Supplementary Materials

The Impact of Choroidal Swelling on Optic Nerve Head Deformation

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Donnan Equilibrium Swelling

This material model allows volumetric change (i.e. swelling or shrinking) of a tissue by achieving equilibrium of charged particles between the tissue and an external bath. These equations typically govern effects associated with osmotic gradients, but have been adopted here as a simple modeling artifice to represent volume changes in tissues within the FEBio simulation code. In short, the Cauchy stress within the choroid is described as:

$$\sigma = -R * T * \left(\sqrt{(c^F)^2 + (\bar{c}^*)^2} - \bar{c}^*\right) + \sigma^e \qquad \text{S-1}$$

where R is the ideal gas constant (8.314 J / mol K), T is body temperature (37^{o}C expressed in Kelvin), and $\bar{c}^*$ represents the external bath osmolality, assumed to be the osmolality of typical biological tissues (300 mOsm). σ^e represents the stress from the solid matrix of the choroid. Here, we assumed the choroid to be represented as a linear-elastic material with a Young's modulus (E) of 0.3 MPa, which is the same value adapted for the central retinal vessel. c^F represents the fixed-charge density of the current configuration compared to the reference configuration and is a function of c_0^F.

$$c^F = \frac{\varphi}{J-1+\varphi} * c_0^F \qquad \text{S-2}$$

φ represents the gel porosity and ranges from 0 to 1, and was chosen to be 0.10. J represents the relative volume (e.g. the Jacobian of the deformation gradient matrix). In this equation c_0^F drives the fixed-charged density and has units of milliequivalent per liter **(**mEq/L). In our simulations, changes in c^F cause changes in the volume of the choroid. Thus, the use of Donnan equilibrium swelling was a convenient vehicle that allowed us to apply a prescribed amount of volume change, i.e. swelling, by changing a single coefficient (c_0^F). Specifically, setting c_0^F = 0 mEq/L corresponded to 0 uL of choroidal swelling while c_0^F = 95 mEq/L corresponded to a 14.2 uL change in choroidal volume for these geometries. It is **important** to note that we based the values of c_0^F directly on the volume change occurring in the choroid, and we do not claim that choroidal swelling in the eye occurs due to Donnan effects.

Abbreviations:

AR – annular ring

BM – Bruch's Membrane

CRV – central retinal vessel

ΔV – choroidal volume change

Dura – dura mater

E- Young's Modulus

IIH – idiopathic intracranial hypertension

ICP – intracranial pressure

IOP – intraocular pressure

LC – lamina cribrosa

LHS – Latin hypercube sampling

MAP – mean arterial pressure

NAION – nonarteritic anterior ischemic optic neuropathy

uL – microliters

ON – Optic Nerve

ONH – optic nerve head

PRCC – Partial Rank Correlation Coefficient

ppSC – peripapillary sclera

Pia – pia mater

PLNT – prelaminar neural tissue

PS – principal strain

RGC – retinal ganglion cells

RLNT – retrolaminar neural tissue

SC – sclera

SANS – space flight-associated neuro-ocular syndrome

ν - Poisson ratio