# Computational characterization of blood vessel strain in wire myography

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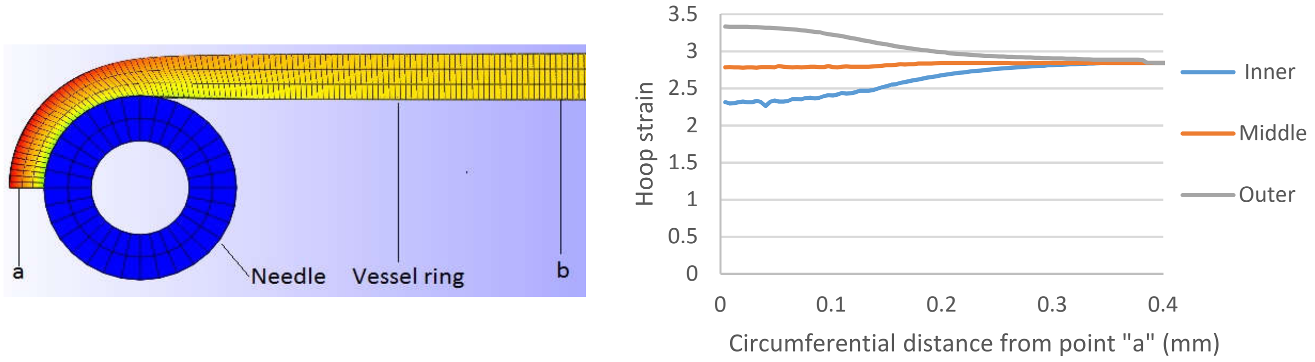
**Introduction**: Blood vessels, and the mechanical forces that act on them, play a key role in both health and disease. As a consequence, the mechanical properties of vessels have been under study for over a century. A variety of approaches have been used to define vessel properties, including stretching of vessel rings to study circumferential behavior, a configuration commonly used in wire myography. We previously used this approach to experimentally characterize cerebral artery microstructural damage that may occur in both trauma and clinical procedures. In the experiments, sheep middle cerebral artery rings were cannulated with two 28 gauge hypodermic needles. Rings were circumferentially distended from an unloaded stated to failure by separating the needles quasi-statically at a rate 0.02 mm/s. Strains between the needles were quantified by tracking microspheres placed on the outer surface of the vessel, but deformations near the needles are complex and vary through the vessel wall. Some portions of the vessel also move perpendicular to the imaging plane as they slide around the needles. As a result, strains in these regions cannot be quantified using microspheres alone. The objective of the present study was to develop a computational model to quantify strains throughout a vessel ring during such loading.

**Materials and Methods:** A finite element model of the vessel ring stretch experiment was created. Geometry, meshing and boundary conditions were generated in PreView, FEBio was used as a solver and results were visualized in PostView. The vessel ring was assumed to be a circular tube and modeled with octant (1/8th) symmetry to reduce computational time (see Fig 1A). Loading in the computational model was applied through a two-step process. First, residual strain was introduced by rotating the flat strip into a quarter circle and, second, the described experiment was simulated by then displacing the needle while the other end of the vessel was fixed in place. Experimentally measured dimensions of the arterial ring (outer diameter: 1.03 mm, wall thickness: 0.13 mm) were used to construct the geometry. A transverse isotropic Veronda-Westmann material model was assigned to the vessel material. Material parameters were established using the parameter optimization function of FEBio and fitting the material model to experimental results. The needle was modeled as a rigid body. Linear hexahedral elements were used to mesh the blood vessel and needle. The blood vessel was meshed with three rows of elements across the thickness in order to observe the stress and strain distribution across the thickness of the blood vessel (8465 elements). A mesh convergence study was conducted to ensure appropriate mesh density. A frictionless sliding contact was established between the needle and blood vessel. The model was validated by comparing nodal displacements and width reductions to experimentally measured values.

**Results and Discussion:** The hoop strain distribution as shown in Fig. 1 is observed along the circumference and across the thickness of the blood vessel for an overstretch of 1.5 mm. The hoop strain distribution of the outer and inner layers has opposite nature whereas the middle layer has a relatively uniform hoop strain distribution.



(A) (B)

Fig 1. Test geometry (A) and strain distribution along circumference as a function of thickness (B)

**Conclusion:** This model, which accounts for residual stress and tissue anisotropy, suggests that strains are highest in the outer layer of a vessel ring tested as described. Further work is required to include layer specific (i.e. adventitia, media, intima) geometry, properties, and residual stresses to make the model more realistic, but for the present scope of the study this model presents satisfactory results.