

Improving prediction of heart attacks and strokes : anisotropic mechanical behaviour of plaques

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Improving prediction of heart attacks and strokes

- Anisotropic mechanical behaviour of plaques

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Introduction

Vulnerable plaques

- Prone to rupture → major cause of strokes and heart attacks
- Therefore, it is desirable to predict plaque rupture
- However, current methods are not reliable [1].

One plaque ruptures,while the other does not!

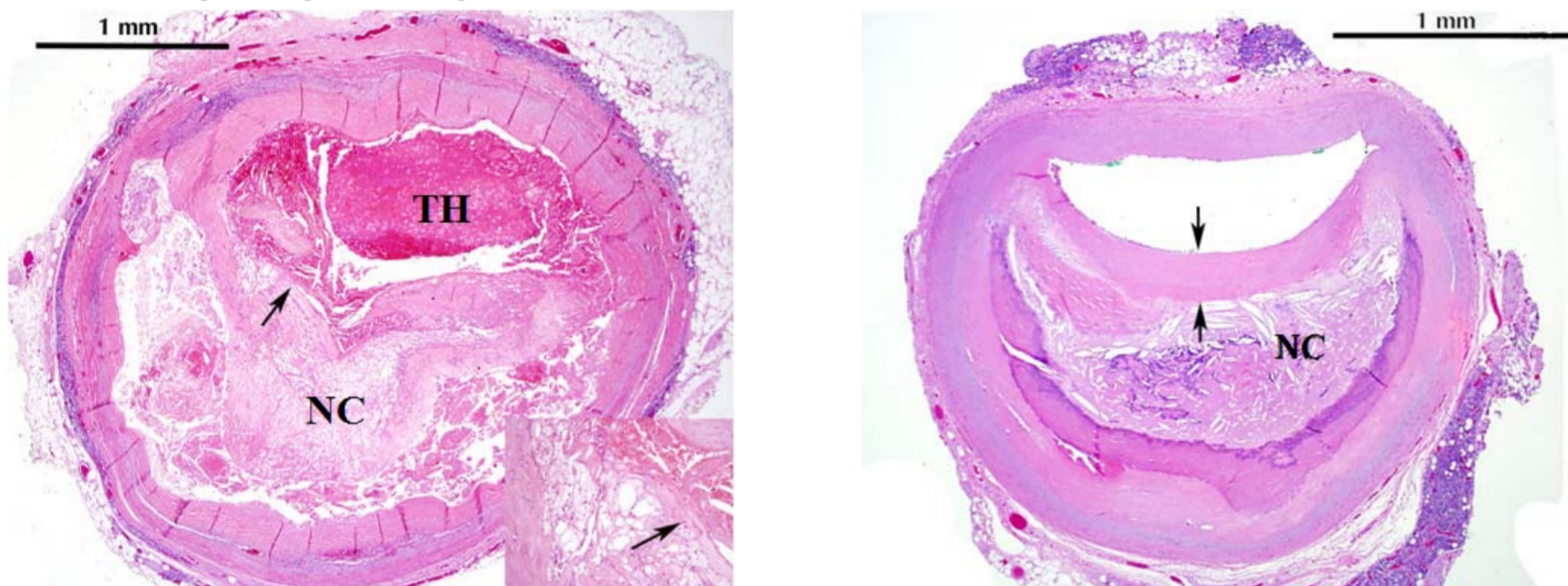


Figure 1: Histological images of two cross-sections of plaques, left: ruptured plaque (arrow indicating the rupture location, NC- Necrotic Core, TH- Thrombus occluding the artery causing heart attack or stroke), right: stable plaque (NC separated from the blood by thick fibrous cap preventing blood clotting and thrombus formation, arrows indicate thick cap) [2].

Biomechanical model

- Plaque rupture occurs when the stresses in the blood vessel exceeds the strength of the plaque
- Biomechanical models have the potential to improve plaque rupture prediction

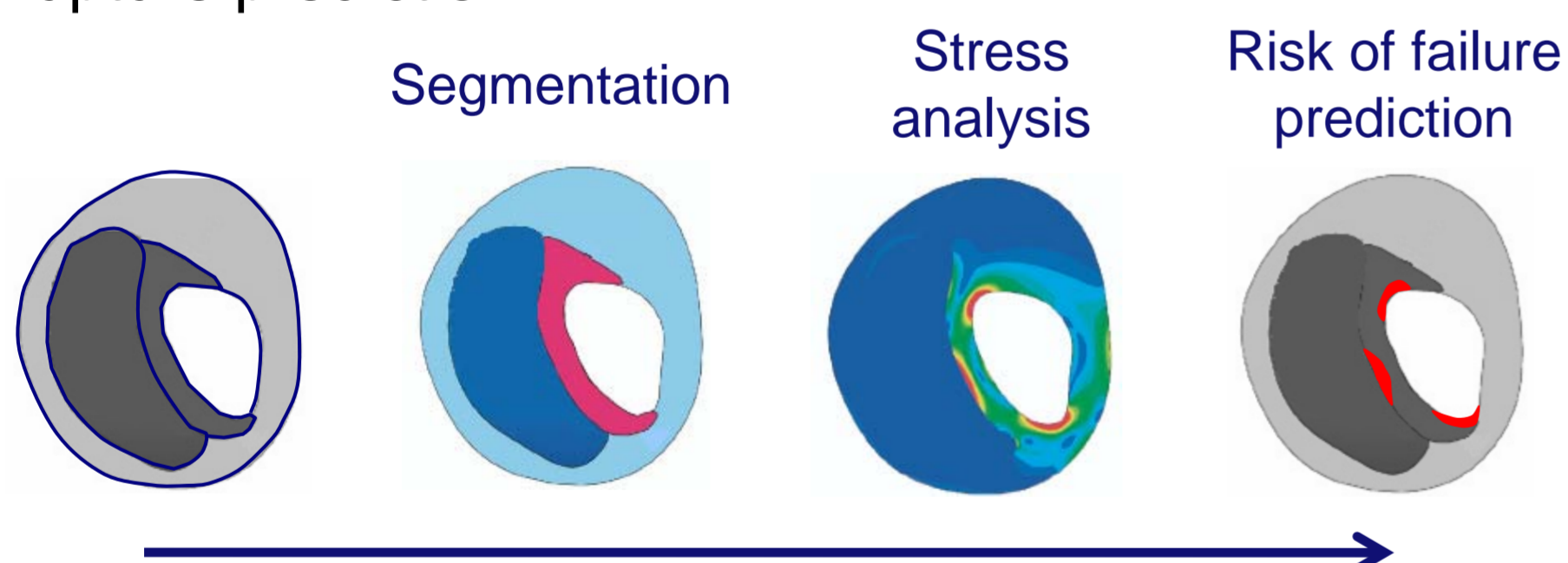


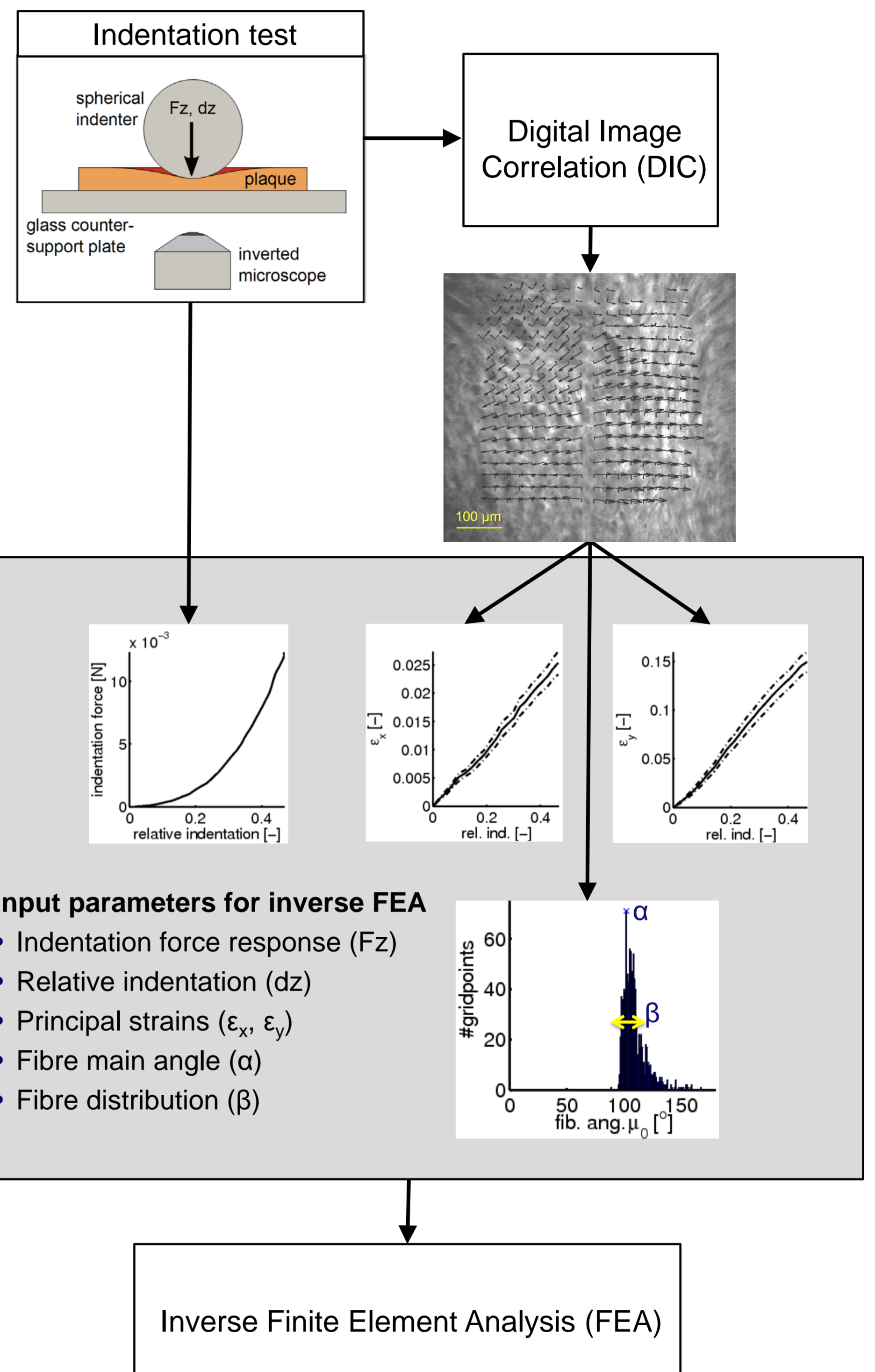
Figure 2: Mechanical models allow stress analysis of the plaque and have shown to reliably predict stress peaks and rupture locations [3].

However, mechanical models depend on the applied material properties. Current models use oversimplified isotropic models, but biological tissue is highly anisotropic.

Aim: To characterise the anisotropic mechanical behaviour of plaque tissue.

Method

- Spherical indenter ($\varnothing 2\text{mm}$) to indent plaque cross-sections locally (plaque tissue is heterogeneous) in axial direction.
- During indentation the deformation of collagen fibres of plaque perpendicular to indentation direction were recorded using an inverted confocal microscope and DIC.



Results

	Matrix Stiffness G_m [kPa]	Fibre Stiffness k_1 [kPa]	Non-linearity k_2 [-]
Median (25-75% perc.)	1.0 (1.0-10.3)	89.9 (17.0-195.6)	3.2 (0.7-10.2)

Compared to healthy tissue [4]:

- Plaque tissue seems to have softer matrix whereas collagen fibres are stiffer → Major reorganisation of the arterial wall during development of atherosclerosis

Conclusion

For the first time data is presented to describe anisotropic material properties of plaque tissue. This data can now be included in biomechanical models and can improve the risk assessment of plaque rupture.

Acknowledgments

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