An extended Darcy equation : how to incorporate the blood rheology into soft tissue mechanics

dulum at least an order of magnitude lower than that of PET and PTFE grafts. The effects of the electrostatic spinning process variables on the directional properties of the grafts have been characterized using narrow strips of the material. Grafts with the ratio of circumferential to longitudinal Young's modulus between 0.53 and 1.39 were produced.

A nonlinear model has been used to characterize the cylindrical elastic properties of a microfibrous polyurethane graft.

The model, developed by Patel and Vaishnav, makes use of a polynomial form of the strain energy function. Using a 3rd order polynomial, strain energy function constitutive equations with 7 material constants were obtained.

Experiments were carried out to determine the material constants and to evaluate the applicability of the model to the polyurethane graft. There was good agreement between the measured and computed external diameter of grafts subjected to an intraluminal pressure between 0 and 220 mmHg and axial extension ratio ranging from 1.06 to 1.12. The maximum error expressed as a percentage of the measured diameter was 2.56%.

The material constants were used to predict the longitudinal force and the compliance (% diametral change between 80-120 mmHg) of 4 mm internal diameter grafts. The values for wall thickness between 0.34 and 0.60 mm and axial extension between 6 and 12% show that the relationship is essentially a power law. The compliance of the natural arteries was calculated from published data. The graft wall thickness which gave the closest match in compliance with the carotid and femoral arteries was identified. The predicted and the actual pressure-diameter response were compared.

An extended darcy equation: how to incorporate the internal blood rheology into soft tissue mechanics

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Several author suggested that the internal blood volume might play an important role in the viscous properties of soft tissues. The theory of deformable porous media, allows to treat blood and tissue as two distinct phases molded into one continuum. However, Darcy's law, representing in this theory the pressure-flow relations of the fluid phase, is unable to account for:

— the arteriovenous pressure gradient and flow
— the non-newtonian blood properties of Fahraeus-Lindqvist effect.

In this paper an extended Darcy equation is presented, which accounts for both of these phenomena.

The statistical approach to microcirculatory pressure-flow relations suggested here seems very promising. It is expected that further research on this path will lead to a comprehensive model of blood-tissue interaction.

Lung tissue mechanics

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The mechanical behaviour of the lung tissue (expressed by its constitutive equations) has considerable influence on the normal and pathological function of the lung. It determines the stress field in the tissue thus affecting the impedance and energy consumption during breathing as well as the localization of certain lung diseases (West, 1971).

The constitutive equations for the lung tissue are derived on the basis of its structure. A stochastic approach to the tissue's structure considers the density distribution function of the membrane's orientation in space as the predominant structural parameter.

If the rheological behavior of both the alveolar membrane and that of its liquid interface with the air are known, it is possible to develop general constitutive equations for the whole tissue by application of a structural strain energy function. This is done and the predictions of the resulting model are compared with previously published three-dimensional data of Hoppin, et al. (1975) with good agreement. Predictions of the tissue's response under other types of deformations are illustrated. It will also be shown how material characterization along the present model can be readily achieved.

The structural approach towards lung tissue characterization has considerable merits: The model parameters are physical quantities; viscoelastic behavior can be readily incorporated; the model is analytic throughout and can potentially offer a diagnostic tool based on mechanical tests.