Protective Biomechanical and Histological Changes in the False Lumen Wall in Chronic Type B Aortic Dissection

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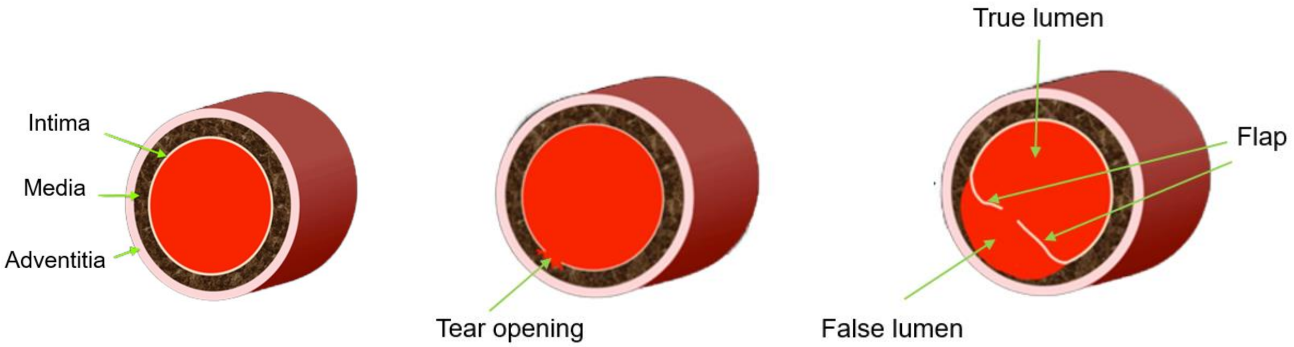
Background

- **Aortic dissection**

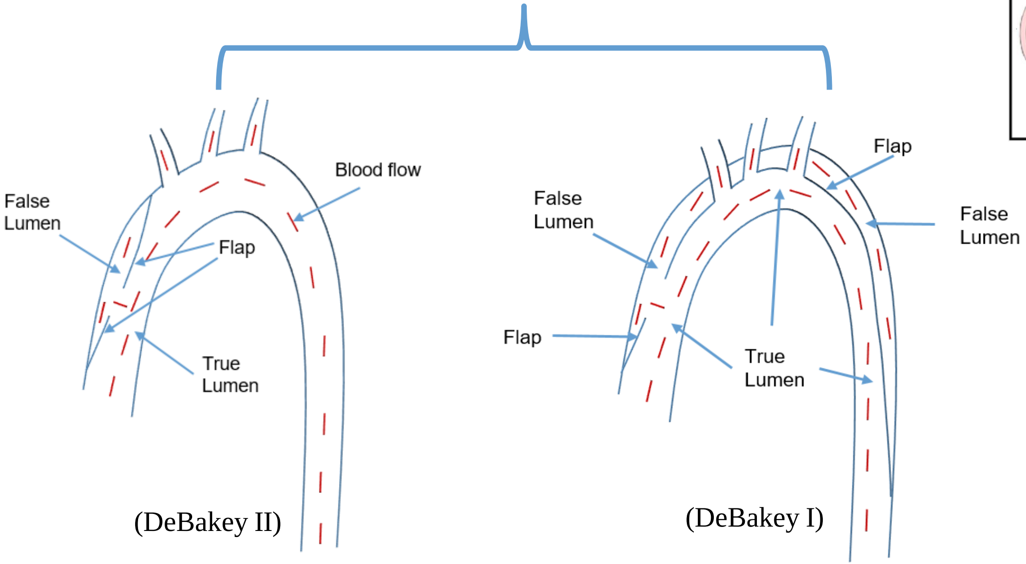
A tear occurs in the inner layer of aorta. Blood rushes through the tear, causing the intima/media (or media/adventitia) layers of the aorta to split (dissect).

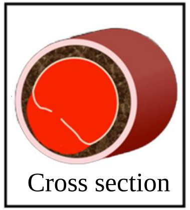


Aortic dissection could be deadly in case of aortic rupture.

Background

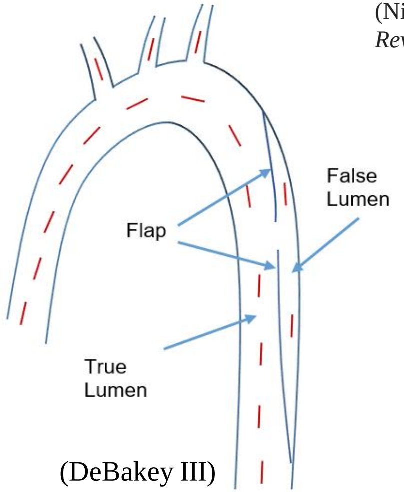
Stanford Type A





Stanford Type B

(Nienaber, et al. *Nature Reviews D. P.*, 2016)



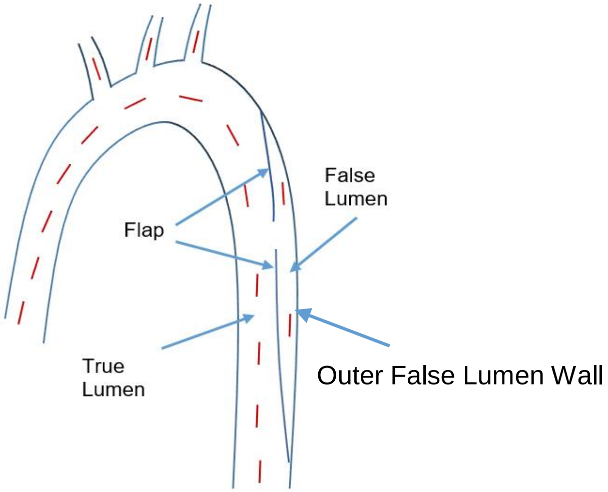
Emergent open aorta surgery

Complicated → TEVAR (Thoracic endovascular aortic repair)

Uncomplicated → Optimal medical therapy (Chronic phase)

Motivation and Objective

Stanford Type B



Complicated → TEVAR

Uncomplicated → Optimal medical therapy

(Chronic phase)

Motivation

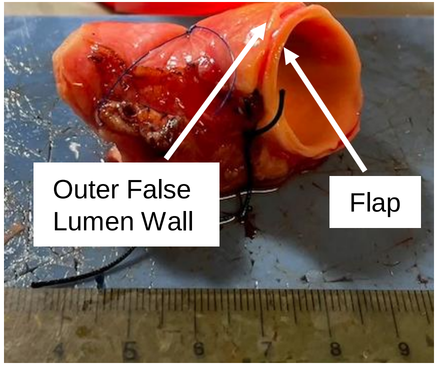
- The outer false lumen wall (FLW), with only partial thickness, undertakes the major loading of the false lumen
- It plays a key role in preventing rupture of chronic Type B aortic dissection
- The biomechanical property is important for estimating the wall stress and rupture risk

Objective:

To investigate the biomechanical stiffness and histological changes of the outer false lumen wall in chronic Type B aortic dissection

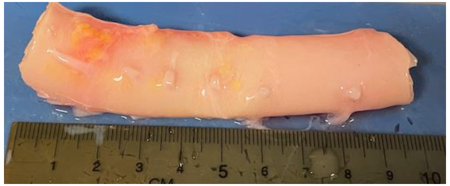
Methods - Tissues collection (n=30)

- Chronic Type B (n=10)

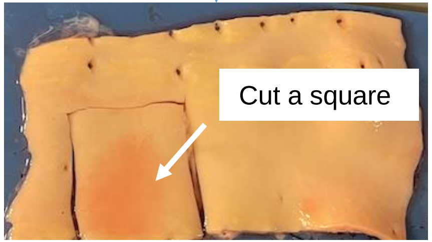


Cut open and take the chronic outer false lumen wall (FLW) for testing

- Normal descending aorta (n=10)
  (Control: simulation of acute Type B)

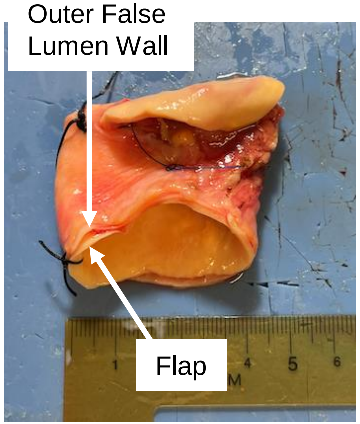


Cut it open



Peel the square sample into two layers and use the outer layer to simulate the acute FLW

- Acute Type A (n=10)

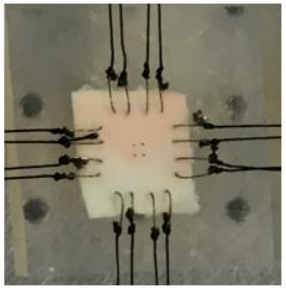


Cut open and take the acute outer FLW for testing

Methods – Biomechanical testing

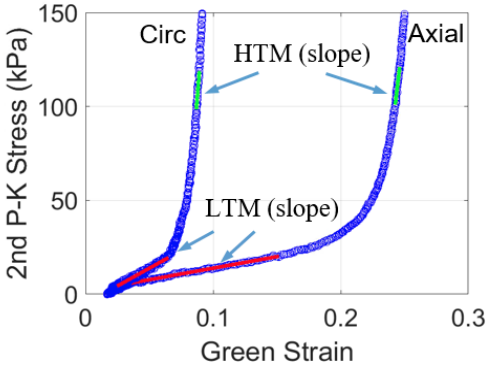
- Biaxial tension testing

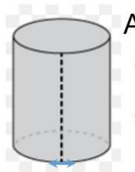
~2*2 cm



Biaxial tension testing in the circumferential (Circ) and axial directions was performed for each sample.

- Stress-strain curves

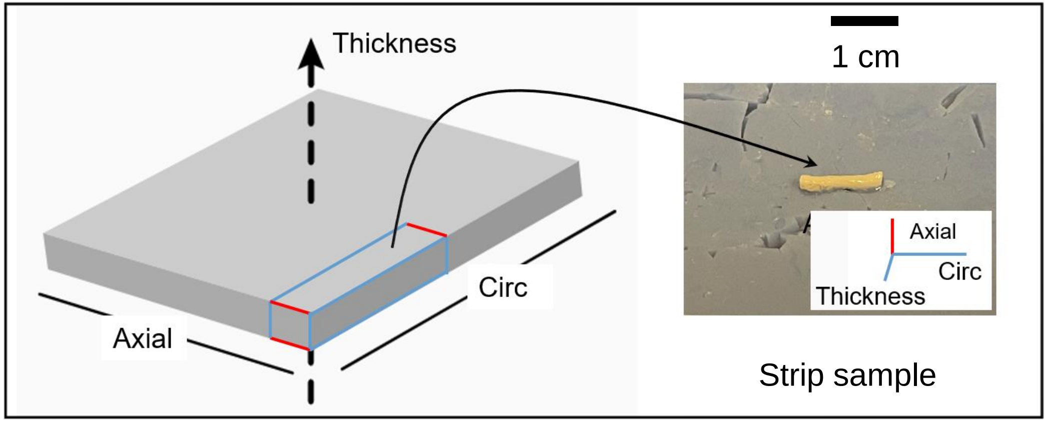




Stress-strain curves were obtained; a lower and higher tangent modulus (LTM & HTM) was determined for each sample to assess tissue stiffness.

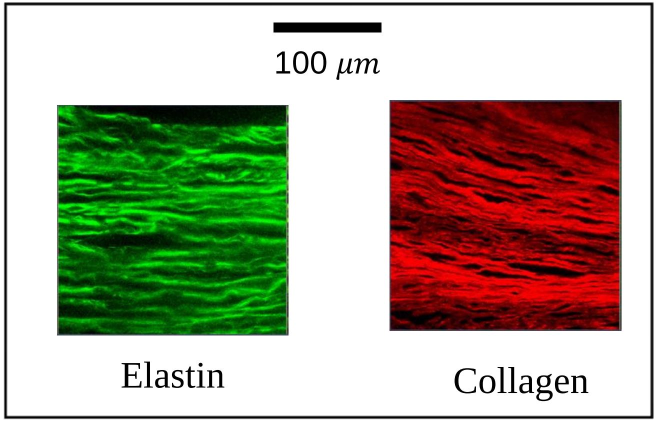
Methods – Histological analysis

- Sample preparation



From Microscopy

- Images of elastin and collagen fibers

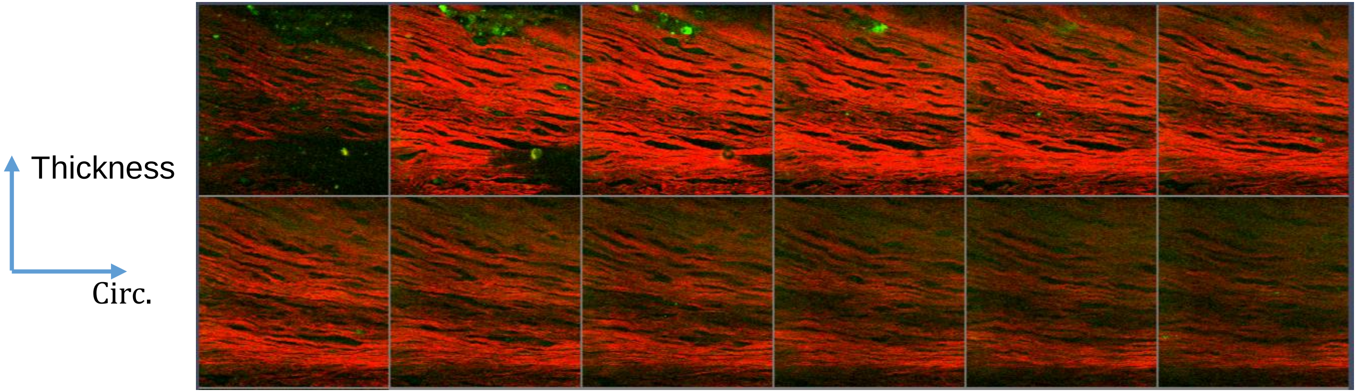


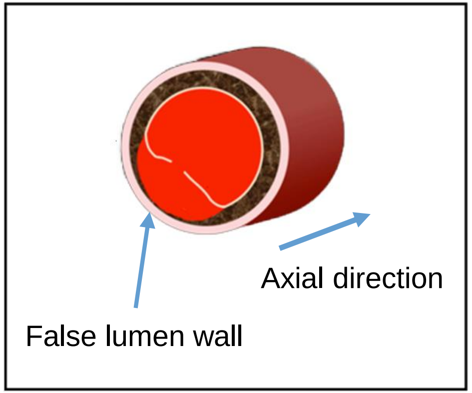
A histological analysis of the tissue microstructure was performed on the collagen and elastin fibers, using second harmonic generation (SHG) microscopy (Zeiss 710 NLO).

Methods – Histological analysis

- Volume fraction (VF) of the fibers based on Z-Stack scans

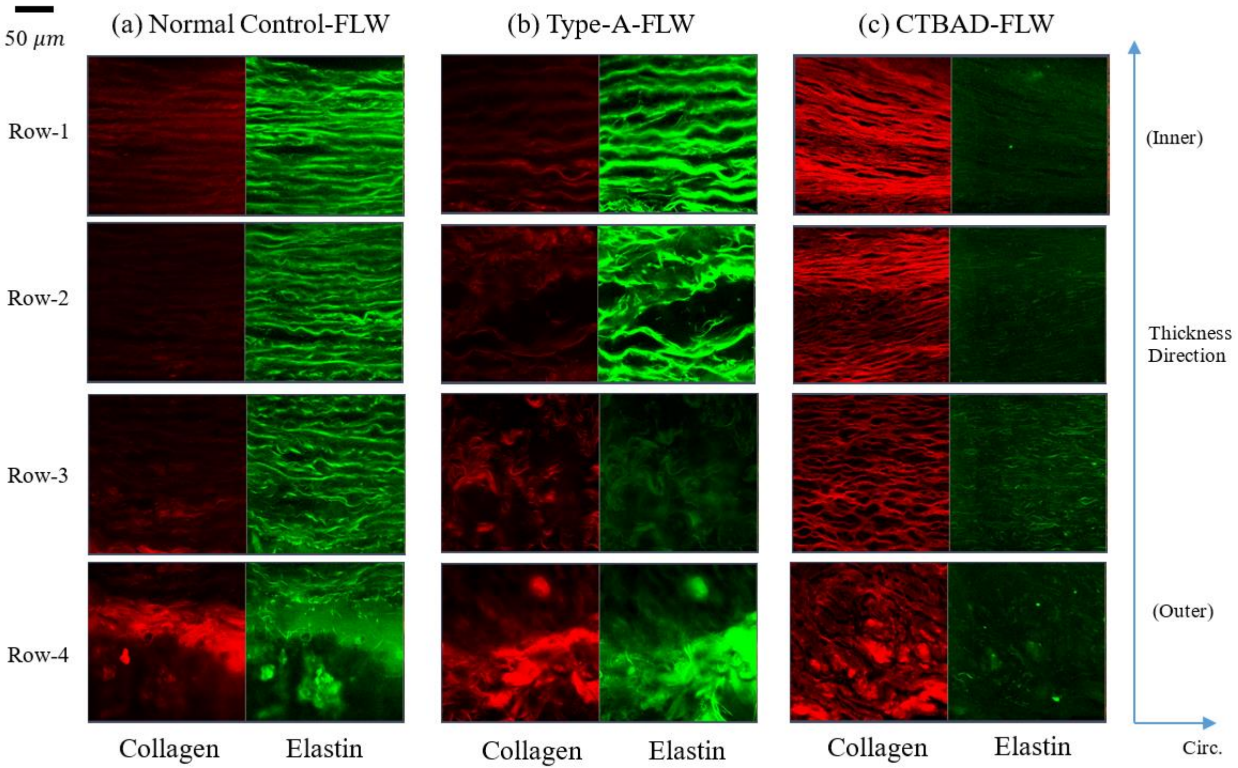
$$\mathrm{VF} = \frac{V_{\text{fiber}}}{V_{\text{total}}} = \frac{\sum_{i=1}^{N} A_{\text{fiber}} \cdot L_{\text{step}}}{A_{\text{total}} \cdot L_{\text{total}}}$$



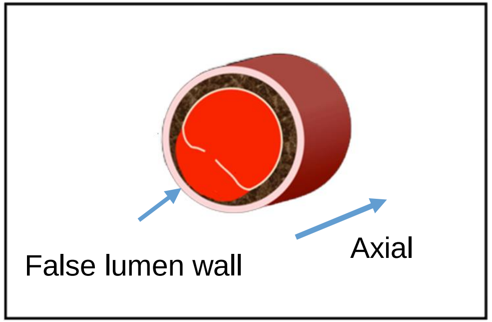


Z-Stack scans with 5 um step in axial direction

Results – Histology

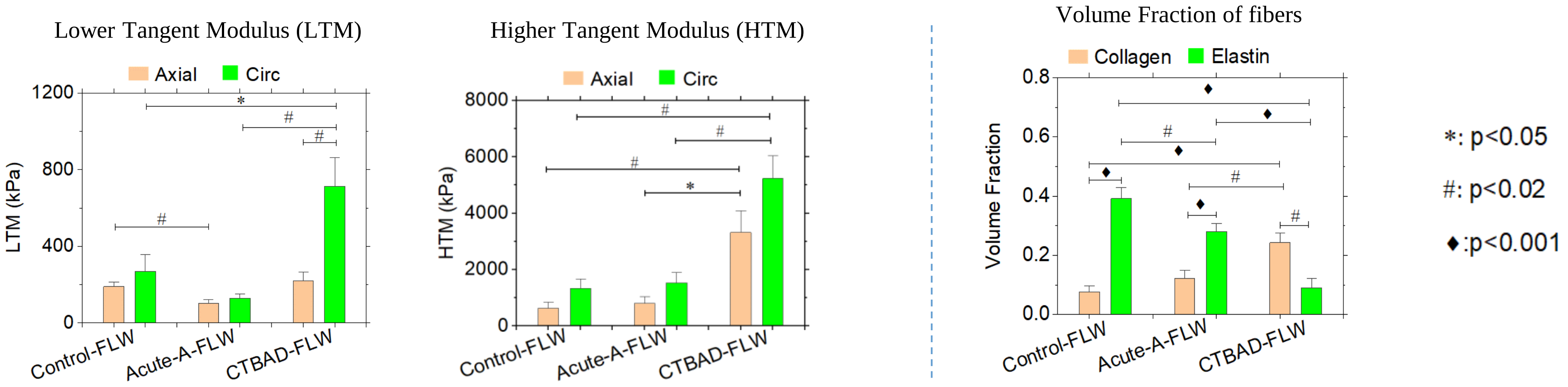


- Row 1-3: Media layer
- Row 4: Adventitia layer



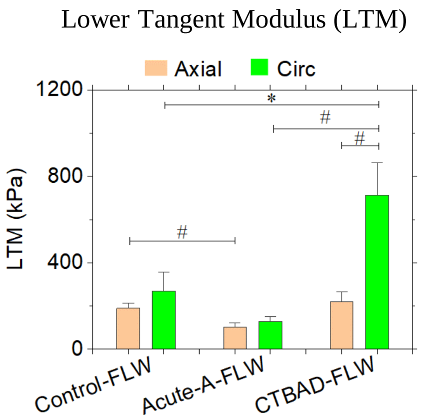
More collagen and less elastin in CTBAD-FLW vs. Control-FLW & Acute-A-FLW

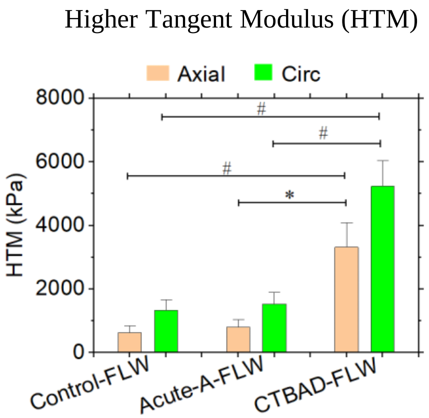
Results

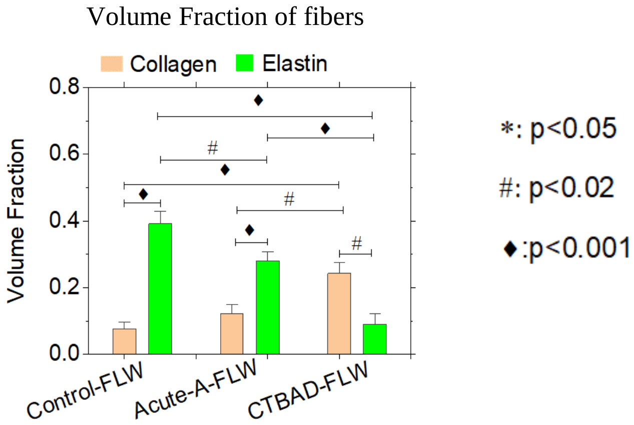


- Stiffness
  - CTBAD-FLW is stiffer than Control-FLW & Acute-A-FLW (both LTM & HTM)
  - Control-FLW vs. Acute-A-FLW: axial LTM is slightly smaller; not much different for HTM
- Volume Fraction of fibers
  - More collagen and less elastin in CTBAD-FLW vs. Control-FLW & Acute-A-FLW
  - Control-FLW & Acute-A-FLW: elastin fraction is larger than collagen fraction

Results – Stiffness and Volume fraction







CTBAD-FLW is stiffer than Control-FLW & Acute-A-FLW

More collagen and less elastin in CTBAD-FLW

Stress in the outer false lumen wall expects to increase after dissection, which may be the driven effect for the stiffness and histological changes

Summary

- We obtained the stiffness and microstructures of false lumen wall (FLW) in chronic Type B dissection, acute Type A dissection and norm tissues
- Stiffness increases in CTBAD-FLW vs. Control-FLW & Acute-A-FLW
- More collagen and less elastin in CTBAD-FLW vs. Control-FLW & Acute-A-FLW which explains the stiffness increase

The change in the composition of false lumen wall may be a protective adaption to prevent aortic rupture and explains the importance of the false lumen wall in the surgical repair of aortic dissection.

Thank you!