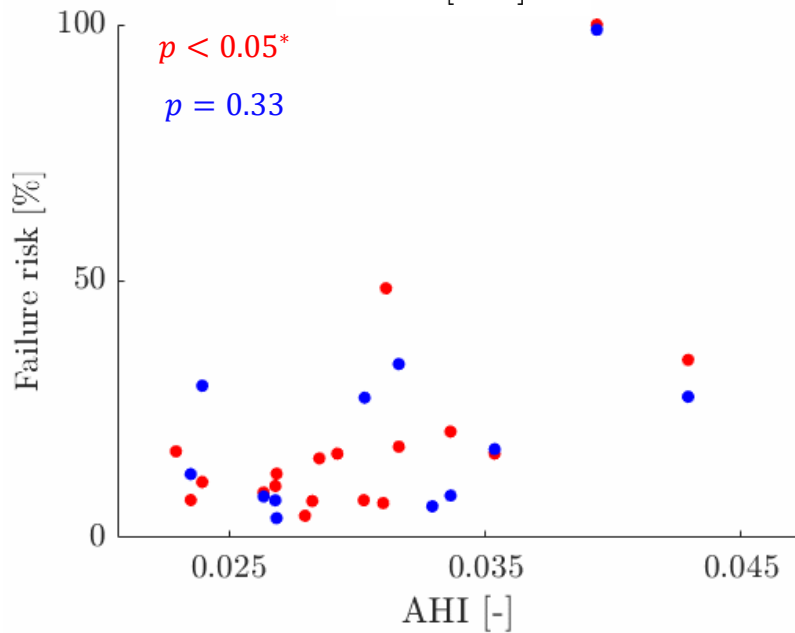
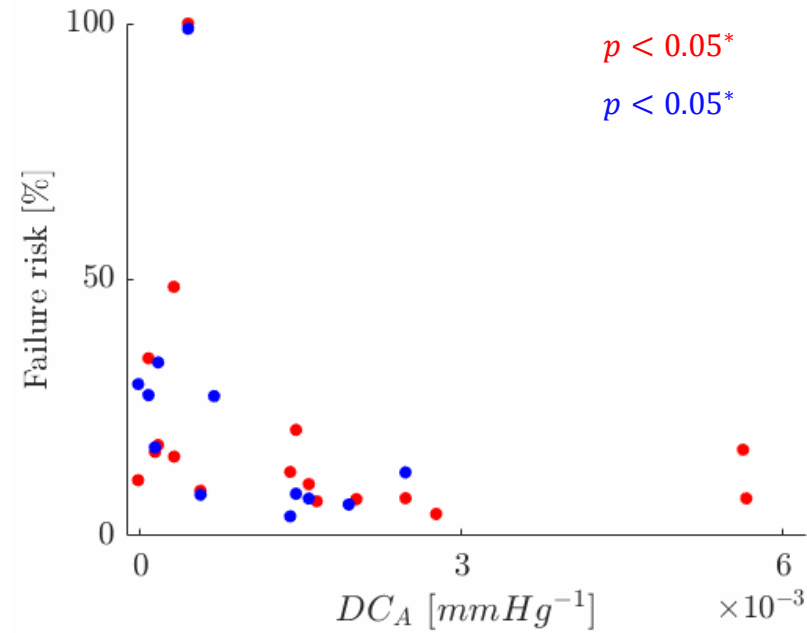
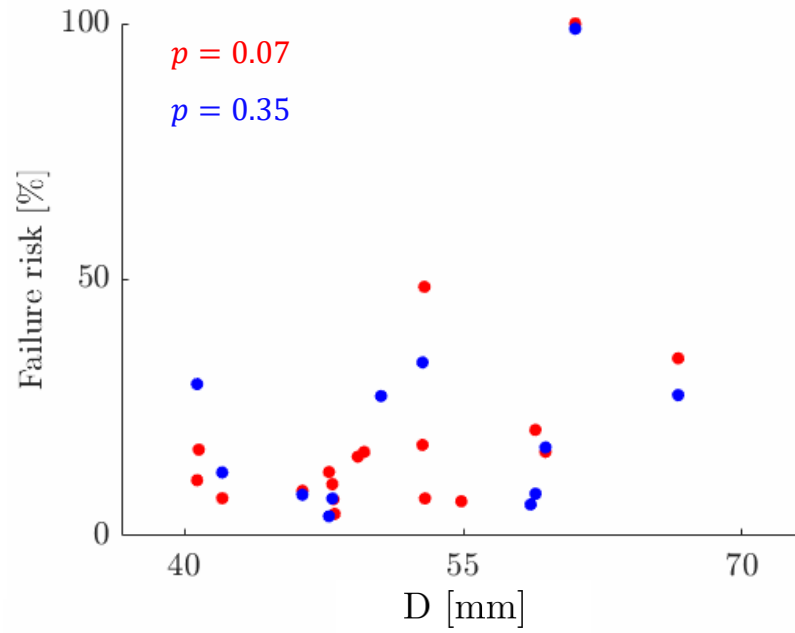
Peak wall stress

Materials & methods:

Retrospective analysis of failure risk through mechanical testing and computation



Results: Retrospective failure risk versus clinical predictors

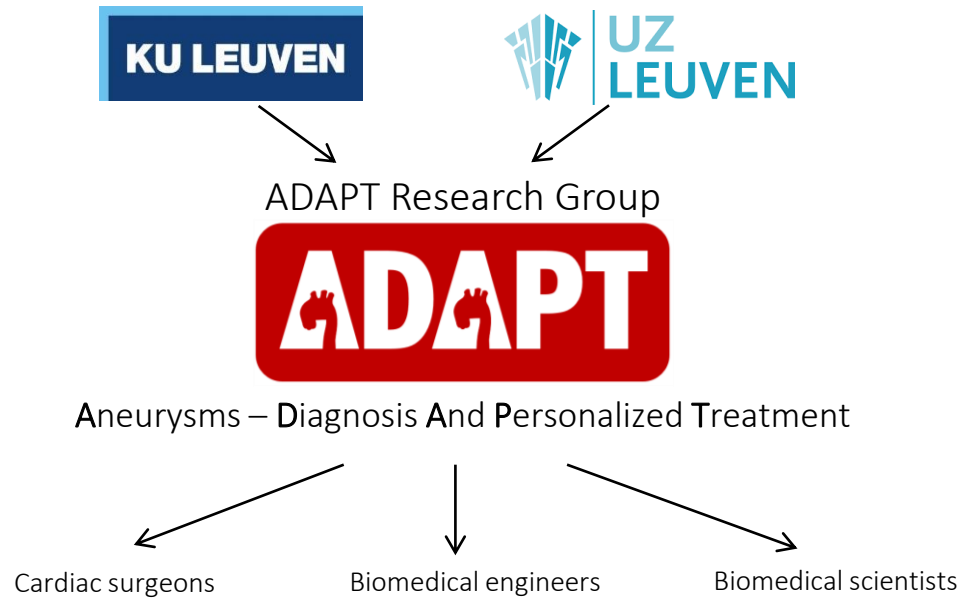


Conclusion

- Mechanical predictors >> Purely geometrical predictors
 - Include multiphasic CT scans in clinical workflow
- Volumetric distensibility (DC_V) also accounts for the axial deformation

Perspective

- Extend database of retrospective cases
- Build population database of DC_V values
- Find consensus on the critical DC_V threshold



Disclosure


C2 project (ZKD1128-00-W01) of the KU Leuven


Two doctoral grants strategic basic research (SB 1S56317N; SB 1SA9119N) and a postdoctoral fellowship (PD0/012) of the Research Foundation Flanders (FWO)




Acknowledgements

- Vastmans Julie
- Fehervary Heleen
- Peeters Liselotte
- Snoeck Ruben
- Kimberly Crevits
- Silke Peeters

 <https://www.linkedin.com/company/soft-tissue-biomechanics-ku-leuven/>

 Nele.Famaey@kuleuven.be

 <https://www.mech.kuleuven.be/en/bme/research/soft-tissue-biomechanics>