The degradation of the extracellular matrix: an ageing indicator of the arteries

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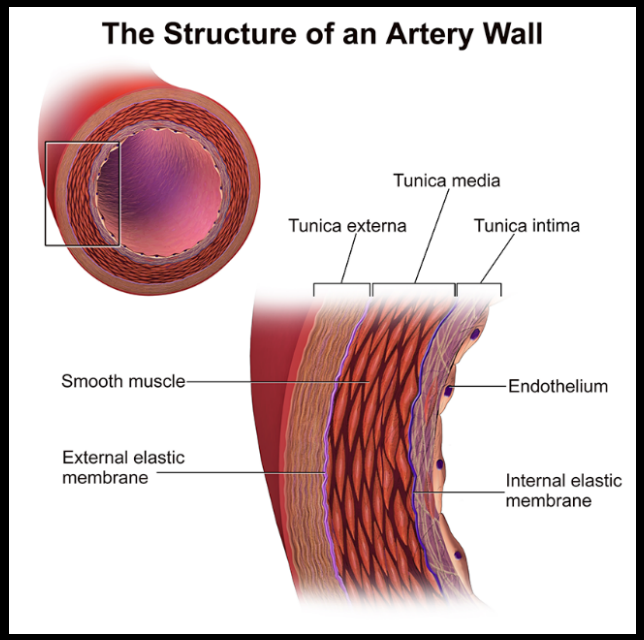
Biological context

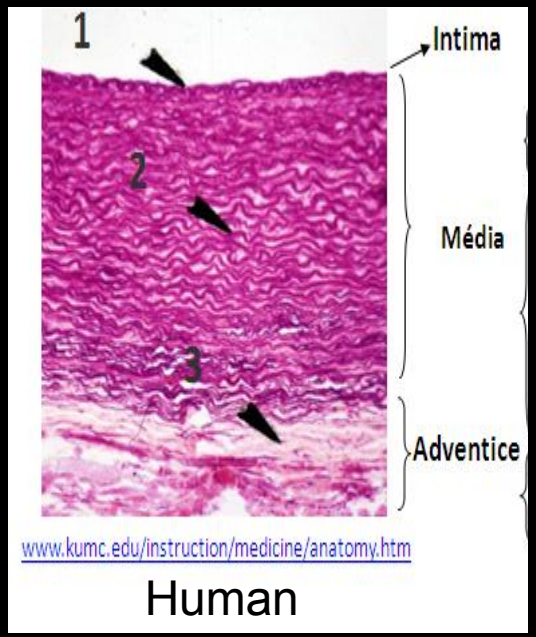
Extracellular Matrix → Role in support/anchoring; Tissue function; Remodeled during → development, ageing, tumorogenesis

Elastin → Elastic fibers are autofluorescent ($\lambda_{em} \simeq$ 560 nm)

Elastin → The whole pool of elastin is synthetized before teen-age

Cancer, Ageing → Elastin degradation → Serious functional trouble (aneurysm, atherosclerosis, emphysema…)



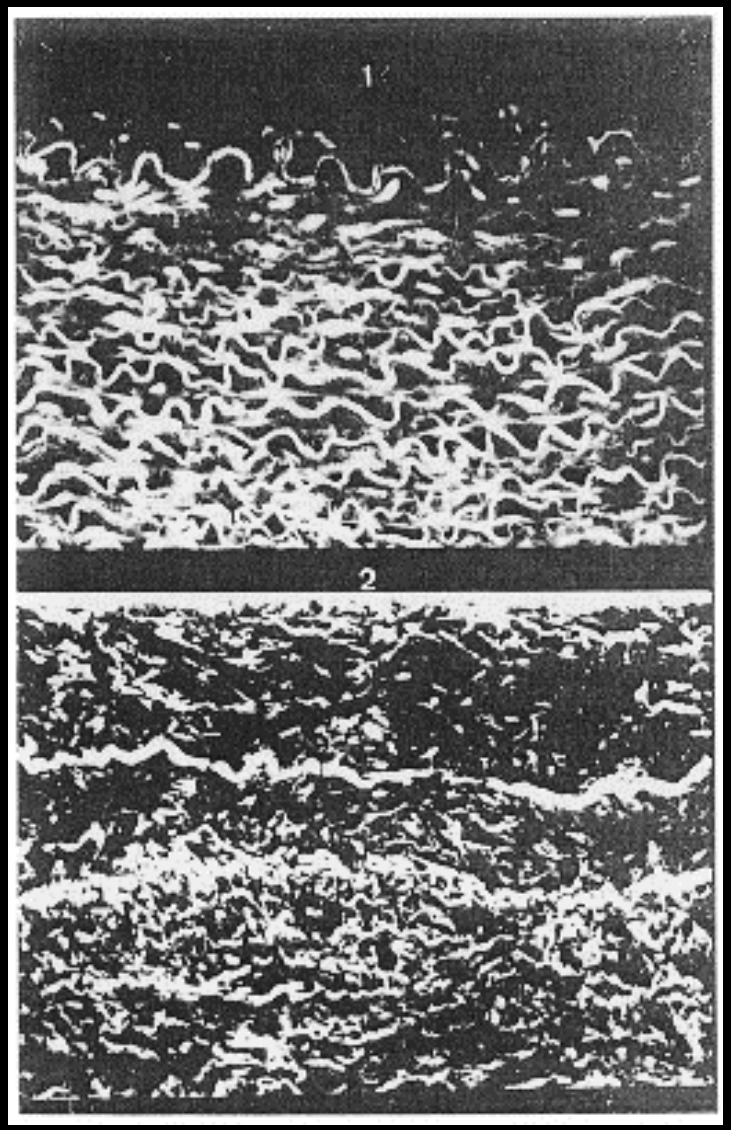


Human

Effect of ageing

Human aorta

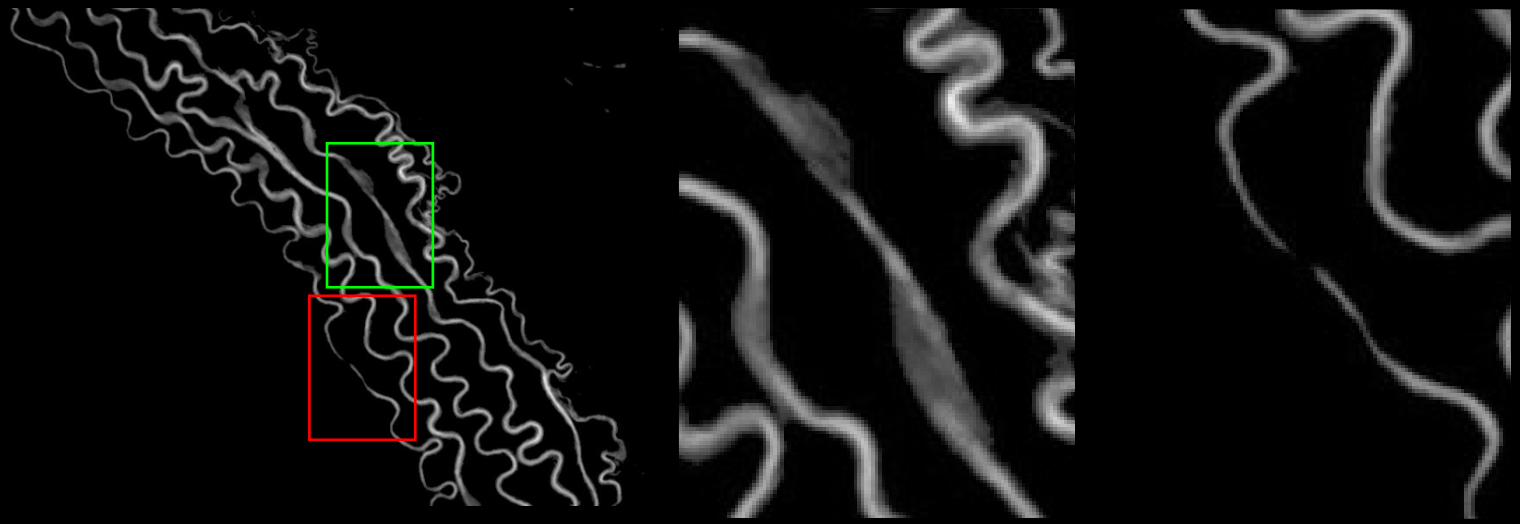
Young



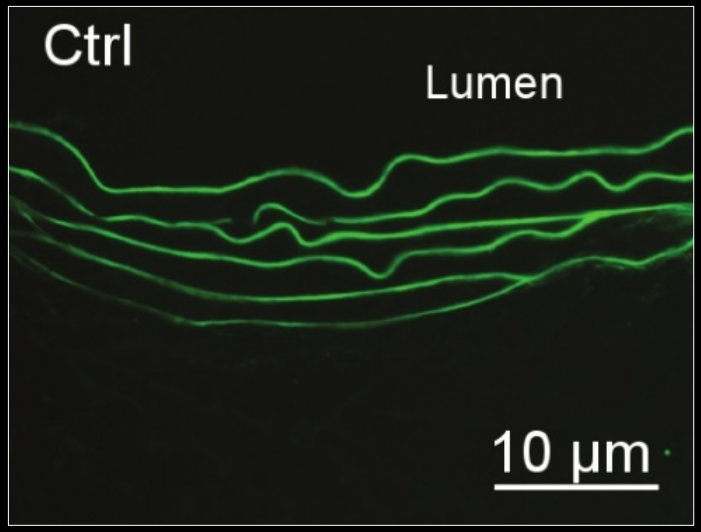
Old

Pathological alterations of arterial walls

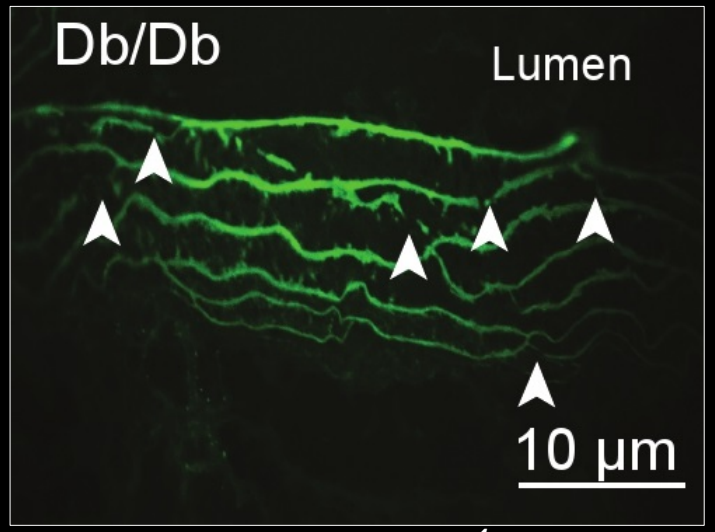
Mice with chronic renal failure



Control mice



Mice model of diabetes



S. Blaise, et. al., Diabetes, 2013

The axiom

These pathologies progress slowly without detectable symptoms until a critical point leading to detectable symptoms

A potential solution

Detecting small changes of the elastic structures in order to anticipate the occurrence and onset of the pathology

The problems in practice

What are the modifications of the elastic structures that intimate a future pathology ?

- *Variety of alterations : holes, split, loss of wrinkling, …*
- *Variety of pathologies*
- *Inter-individual variability*
- *Obtaining samples, number of samples…*

Image processing approach

The goal of this task is to prepare each image so the features that will be later extracted can be compared (somewhat normalizing the data)

A typical example of brightness / contrast difference between two images from different sample

Image processing approach

Four (main) steps applied in this pre-processing step

1) a brightness / contrast normalization

2) Image filtering,
Using Frangi's filtering approach targeting the detection of vessel.
Mostly to enhance edges and smooth noisy background.

3) binary conversion
in our implementation using Otsu's thresholding method

4) segmentation
Only by removing the remaing structure
of small area using mophological operations

Well, a small sketch tells more than a thousands word right ?

The feature extraction

We proposed, together with "biologists" to extract five types of features :
1) Segments length
2) Actual length vs approximative arc length → quantify the reserve

For those two first measure we propose to model each segment as a parametric curve :
$x(t) = a+bt+ct^2 + \ldots$
$y(t) = a+bt+ct^2 + \ldots$
Two approximations are used, one of very degree, that match almost perfectly the segment and a second of degree 3, that is used to measure the reserve length

3) Curvature (that is measure thank the "good" approximation and analytic expression of parametric curve curvature.

4) Segment width
5) Segments number

The classification

Up to now, not much have been done in this field.
Among the several supervised learning method tried, random forest (ensemble) classifier gave the best performance achieving about 0.75 detection / classification accuracy.

We noted that feature dimensionality reduction approach did not help (perhaps that why random forest work well).

Major concern are
1) lack of data
2) difficulty to reproduce image acquisition settings

What next ?

Encouraging first results.

Need to stabilize the imaging process

Need to investigate the evolution in time of feature for the same sample (problem unsolved is that we deal with heart vessel that are cut into piece …)

More generaly, need to study the intra-class/sample and inter-class/sample variability

On a statistical point of view, need to design supervised learning method for sample size way smaller than feature dimension

Perhaps, address this problem with hypothesis testing theory (using parametric model ?)