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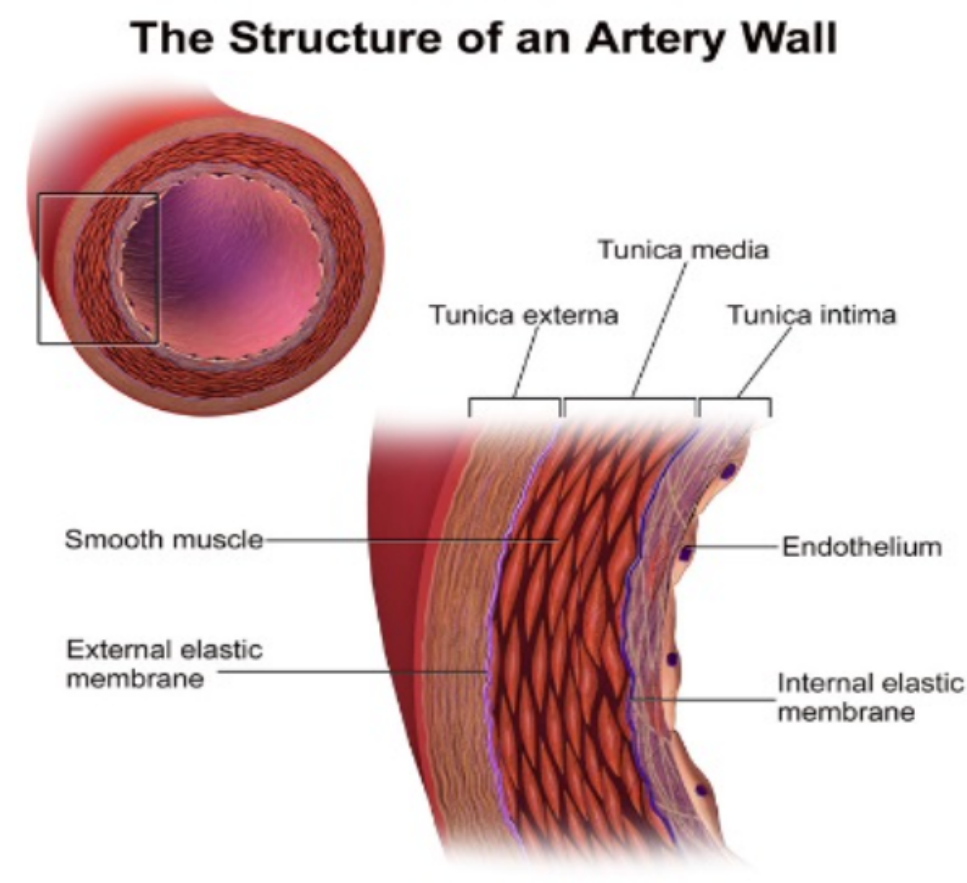
MOUSE ARTERIAL WALL IMAGING AND ANALYSIS FROM SYNCHROTRON X-RAY MICROTOMOGRAPHY

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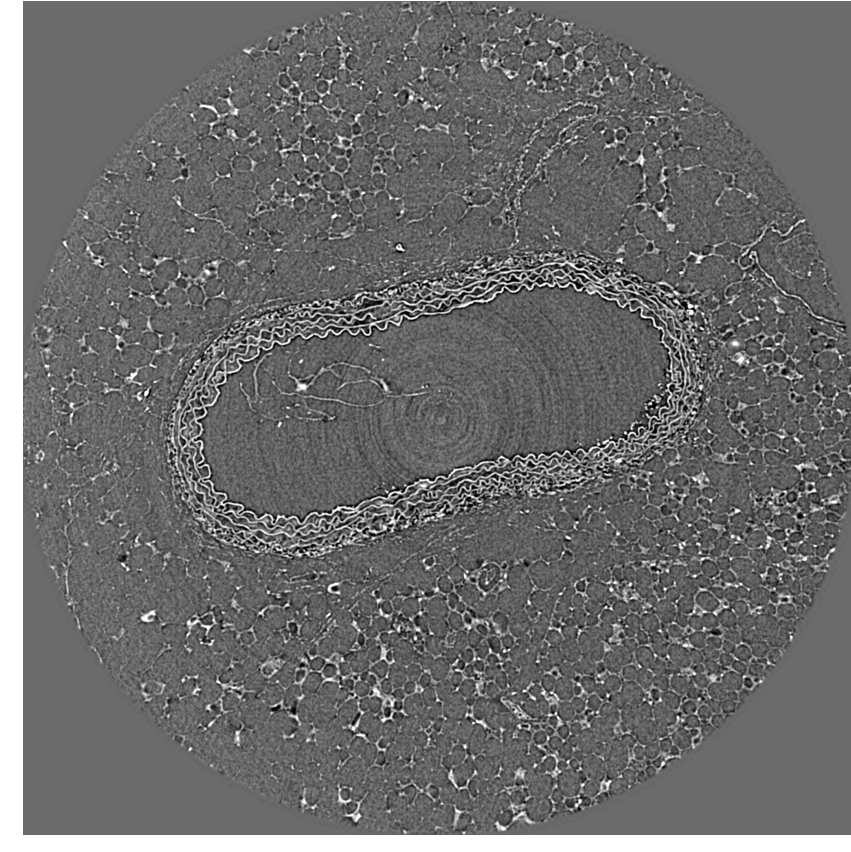
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CONTEXT



Cross section of artery (source: Blausen medical)



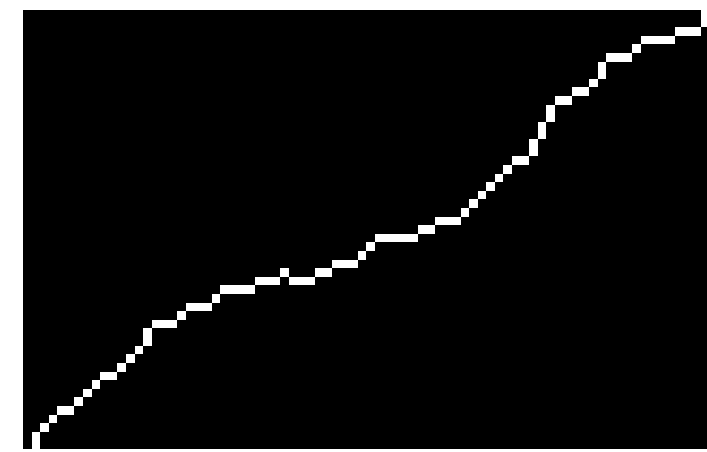
A frame of acquired images

Vascular ageing is characterized by profound modifications of the large elastic arteries (mainly aorta), leading to consequences such as aneurysm formation. Age-related diseases can be precipitated by metabolic disorders, e.g. diabetes or chronic kidney diseases. Vascular diseases involve morphological changes of the arterial extracellular matrix, particularly remodelling of the elastic lamellae found in the wall. Synchrotron X-ray microtomography (μCT) gives access to images with a micrometric resolution.

A 2D FRAGMENT ANALYSIS

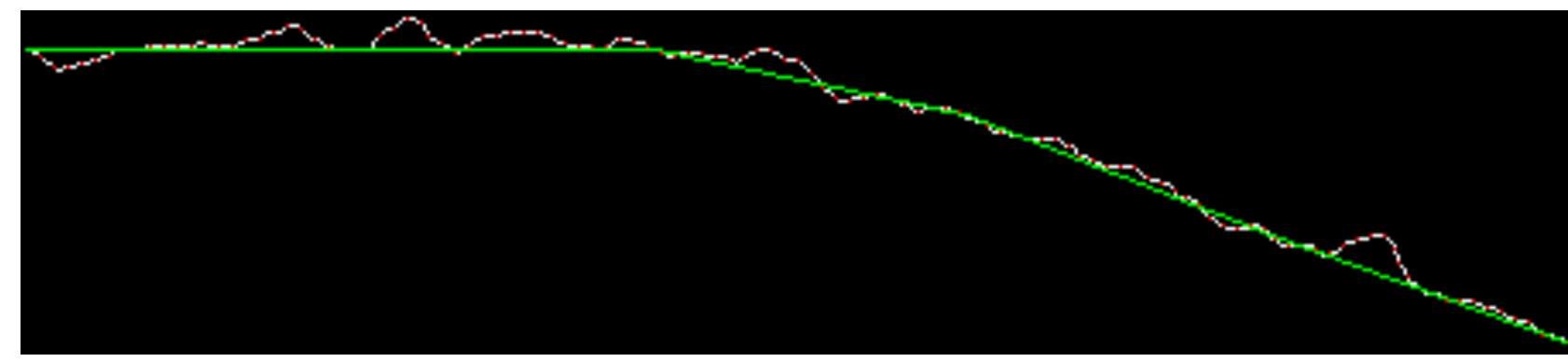


Normal mouse



Diabetic mouse

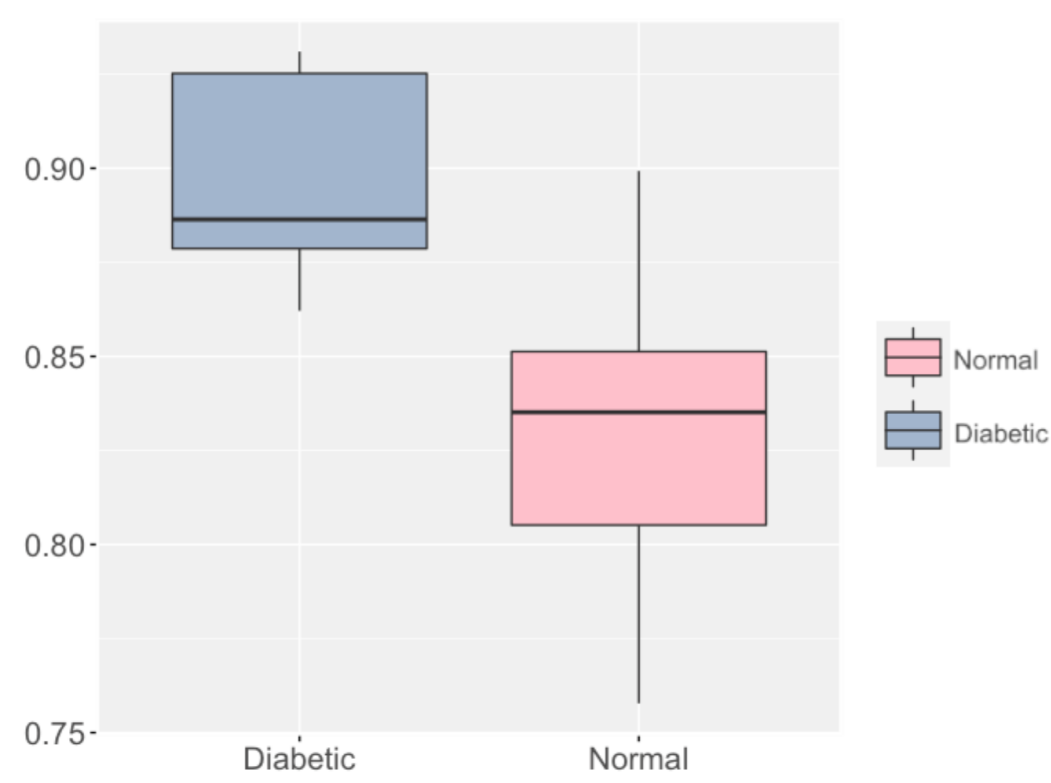
Mice are divided into 2 groups (normal and diabetic). A measurement is proposed to quantify their waviness.



$$\rho = \frac{L_{Euc}}{L_{Geo}}$$

$L_{Geo} = \sum_{0 \leq i < k} \|V_{g_{i+1}} - V_{g_i}\|_2$, k : number of pixels, V_i : vertices of curve

$L_{Euc} = \sum_{0 \leq j < L_{Geo}/\sigma, (j+1)\sigma \leq L_{Geo}} \|V_{e_{(j+1)\sigma}} - V_{e_{j\sigma}}\|_2$, σ : sampling rate of L_{Geo} , j : subsampled indices

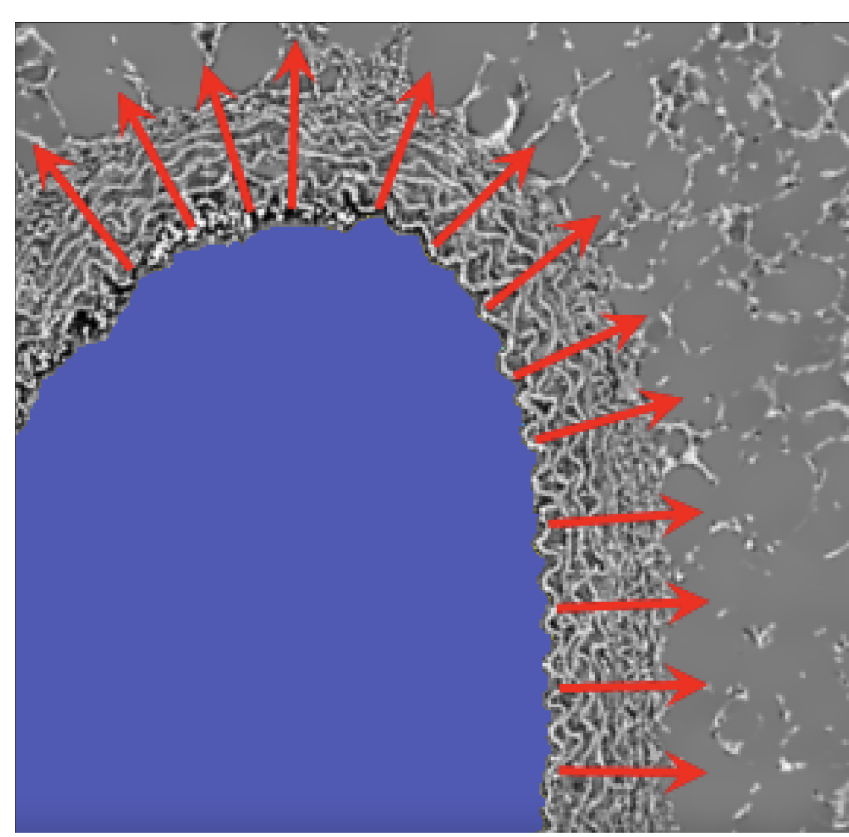


21 samples, 2000 ~ 3000 fragments for each sample

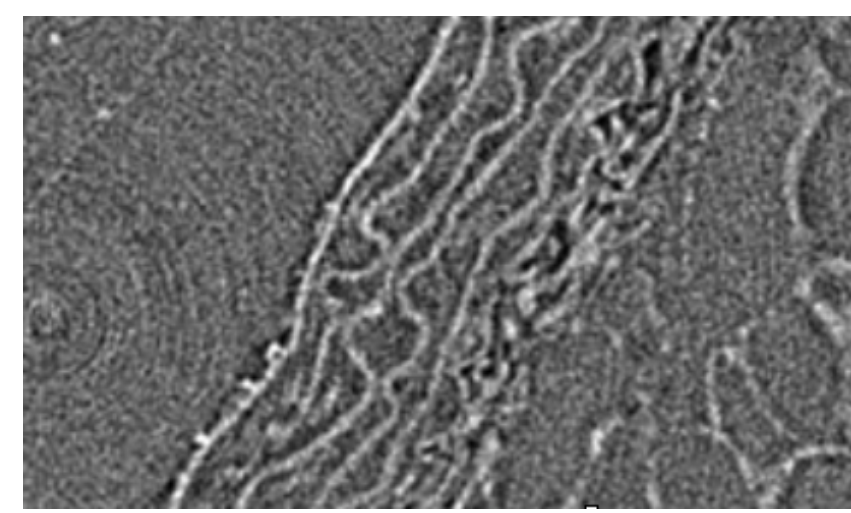
Mann-Whitney U test :
 p -value = 0.0035 \ll 0.05

A significant difference between healthy and diabetic mice in terms of elastic lamellae waviness. (Ben Zemzem A., Liang X. *et al.*, *Int. J. Mol. Sci.* **2022**)

A 2D SEGMENTATION

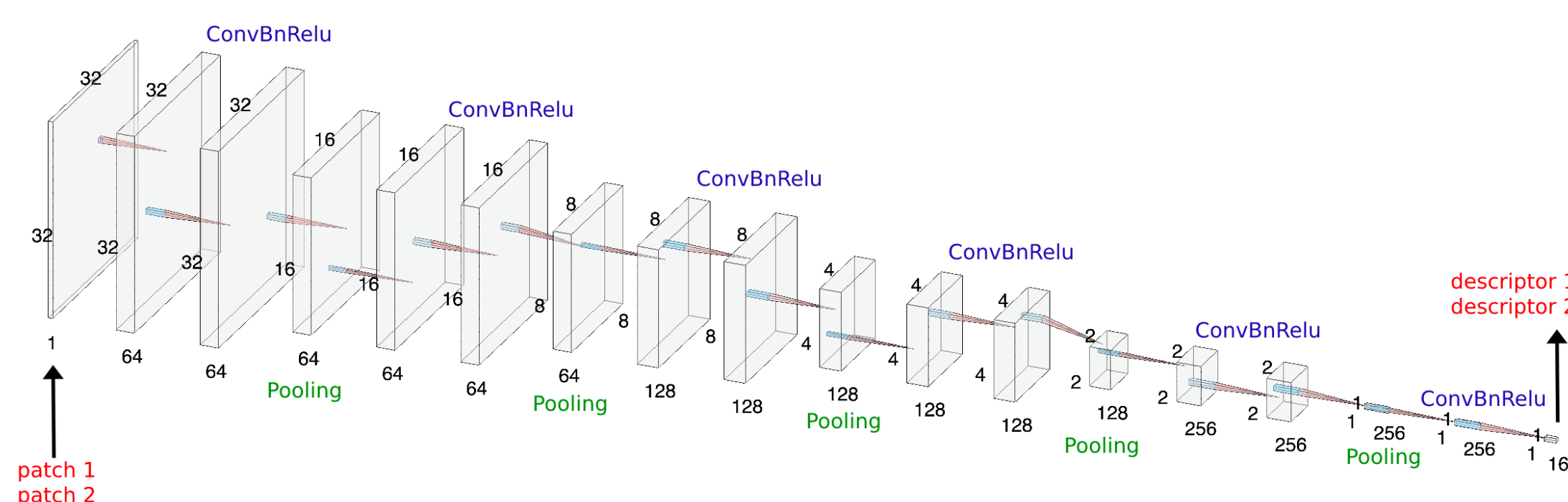


Segmented lumen and normal vectors



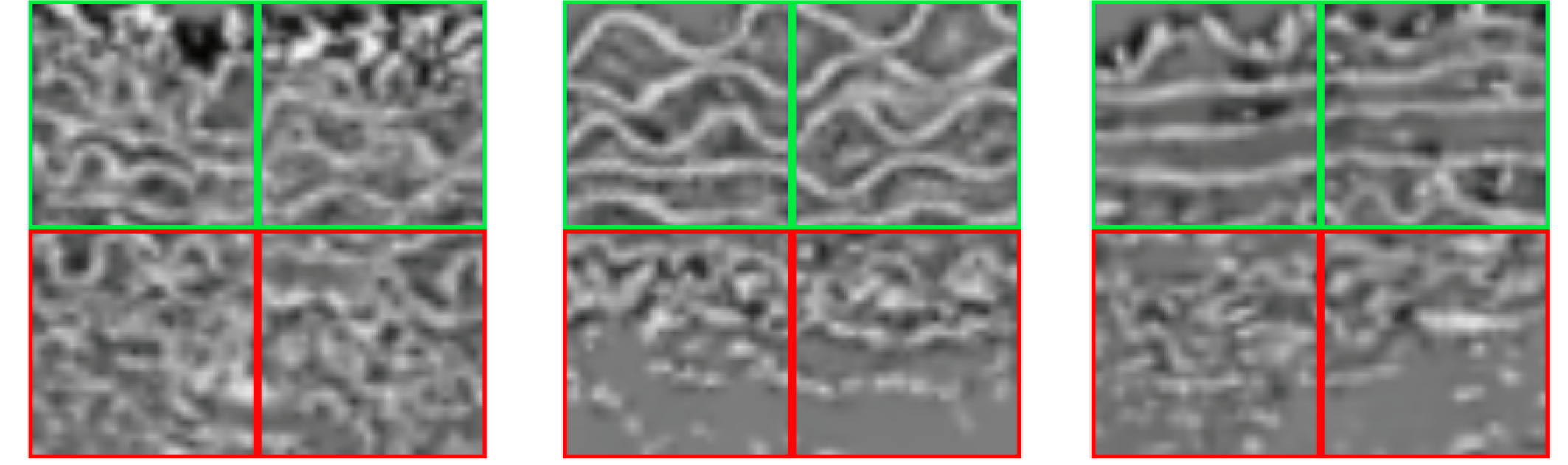
Border of tunica media and adventitia

- ▶ The lumen is segmented by a method based on co-occurrence matrix and region growing
- ▶ Normal vectors are calculated at each point of the inner contour
- ▶ The border between *tunica media* and *adventitia* is not clear



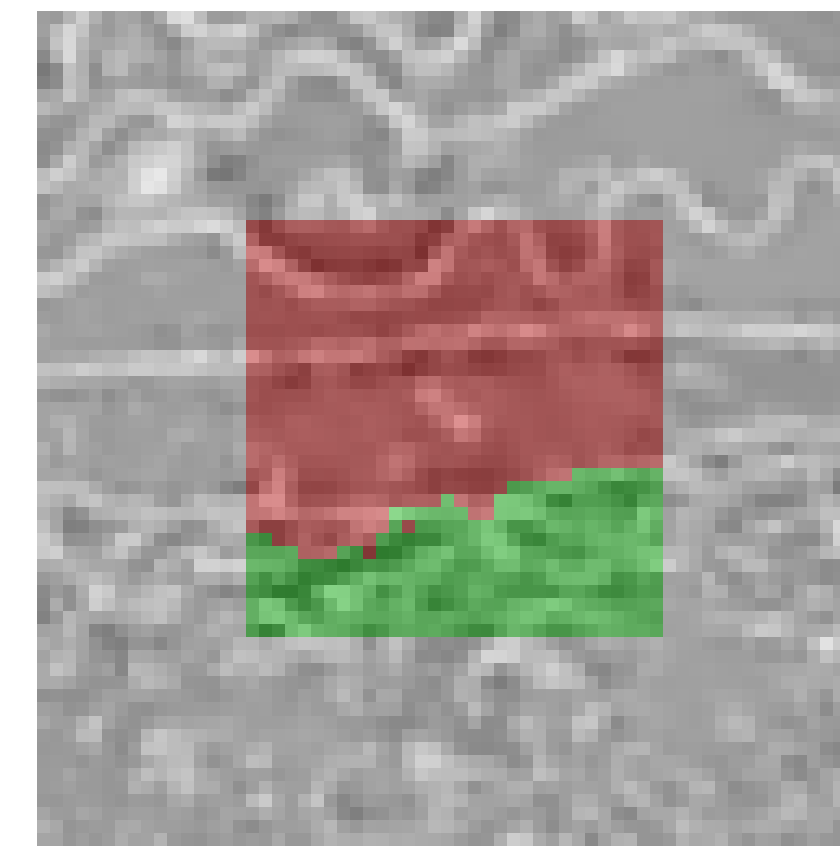
A Siamese network is used to distinguish 2 types of textures. The similarity of input patches is measured by that of the output descriptors.

▶ Loss function: $\mathcal{L}(d_{ij}, d_{kl}) = \alpha \cdot \delta_{ik} \cdot \Delta^T \cdot \Delta + \beta \cdot (1 - \delta_{ik}) \cdot [\max\{0, m_p - (\Delta^T \cdot \Delta)^{1/2}\}]^2$,
 $\Delta = d_{ij} - d_{kl}$, $\alpha = 2$, $\beta = 1$, $m_p = 2$

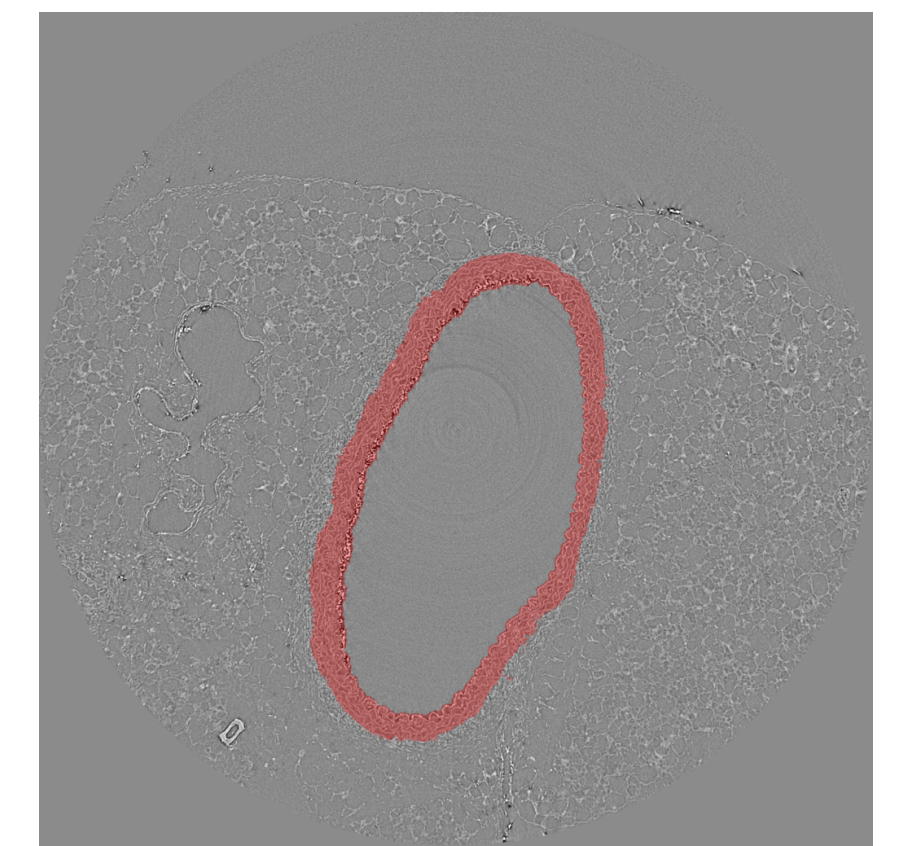


Training samples are obtained from patches oriented with the help of normal vectors. Each time a pair of sub-patches is an input, with "green-green" labeled as 1, "green-red" labeled as 0.

▶ Dataset: 47118 image patches of size 64^2 generated by 1457 2D slices

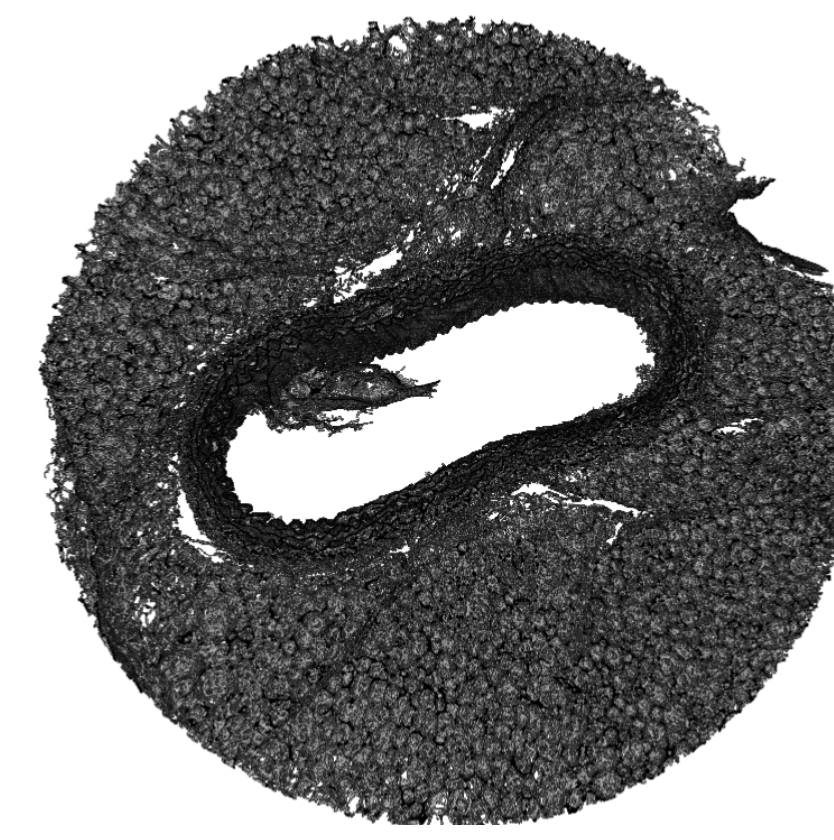


Prediction on a patch

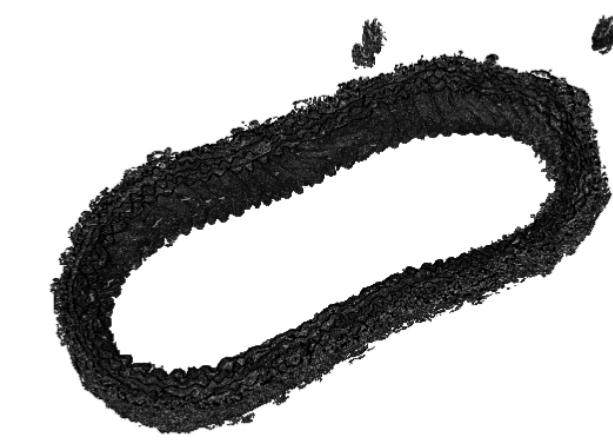


Prediction on an entire image

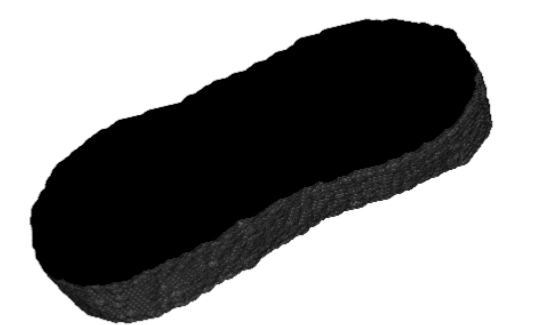
A 3D SEGMENTATION



3D image with agarose

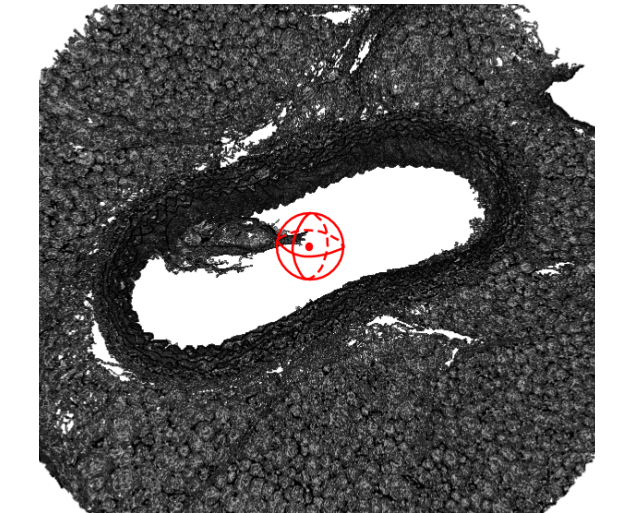


Extracted elastic lamellae



Extracted lumen

- ▶ The elastic lamellae and the lumen are extracted by moving spheres
- ▶ For elastic lamellae extraction, use a single sphere to count the number of inner pixels
- ▶ For lumen extraction, use 3 concentric spheres to count the number of pixels between each 2 neighboring spheres



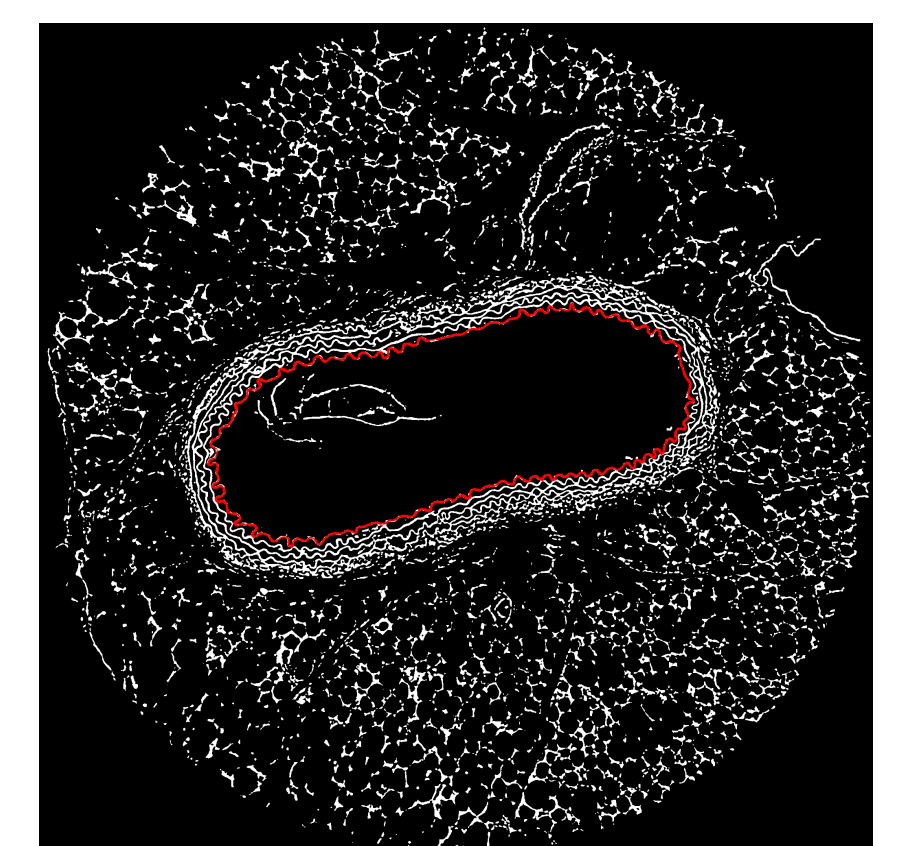
- ▶ Straighten a stack of 2D images
- ▶ Extract the upper space by region growing
- ▶ Reject regions that are erroneously spread (green) by comparing their "weights" and their connections to the upper space



- ▶ With the upper space extracted, the first elastic lamella is the boundary between this space and the rest of the background



The first elastic lamella in its initial shape



2D frame with the first lamella marked

CURRENT WORK

- ▶ Extend the 2D segmentation approach to 3D to distinguish *tunica media* and *adventitia* in 3D
- ▶ With the segmented region of elastic lamellae in 3D, segment the other 4 layers of them
- ▶ Extend the 2D waviness analysis to 3D and apply it to 5 elastic lamellae individually