Introduction

An aneurysm is a pathological widening of the blood vessel, which may grow with time. Aneurysms pose a serious problem because of the possibility of rupture. They can be visualized by modern X-ray medical equipment, but the question of their likelihood of rupture is open. Physicians make decision about treatment based on the aneurysm’s size, which is not a good criterion, while the rupture risk is expected to be related to the collagen stretch.

This study analyses the potential of introduced adaptation model to get insight into aneurysm development. Growth of an aneurysm is hypothesised to be the consequence of the elastin degradation and the collagen remodeling.

Material and methods

An assumed remodeling process [1] is depicted on the Fig.1. Under a certain load $F_1$, the tissue is stretched by a factor $\lambda$, and initially tortuous collagen becomes uncrimped. At the physiological load $F_{phys}$, the collagen stretch equals “allowed” $\lambda_0$ stretch. The elastin degradation causes an excessive collagen stretch, upon which $\lambda_0$ is restored in the remodeling either by softening or by thickening.

\[
\sigma = c_0(\mathbf{B} \cdot I), \quad \tau = 2nk_2(\lambda^2 - 1)\exp\left[k_1(\lambda^2 - 1)^2\right]. \quad \lambda = \frac{A}{\rho}
\]  \(\text{(2)}\)

where $\rho$ is hydrostatic pressure, $\sigma_\epsilon$ – Cauchy stress tensor of elastin, $c_0$ – the shear modulus of the elastin, $\tau_\epsilon$ – the stress in the collagen fibres, $\mathbf{B} = F \cdot F^T$ – the left Cauchy–Green strain tensor, $k_1$ and $k_2$ – material parameters of the collagen fibres, $\lambda$ – stretch of the elastin in the direction of the collagen fibres, and $\lambda_0$ – stretch of the collagen.

Degradation of the elastin is modeled through decreasing the shear modulus $c_0$ in time (Fig. 3). The recruitment and thickening variables change according to evolution equations

\[
\frac{d\rho}{dt} = \alpha(\lambda - \lambda_0), \quad \frac{dn}{dt} = \beta(\lambda - \lambda_0).
\]  \(\text{(3)}\)

where $\alpha$ and $\beta$ are rate constants of remodeling.

Cerebral artery is represented by one-layered cylinder (Fig.2), consisting of the elastin and collagen fibres.

Results

At increasing elastin stretch (Fig. 4), reflecting increasing aneurism size, collagen stretch may either increase or decrease (Fig. 5), indicating dangerous or safe aneurysm.

Conclusions

The mathematical model as described above enables the analysis of tissue growth parameters in terms of collagen stretch. This is believed to be of importance for rupture risk assessment beyond the use of aneurysm size solely.

References