Constitutive modeling of healthy and aneurysmatic veins of arteriovenous fistulae

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Summary

This study presents the results of uniaxial tensile tests conducted on healthy human basilic veins and aneurysmatic tissue that developed following the creation of an arteriovenous fistula for hemodialysis access. Regression analysis of the data was performed, fitting an anisotropic hyperelastic model to the measured data. The derived model parameters can be utilized in computational simulations related to the mechanobiology of arteriovenous fistulae.

Introduction

Arteriovenous fistulae are created in patients with end-stage renal disease to establish vascular access for hemodialysis. The mechanical loading of the vein is altered by increased blood flow and pressure as well as repeated insertion of the dialytic needle, often leading to the formation of venous aneurysms. Significant scientific efforts have been dedicated to understanding the biomechanical interactions within arteriovenous fistulae, aiming to enhance the performance of hemodialysis access and mitigate potential health risks. This study presents the results of mechanical testing and constitutive modeling of veins involved in the fistula. Samples of healthy basilic veins and aneurysmatic tissue from the venous segment of the fistula were analyzed. A hyperelastic model was applied to fit the mechanical response observed in uniaxial tensile tests.

Methods

Sections of healthy basilic veins and aneurysmatic veins from arteriovenous fistulae were obtained during routine autopsies and from aneurysmoraphy surgery, respectively. Thin strips were excised from each sample in circumferential and longitudinal direction. Uniaxial tensile tests were then carried out with the specimens. For each donor, a representative response was generated by averaging data from experiments in both directions. These average stress-strain curves were fitted with an anisotropic hyperelastic exponential model proposed by [1]. The model comprised a total of 8 independent constitutive parameters (μ, k_1^1, k_2^1, k_1^2, k_2^2, k_1^3, k_2^3, β).

Results and Discussion

Pathological changes in the vein induced alterations to its mechanical properties. A decrease of stiffness was observed in aneurysmatic samples (Figure 1). The optimized constitutive parameter values are shown in (Table 1).

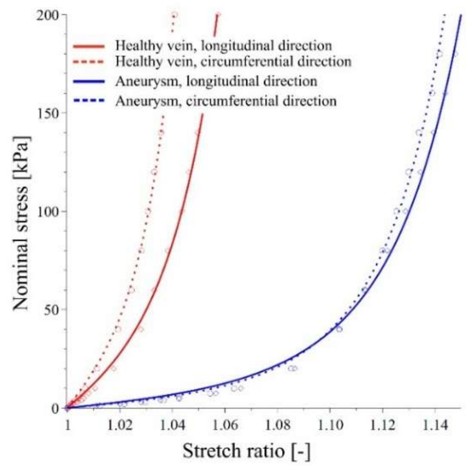

Figure 1: Measured (points) and model (lines) averaged mechanical response of a healthy basilic vein (red) and a venous aneurysm (blue) from two selected donors.

Conclusions

Changes of mechanical properties in aneurysmatic veins of arteriovenous fistula were observed. A hyperelastic model was fitted to the data, which could be used in computational simulations concerning the fistulae.

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References

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Table 1: Constitutive parameters for selected samples of a healthy and aneurysmatic vein.

	μ [kPa]	k_1^1 [kPa]	k_2^1 [-]	k_1^2 [kPa]	k_2^2 [-]	k_1^3 [kPa]	k_2^3 [-]	β [-]
Healthy	1	209.8	221.9	1	88.8	17 420	12.90	0.8
Aneurysm	1	58.56	23.96	1	1.024	257.1	0.257	0.87