Impact of formaldehyde on mechanical properties of atherosclerotic carotid arteries

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Motivation

- Determination of impact of formaldehyde on mechanical properties of CA (carotid artery) — used at specimens prepared for histological analyses
- Characterisation of material properties for structure-based constitutive models
- Importance in prediction of stresses in the plaque and its consequent rupture

Introduction

Atherosclerotic plaque

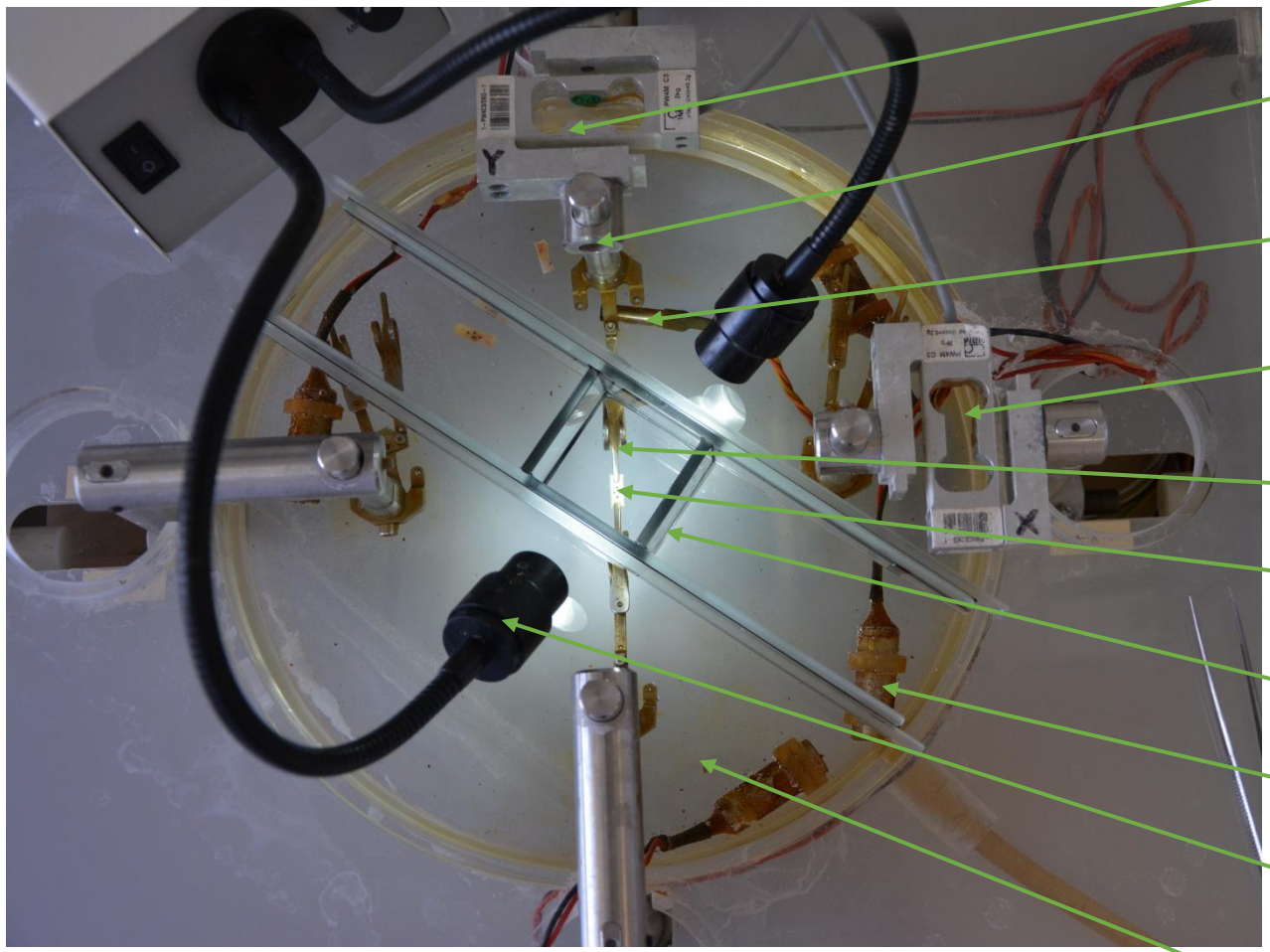
- Created by progressive accumulation of lipoproteins in the inner artery wall
- Lipid core covered by fibrous cap
- Reduction of blood flow – hemodynamic consequences
- Risk of lesion rupture which results in creation of thrombus and a stroke at carotid arteries

Specimen extraction and preparation

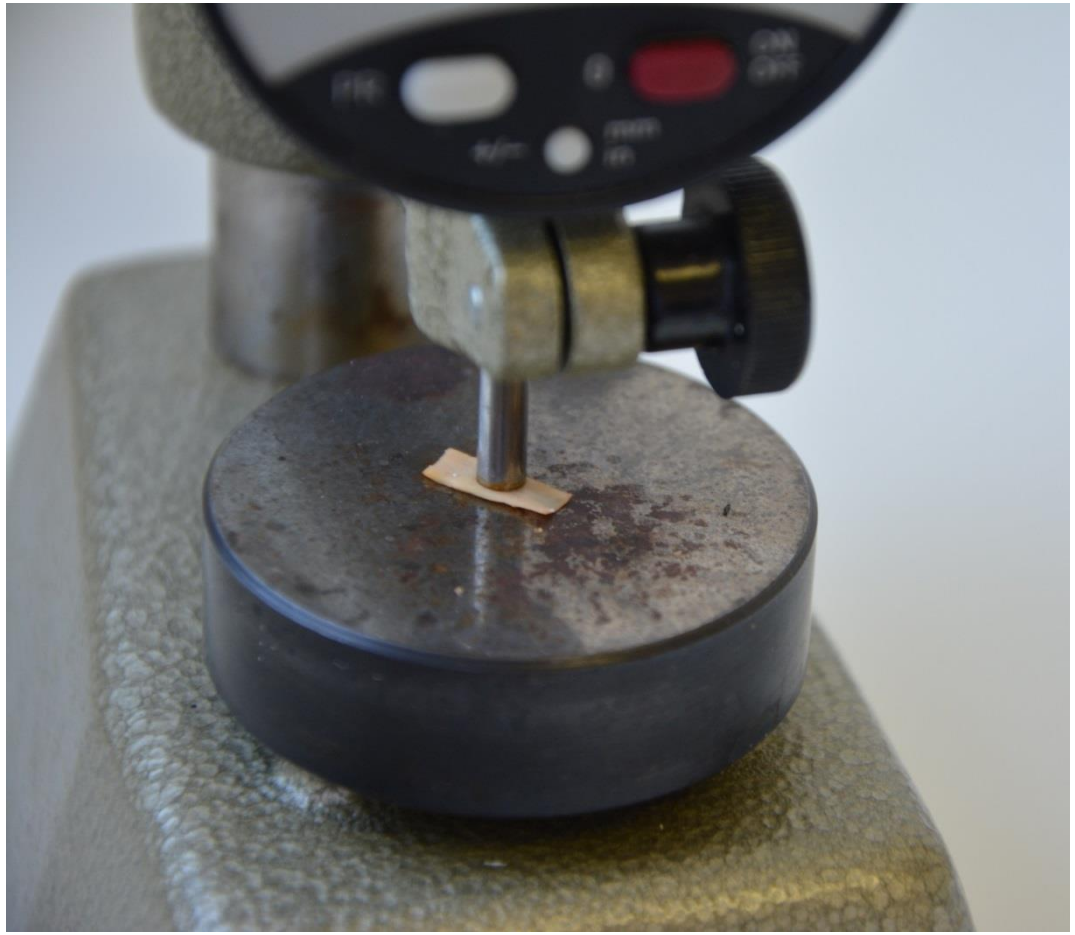
- Samples harvested during standard endarterectomy — intima layer with atherosclerotic plaque
- Samples tested either immediately after surgery (within 24 hours) or frozen at -18°C and tested later
- 70 specimens from 27 patients harvested
- 44 specimen in saline solution
- 26 specimens treated with formaldehyde
- Either dogbone shaped specimens were cut out with a special cutting knife or rectangular specimens cut with a scalpel

Testing device

- Force measured by strain gauge
- Specimen gripped with 2 clamps
- Pretension of 0.02 N applied (up to 0.08 for formaldehyde specimens)
- Bath with saline solution heated at 37 ± 0.5 °C

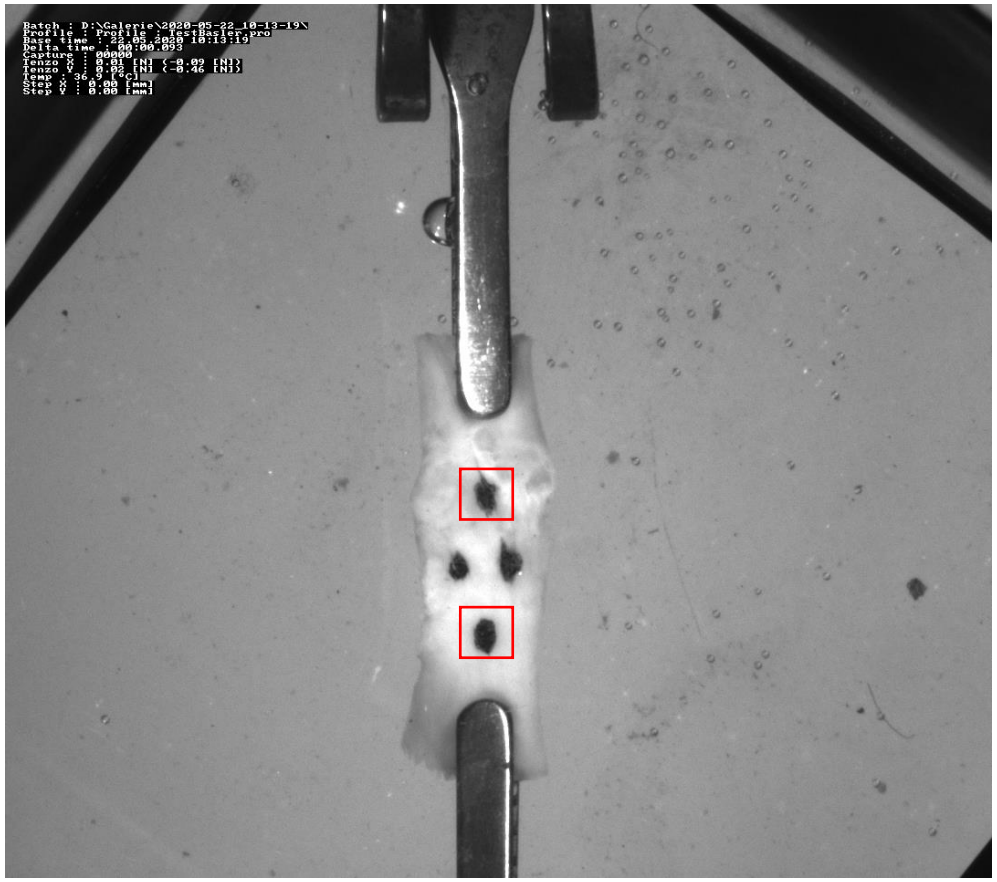


Thickness measurement



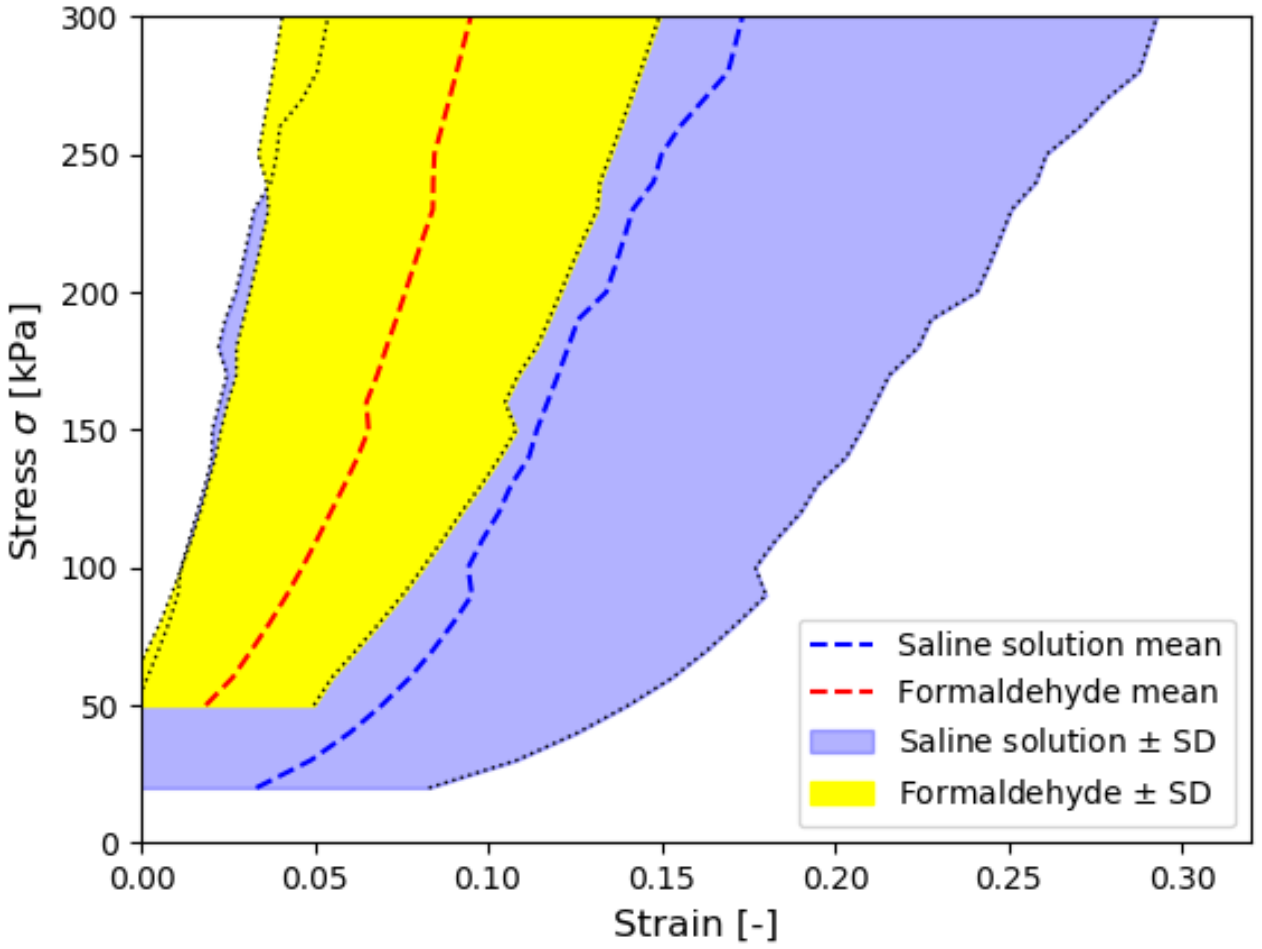
- Distance indicator with 0.01 mm accuracy was used
- Thickness measured at 3 different locations
- Mean value of thickness used for further analysis

Evaluation of deformation



- Surface captured with a CCD camera with frequency of 130 ms
- Longitudinal deformation (displacement, stretch, strain) was evaluated from positions of 2 markers
- Transversal deformation can be evaluated from the other 2 markers – not used here

Results



- Stress based averaging
- Directional anisotropy was not confirmed — further not distinguished
- Welch's test was used due to unequal sizes of both groups
- Null hypothesis – no difference in strains between both groups – rejected with $p<0.05$
- A significant difference exists between both groups

Conclusion

- Confirmation of nonlinearity of tissue response
- Large dispersion in stiffness — considerably smaller with the formaldehyde group
- Formaldehyde impact — increase of stiffness and reduction of data variance
- Specimens treated with formaldehyde cannot be used for evaluation of mechanical properties

Further investigations

Impact of direction, sex and calcifications was further investigated together with tissue strength : Lisický O., Hrubanová A., Staffa R., Vlachovský R., Burša J. – *Constitutive models and failure properties of fibrous tissues of carotid artery atheroma based on their uniaxial testing* – under review in Acta Biomaterialia

Different approaches to creation of a population representative response from the experimental data were compared: Lisický O., Hrubanová A., Burša J. – *Interpretation of experimental data is substantial for constitutive characterization of arterial tissue* – under review in Journal of the Mechanical Behavior of Biomedical Materials

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Thank you for your attention.