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

Soft Tissue Biomechanics & Engineering

funded by the dutch heart foundation
Hartstichting

Technische Universiteit Eindhoven University of Technology

# Improving prediction of heart attacks and strokes - Anisotropic mechanical behaviour of plaques

C-K Chai[1], AC Akyildiz[2], L Speelman[2], FJH Gijsen[2], CWJ Oomens[1], MRHM van Sambeek[3], A van der Lugt[4], FPT Baaijens[1]

1: Department of Biomedical Engineering, Eindhoven University of Technology, The Netherlands
2: Department of Biomedical Engineering, Erasmus Medical Centre Rotterdam, The Netherlands
3: Catharina Hospital Eindhoven, The Netherlands
4: Department of Radiology, Erasmus Medical Centre Rotterdam

parisk a ctmm project

## 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!

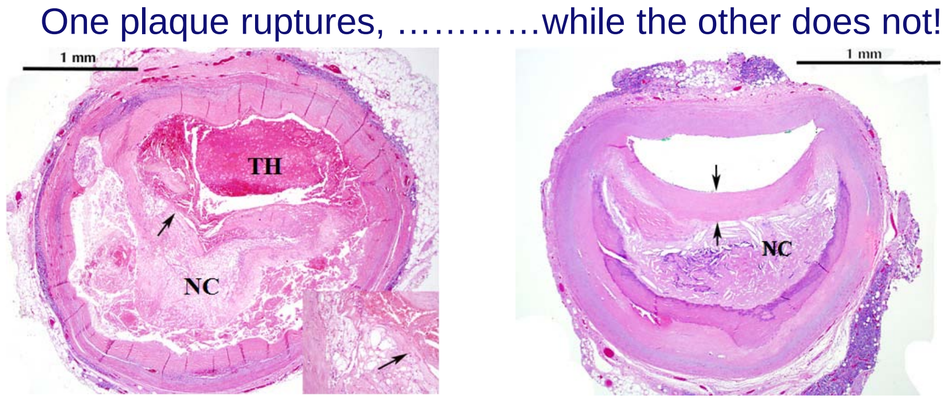



**Figure 1:** Histological images of two cross-sections of plaques, left: ruptured plaque (arrow indicating the rupture location, NC- Necrotic Core, TH-Thrombus occluding the artery causing heart attack or stroke), right: stable plaque (NC separated from the blood by thick fibrous cap preventing blood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

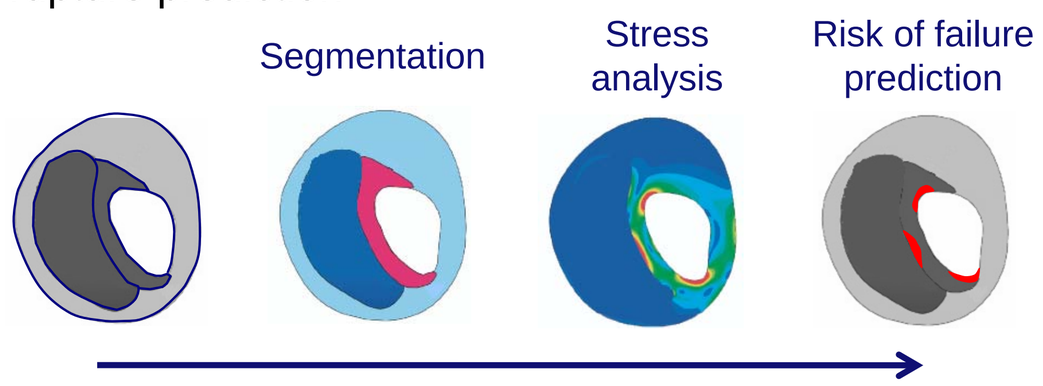


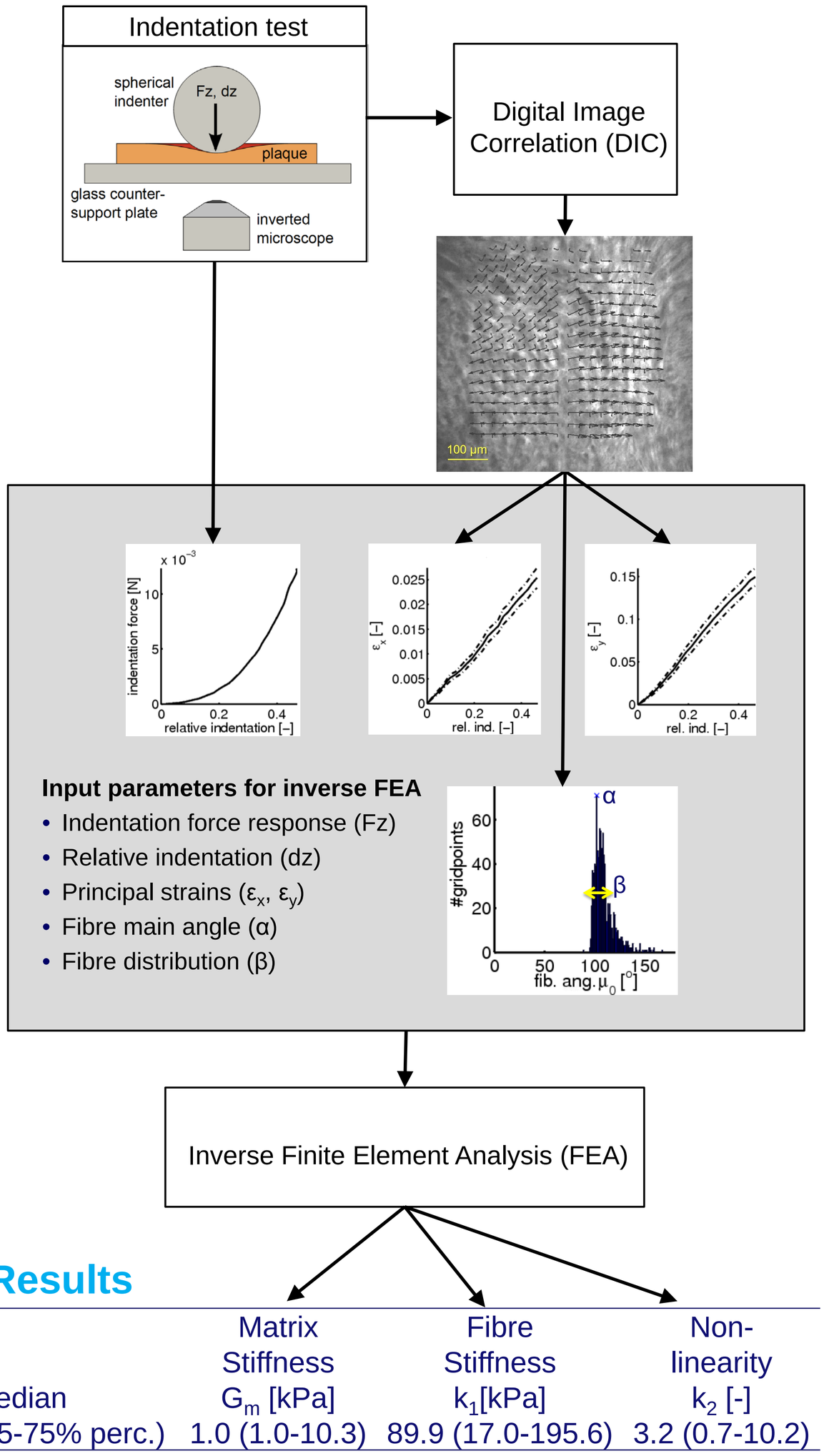

**Figure 2:** Mechanical models allow stress analysis of the plaque and have shown to reliably predict stress peaks and rupture locations [3].

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 (Ø2mm) 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**
This research was supported by the Centre for Translational Molecular Medicine and the Dutch Heart Foundation (PARISk).

**References**
[1] Salunke et al. Crit. Rev. BME, 25(3), 1997.
[2] Tavora et al. Arq. Bras. Cardiol. , 94(2), 2010.
[3] Gillard et al., Cerebrovasc. Dis., 24, 2007.
[4] Sommer et al., J. Mech. Beh. Biom. Mat., 5, 2012.