A STRUCTURAL MODEL FOR ARTERIAL WALLS INCORPORATING THE STATISTICAL DISTRIBUTION OF COLLAGEN FIBER DIRECTIONS

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A healthy arterial wall is considered as a heterogeneous composite structure composed of three layers, with layer-specific histological features. The intima (the innermost layer of the artery) consists basically of a single layer of endothelial cells lining the in healthy young arterial walls the intima is a component which is (solid) mechanically not relevant. The media (the middle layer) is formed by a complex 3D network of smooth muscle cells (SMC), and elastin and collagen fibrils. It is the structural arrangement of the media that allows to resist loads in both the longitudinal and circumferential directions. From the mechanical point of view, the media is the most significant layer in a healthy artery under physiological loading conditions. The adventitia (the outermost layer) is mainly composed of fibroblasts and fibrocytes, histological ground substance and thick bundles of collagen fibrils forming a fibrous tissue. At hypertensive states and during balloon angioplasty, the adventitia is the mechanically predominant layer, carrying >50% of the pressure load [1].

The passive response of healthy arterial walls (no contractile behavior of the SMC) is usually modelled as an incompressible, highly nonlinear, anisotropic elastic and multi-layer material. Each individual layer is treated as a fiber-reinforced material with the fibers corresponding to the collagenous component of the tissue. The mechanical response of each layer is characterized by a constitutive model, which includes information about the mean orientations of the collagen fibers [2],[3] in terms of two *structural tensors*, which render the model anisotropic. The structural tensors are derived from unit vectors, which point in the mean direction of the collagen fibers. However, the information on the statistical distribution of collagen fiber directions is not yet considered in the structural model of the arterial wall.

In this communication we present an expansion of the structural model in terms of the *von Mises distribution* to include not only mean orientations of the collagen fibers, but also how these fibers are distributed in space. The von Mises distribution is a symmetric unimodal distribution, which describes samples of circular data in terms of a mean direction, μ say, and a concentration parameter, κ say. The use of the von Mises distribution allows a reformulation of the structural tensors, which depend now not only on the mean fiber direction μ, but also on the parameter κ. A discussion on the physical meaning of these new parameters as well as value ranges and theoretical limits are presented along with important aspects of a finite element implementation. The peculiar anisotropic response of a thick-walled, fiber-reinforced circular cylindrical tube subject to internal pressure and axial extension is studied for different values of the concentration parameter κ. Numerical results are compared with analytical solutions.

References

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