Geometrical, mechanical and vascular factors in glaucoma

Purpose:
Geometrical, mechanical and vascular factors may contribute to glaucoma. This study investigates the relation of geometrical/mechanical to vascular factors by the means of mathematical models which estimate how ocular axial length, IOP, CSF, systemic blood pressure, and elastic properties of sclera and lamina cribrosa affect laminar deflection and blood flow in the central retinal artery.

Method:
The sclera is modeled as a pressurized spheroidal elastic membrane. IOP-induced tensile stresses in the sclera are computed as a function of ocular axial length and scleral thickness. The lamina cribrosa is modeled as a circular plate subject to IOP and CSF, and stretched by IOP-induced scleral tensile stresses. Laminar deflections are computed using linear elasticity theory. The retinal artery is modeled as a cylindrical tube with elastic walls, where the blood flows as a Newtonian viscous fluid. The arterial wall deforms under the action of internal pressure (blood pressure) and external pressure (IOP). Arterial wall deformations and blood flow in the retinal artery are computed as a solution of the coupled fluid-structure problem.

Results:
Different ocular axial lengths give rise to significant differences in IOP-induced tensile stress in the sclera. The longer the axial length the lower is the scleral tension acting on the lamina cribrosa. Lower scleral tension in the lamina cribrosa induces larger laminar deflections. For a given IOP, the blood flow in the central retinal artery significantly decreases with increases in blood viscosity, arterial wall stiffness and thickness.

Conclusions:
Myopic eyes experience lower scleral tensile stresses on the ONH and larger laminar deflections than normal or hyperopic eyes, for a given IOP. This may lower the IOP safety level and increase susceptibility to glaucomatous damage for myopic eyes. The IOP safety level may be further lowered in the presence of vascular diseases altering blood viscosity and compliance of the arterial wall.