MECHANICAL PROPERTIES OF DIFFERENT TISSUES OF CAROTID ATHEROMA: EXPERIMENTAL APPROACH

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Introduction

Atherosclerosis is a life-threatening disease mainly occurring in carotid or coronary arteries. In case of carotid arteries, the rupture of fibrous cap encapsuling the cell debris, also known as lipid core, can induce a stroke. In clinics, the severity of the plaque is assessed only through the size of the stenosis. Computational modelling can help in the decision-making process and can bring deeper insight into the dilemma. The tissues both above the lipid core (referred to as fibrous cap) and beneath it are often not distinguished and specified as "fibrous tissue". Although some publications suggested that both these tissues have similar mechanical properties [1], others recommend that plaque specific material properties are needed [2]. In this study, the potential difference in mechanical response between fibrous cap and original artery wall (media) is investigated combining histological and mechanical experiments.

Methods

Samples from carotid endarterectomy (Fig. 1A) were harvested at St. Anne's University Hospital. From the plaque, rectangular specimens were dissected and tested under uniaxial tension (Fig. 1B). Note that all specimens were tested fresh, (less than 12 hours after extraction). Then, the specimens were fixed in formaldehyde solution and underwent histological analysis using H-E stain, Orcein stain and Masson-Goldner stain (M-G stain - Fig. 1C). From the histological images, the percentage of different tissue types (fibrous tissue, original media wall, cell debris ≈ atherosclerotic mass and calcifications) were determined. Based on the amount of these tissues, the specimens were divided into 3 groups: prevailing fibrous tissue, media wall (mainly smooth muscle cells with elastic fibers) and specimens with majority of atheroma mass. Then, the stress-strain responses of the tissue types are compared to detect differences between the individual groups.

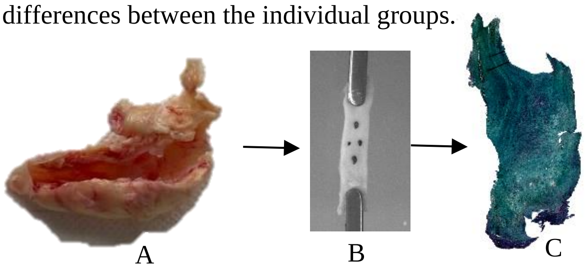

Figure 1: A: Carotid plaque, B: Uniaxial tensile specimen, C: Histological slice (M-G stain).

Results

The responses are shown in Fig. 2.

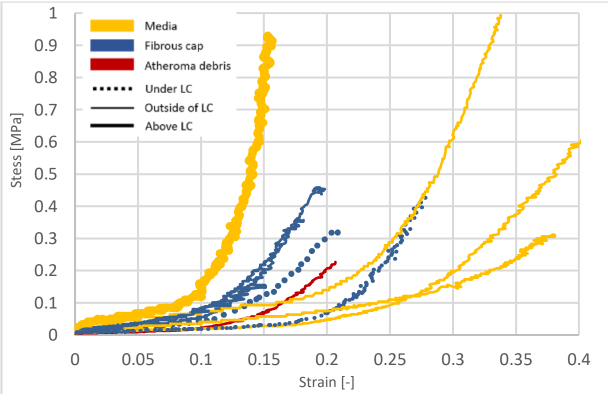

Figure 2: Stress-strain responses of n=10 different specimens (3 blue curves are almost identical).

Discussion

The results suggest that the fibrous tissue (n=5) may have mechanical properties slightly different from the original artery wall (media, n=4). The stress-strain responses show high variability but the fibrous tissue seems to be stiffer and have slightly lower tensile strength compared to the media specimens, whereas strength of the atheroma specimen (n=1) is the lowest. The lower stiffness of media specimens might be due to difficulties in distinguishing between original media wall and the atheroma debris. Note that the media specimen with the lowest strength was influenced by a pre-existing defect in it.

Furthermore, the tissue located directly under LC was detected as (newly formed) fibrous tissue. This may suggest that the pathological changes occur both above and under the lipid core supporting thus the hypothesis of similar mechanical properties.

The collection of data continues to reach a data set sufficient for statistical analysis of differences between mechanical properties of the investigated tissue groups.

References

1. Teng, Z. et al. Acta Biomaterialia 10.12, 5055–5063, 2014.
2. Akyildiz, A. C. et al. Journal of biomechanics 47.4, 773–783, 2014

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